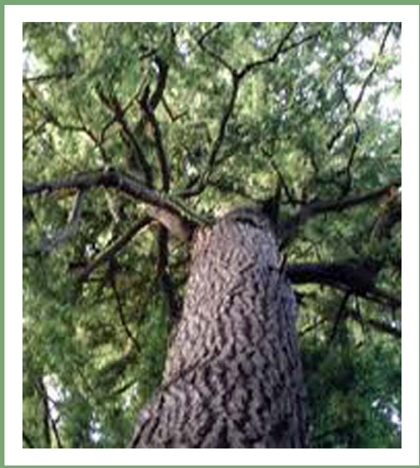
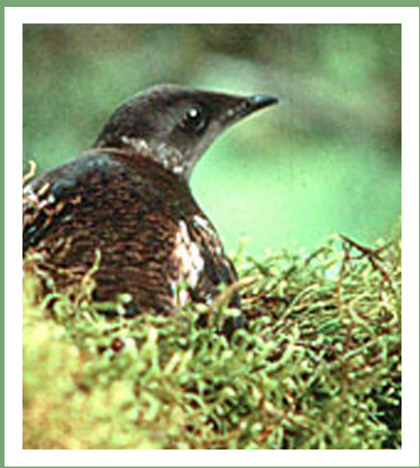


A REVIEW OF MARBLED MURRELET RESEARCH RELATED TO NESTING HABITAT USE AND NEST SUCCESS

Prepared for:

Oregon Department of Forestry

Salem, Oregon



Submitted by:

Jonathan H. Plissner

Brian A. Cooper

Robert H. Day

Peter M Sanzenbacher

ABR, Inc.—Environmental Research & Services

Forest Grove, Oregon

Alan E. Burger

Alan Burger Consulting

Merritt, British Columbia

Martin G. Raphael

Raphael Ecological Consulting, LLC

Olympia, Washington

A Review of Marbled Murrelet Research Related to Nesting Habitat Use and Nest Success

Final Report

Prepared for

Oregon Department of Forestry
2600 State Street, Bldg. C
Salem, OR 97310

Prepared by

Jonathan H. Plissner, Brian A. Cooper, Robert H. Day, Peter M. Sanzenbacher
ABR. Inc.—Environmental Research & Services
P.O. Box 249
Forest Grove, OR 97116

Alan E. Burger
Alan Burger Consulting
P.O. Box 2539
Merritt, BC, Canada, V1K1B8

Martin G. Raphael
Raphael Ecological Consulting, LLC
2422 44th Ave. NW
Olympia, WA 98502

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Introduction

Background

The Marbled Murrelet *(Brachyramphus marmoratus)* is a small seabird that nests in large coniferous trees of coastal forests throughout most of its range in North America (Nelson 1997). In 1992, the Washington, Oregon, and California population of the Marbled Murrelet was federally listed as a Threatened Species (USFWS 1992, 1997), requiring that landowners take measures to "avoid take" of the species or develop programmatic approaches to listed species management that may include application for "incidental take" permits. Murrelets are present in some Oregon State Forests (i.e., in the Clatsop, Tillamook, and Elliott State Forests), where they presently are managed by the Oregon Department of Forestry's (ODF's) State Forests Division under a "take avoidance approach," as outlined in the Division's Marbled Murrelet Operational Policies.

This management approach relies heavily, although not exclusively, on the Pacific Seabird Group's (PSG's) "Methods for surveying Marbled Murrelets in forests: a revised protocol for land management and research" ("PSG protocol;" Evans Mack et al. 2003) for designating forest stands as occupied by murrelets. The PSG protocol provides standardized techniques for detecting murrelets in forests while partially accounting for imperfect detection. The document also identifies procedures for delineating potential murrelet nesting habitat and classifying survey areas based on results of audio-visual surveys designed to detect birds in flight near nesting areas. Survey data are used to classify survey sites and areas as having "probable absence" of murrelets, "presence" of murrelets flying over the area, or "occupancy" by nesting birds, based on observed flight behaviors (p. 22 of PSG protocol). Plans are underway to revise the 2003 survey protocol, based upon the current state of knowledge regarding the species breeding biology and habitat associations.

The State Forests Division has sponsored a science assessment employing methods used in Systematic Evidence Reviews (also known as Systematic Review [SR]) to assess the amount, strength, and relevance of the science related to several central elements of the PSG protocol and to a question that will inform the evolution of Marbled Murrelet protection measures. The methodology for conducting this review largely follows that established for SR's (CEE 2013); however this review differs from standard SR's in that it explores the amount, strength, and relevance of evidence related to several hypotheses regarding Marbled Murrelet ecology, rather than develop and address questions directly related to a management intervention.

The Division expects to use the results of the Marbled Murrelet review in the following ways:

1. to inform the ongoing development and revisions to murrelet survey protocols;
2. to inform longer term Division policies, plans and strategies for murrelet protection;
3. to develop and refine research and monitoring questions;
4. to inform ODF interactions with other agencies, professional organizations, and other interested parties;
5. to further learn about the SR method, and if/how it may be applied to other topics.

The assessment is a transparent, objective science review. While the review does not include any specific policy recommendations, ODF expects that it will help better differentiate questions of science from value and policy questions.

Systematic Review Protocol

A Systematic Review is a rigorous, transparent, and repeatable process that differs from traditional literature reviews in that an SR focuses tightly on a specific question or small set of questions and uses pre-established, explicit protocols for finding, screening, and rating the quality and relevance of studies before using evidence from the most methodologically-sound studies to formulate answers. The process is transparent and repeatable in documenting the specific criteria used for identifying and rating studies included in the review, as well as specifying how the evidence is analyzed. Elements incorporated in an SR are outlined in Table 1. The protocol initially was tested by the principal reviewers on a small sample of studies (one per question) and underwent minor modifications following these tests and later during the review process; however, changes to the protocol were approved by ODF and fully documented for transparency (see Appendix 1).

Table 1. Elements described in a protocol for conducting a systematic review (Czarnomski and Hale 2013).

Elements	Brief Explanation
Question	Focused, scientifically answerable question that guides search strategy and inclusion criteria
Search strategy	Methods (e.g., search terms and databases) to find studies pertinent to the question
Inclusion criteria	Filters used to determine relevance of studies to question
Study quality and relevance assessment	Criteria used to determine strength of study methodology, and the relevance of study findings to the review question
Data extraction	Tables used for consistently recording data and meta-data from studies and associated reviewer notes
Data synthesis	Methods (quantitative, qualitative) used for synthesizing data with respect to the review question

Review Partners

ODF contracted with a team of external scientists from ABR, Inc. to conduct the review. The review team included four ABR scientists (Dr. Jonathan Plissner, Brian Cooper, Dr. Robert Day, Peter Sanzenbacher) and two additional Marbled Murrelet experts, Dr. Martin Raphael (U.S. Forest Service) and Dr. Alan Burger (University of Victoria). The quality of the review was further enhanced by the input of members of the PSG Marbled Murrelet Technical Committee and numerous other stakeholders including university, federal, forest industry, and state scientists; other agency staff; and representatives of nongovernmental organizations with interests in Marbled Murrelets (Appendix 2). Stakeholders provided input on both the formulation of the review questions and the protocol. Stakeholders also were asked to 1) assess the implementation of the inclusion criteria on considered publications and provide input on whether any additional studies should be considered for inclusion; and 2) comment on a final draft of the synthesis report. All comments submitted were documented and addressed by the report authors and are included in Appendix 3. ODF staff composed initial drafts of the review questions, provided guidance in development of the study protocol, and reviewed drafts of all documents before they were sent to stakeholders for review.

Review Questions

This review addressed five questions on topics considered high priority for ODF. The first four questions were designed to inform discussions of the PSG murrelet inland survey protocol (Evans Mack et al. 2003). The fifth question was designed to inform discussions and decisions on the evolution of Marbled Murrelet protection measures and is not directly linked to the PSG protocol.

Although Systematic Reviews often conclude with a quantitative analysis (i.e., meta-analysis) of the data extracted from appropriate studies, such an analysis often is not appropriate for ecological studies because of differences in methods and scope among studies (CEE 2013); and we therefore provided a narrative synthesis for all questions. As noted below, our search strategies and types of studies included in the review were well-defined and included sources of primary data and analyses in both peer-reviewed literature and other documents (i.e., "gray" literature); however, we did not include undocumented data (e.g., personal communications) or sources of raw data in the review.

The context given below for each question provides some background on ODF's intent behind the question and some key concepts embodied in the question. Operational definitions for many terms are included in Appendix 4.

Question 1. How are individual behaviors (subcanopy flight, circling, landing, vocalizations) of Marbled Murrelets indicative of nesting in the forest stand where those behaviors occur?

This question addresses the current information on the significance of various Marbled Murrelet behaviors as indicators of nesting, and is related to information on pages 20–21 of the Evans Mack et al. (2003) survey protocol. We acknowledge that forest habitats also have value for murrelets beyond a direct association with nesting (e.g., prospecting for nest sites, pair-bonding, roosting), but for this question we focused only upon the measureable indicators of nesting.

Question 2. To what extent do Marbled Murrelets exhibit nest-site fidelity at various spatial scales (i.e., at the scale of a watershed, forest stand, tree, branch, and platform), and how does the spatial extent of continuous potential habitat affect nest-site fidelity?

Question 3. How does the spatial extent of continuous potential habitat relate to the co-occurrence (i.e., nesting by multiple pairs) of murrelets in a forest stand and at other spatial scales?

These two questions address current information used to inform "site classification" within the PSG murrelet inland survey protocol (Evans Mack et al. 2003). The analysis of survey effort required to classify occupancy correctly (Appendix A of the PSG protocol) was done at the survey-site level; however, the protocol extends "site classification" beyond the survey site to the entire survey area (see Appendix 4 for definitions of survey site and survey area). The protocol recommends consulting with appropriate regulatory agencies regarding habitat beyond the survey area boundary. The spatial extent to which occupancy status applies currently is based on explanations regarding the importance of "continuous habitat" for current and future nesting by one or more pairs (pages 6 and 23 of the PSG protocol). The overall question of the importance of continuous habitat, however, is broad and includes subsidiary questions; for example: "How does the amount and extent of continuous habitat relate to murrelet breeding, occupancy, abundance, and persistence at a site?" The questions in this review focus on two aspects of Marbled Murrelet breeding ecology: site fidelity (including re-use of nest sites by the same or different individuals) and the distribution of nesting pairs at different spatial scales. At the level of the forest stand data on these two aspects are cited in the survey protocol as supportive evidence for the importance of continuous habitat beyond the survey site. The relevance of results on the extent of continuous habitat considered important to the application of survey results will be addressed in the synthesis. Note that our use of the term "site fidelity" in this SR includes repeated use of a nest site within a year or between years by the same or different individuals.

Question 4. How is the occurrence of Marbled Murrelet nest sites related to the number and size of potential nest platforms and platform-tree density within stands of different age-classes (young, mature, and old growth)?

This question is associated with definitions of suitable habitat (p. 2 of the PSG protocol) that can be used to inform decisions on which stands to survey. There currently is a brief description in the protocol of potential murrelet habitat, including a qualifying platform diameter (10 cm/4 inches). ODF would like to understand better the information base to inform decisions on where/what to survey and to determine whether platform characteristics of murrelet-occupied habitats vary among stands of different age-classes.

Question 5. How is Marbled Murrelet nesting success affected by habitat characteristics?

This question focuses only on habitat associations with nest success and not on the much broader question of habitat associations with the presence of nests. In this question, habitat characteristics are assumed to include stand-level (and patch-level) parameters, such as habitat quality and quantity, and larger-scale features, such as habitat continuity and configuration, and corvid abundance. It also includes other abiotic factors (e.g., slope, aspect, elevation, human activity) relating to the location of the nest within the stand. This question is not centered on the survey protocol. Rather, it focuses on understanding the information available to inform management decisions in areas where occupied sites are identified.

Methods

Search Strategy

Systematic reviews use a search strategy that specifies, a priori, how a comprehensive and unbiased sample of the literature will be sought and obtained. For this review, a search strategy was drafted by the ABR team and modified following input from ODF and stakeholders. Our strategy was to search the literature as widely as possible, then use rigorous inclusion criteria to determine which studies to include in the review. All publications found during each stage of the search process were imported or entered into EndNote bibliographical software. Only the first 50 results (based on relevance) of internet searches were reviewed for relevant publications. Duplicate results and those with indeterminate information (e.g., incomplete citation) were discarded. The source of each reviewed publication was specified in the study inclusion table (Appendix 5).

Search strategies for SR's typically start with extraction of literature from publication databases, catalogs, and web-based search engines, using pre-determined search terms. Because most of our questions address hypotheses and supporting evidence stated in the PSG survey protocol (p. 6) and/or other review documents, and because we chose to include relevant work in unpublished and "gray" literature that may not occur in on-line databases, we instead began our searches by identifying and searching the bibliographies and citations of appropriate "seed" documents for each question. These documents included the Inland Forest Survey Protocol for Marbled Murrelets (Evans Mack et al. 2003), the Birds of North America species account for Marbled Murrelets (Nelson 1997), and several in-depth reviews (Ralph et al. 1995, Burger 2002, Raphael et al. 2002, McShane et al. 2004, Piatt et al. 2007, Raphael et al. 2008, USFWS 2009, Raphael et al. 2011). We conducted subsequent searches for additional resources via online databases, search engines, and agency and institutional websites. For these searches, we identified sets of question-specific search terms (see below).

For every search, the following information was documented:

- Date when search was conducted
- Database, search engine, website, or professional network that was searched
- Exact search terms used
- List of hits and outputs (first 50, sorted by relevance)

After completion of searches, members of the review team and other stakeholders were provided an opportunity to identify additional resources (particularly unpublished works and manuscripts in press) to be considered for inclusion in the review process. To be considered for inclusion and to provide transparency of this process, all studies that were in-review or in-press required the primary author's consent that those documents could be made available for scrutiny upon request to the authors.

For studies that met the criteria for inclusion in the review (see section below on Study Inclusion Criteria), we conducted citation searches on the titles via the search engines listed. The bibliographies of included studies also will be searched for additional studies to consider.

Publication Databases and Search Engines

The following publication databases were searched:

- BioOne
- JSTOR
- World Cat
- Directory of Open Access Journals.

An Internet search also was conducted with Google Scholar (www.scholar.google.com). The first 50 hits (based on relevance) from each internet search (not database search) were examined for appropriate studies that have not been identified previously.

Specialist Websites

Websites of the following organizations were searched for links or references to relevant publications, including gray literature:

- British Columbia Ministry of Forests, Lands, and Natural Resource Operations (www.gov.bc.ca/for/)
- California Department of Fish and Wildlife (www.wildlife.ca.gov/)
- Environment Canada (www.ec.gc.ca/default.asp?lang=En&n=FD9B0E51-1)

- National Park Service (www.nps.gov/index.htm)
- Oregon Department of Forestry (www.oregon.gov/ODF/Pages/index.aspx)
- Oregon Department of Fish and Wildlife (www.dfw.state.or.us/)
- Tree Search: USDA Forest Service Research (http://www.treesearch.fs.fed.us/)
- USDA Forest Service (www.fs.fed.us/)
- U.S. Fish and Wildlife Service (www.fws.gov)
- Washington Department of Fish and Wildlife (wdfw.wa.gov/)
- Washington Department of Natural Resources (www.dnr.wa.gov/Pages/default.aspx)
- Regional Ecosystem Office (www.reo.gov/monitoring/reports/marbled-murrelet-reports-publications.shtml)
- Pacific Seabird Group (www.pacificiseabirdgroup.org)
- Universities listed in the following section

Master's and PhD Theses

To capture unpublished chapters of theses and dissertations, the search included catalogues of electronic graduate theses from research universities in the Pacific Northwest:

- Oregon State University;
- University of Oregon;
- Portland State University;
- University of California (system);
- University of Alaska;
- University of Washington;
- Washington State University;
- Simon Fraser University;
- University of Victoria;
- University of British Columbia.

Search Terms and Exclusions

Search terms were divided into sets that represented a particular review question. To the extent that they were permitted by particular websites, Boolean operators (e.g., AND, OR) were used to combine search terms within each set. These terms were determined via consultation with ODF partners, and by looking at protocols of similar SRs (e.g., Bernes et al. 2013; Czarnomski and Hale 2013). No foreign-language searches were conducted, because we presumed that all pertinent literature on these topics is published in English or has English-language summaries.

We acknowledge that, in the absence of information on Marbled Murrelets, data on similar species may be considered the "best available science." However, the extent to which studies of related species, with different breeding ecologies and geographic distributions, can be considered appropriate for inclusion as evidence for questions regarding Marbled Murrelets is uncertain. For example, tree-nesting murrelets in forested areas obviously have very different breeding habitats than most cliff- and burrow-nesting alcids in coastal or oceanic ecosystems. Studies regarding non-forested habitat characteristics, therefore, are unlikely to be relevant. Further, differences between Marbled Murrelets and related species in nest-site fidelity are likely at some if not all spatial scales because documented breeding site fidelity rates of alcids, while high, are variable among species (e.g., Divoky and Horton 1995, Gaston and Jones 1998, Schreiber and Burger 2002) and may be more strongly associated with coloniality than with genetic relationships. Lastly, one would expect to see some differences in flight behaviors near nests between Marbled Murrelets and most other alcids because Marbled Murrelets do not nest in dense colonies (as do many alcids) and generally nest in trees (vs. treeless areas) in inland areas (vs. marine islands and cliffs). While some flight characteristics near nests are likely to be similar to those of other species (both alcids and non-alcids), there is no basis to assume similar associations with habitat or proximity to nests. Although we acknowledge that similarities are likely between some aspects of the breeding ecology of Marbled Murrelets and other alcid species, for the purpose of this review, we limited our searches to studies pertaining to Marbled Murrelets and the previously conspecific long-billed murrelets, Brachyramphus perdix.

For each question, we applied the following search terms to database searches (* indicates wildcard search term):

Search terms for question 1 (How are individual behaviors [subcanopy flight, circling, landing, vocalizations] of Marbled Murrelets indicative of nesting in the forest stand where those behaviors occur?):

("Marbled Murrelet" OR "*Brachyramphus marmoratus*") AND

(nest* OR breed*) AND

("flight behav*" OR subcanopy OR circling OR "jet sound" OR arcing OR calling OR vocaliz* OR wing-beat OR "wing whir" or "occupied behav*")

Search terms for question 2 (To what extent do Marbled Murrelets exhibit nest-site fidelity at various spatial scales [e.g., at the scale of a watershed, forest stand, tree, branch, and platform], and how does the spatial extent of continuous potential habitat affect nest-site fidelity?):

("Marbled Murrelet" OR "*Brachyramphus marmoratus*") AND

(nest* OR breed*) AND

(fidelity OR dispers* OR philopatry OR re-occup* OR renest* OR return OR re-use)

Search terms for question 3 (How does the spatial extent of continuous potential habitat relate to the co-occurrence [i.e., nesting by multiple pairs] of murrelets in a forest stand and at other spatial scales?):

("Marbled Murrelet" OR "*Brachyramphus marmoratus*") AND

(nest* OR breed*) AND

(co-occur* OR "nest density" OR "breeding density" OR colon* OR multiple)

Search terms for question 4 (How is the occurrence of Marbled Murrelet nest sites related to the number and size of potential nest platforms and platform-tree density within stands of different age-classes [young, mature, and old growth]?):

("Marbled Murrelet" OR "*Brachyramphus marmoratus*") AND

nest* AND

(branch OR limb OR platform)

Search terms for question 5 (How is Marbled Murrelet nesting success affected by habitat characteristics?):

("Marbled Murrelet" OR "*Brachyramphus marmoratus*") AND

("breeding success" OR "reproductive success" OR "nest success" OR fledging

OR "nest failure" OR predation OR depredation OR mortality) AND

(habitat OR stand OR landscape OR continu* OR fragment*)

Study Inclusion Criteria

Study inclusion criteria were predefined to ensure an objective selection of the relevant literature. For this review, only primary studies (i.e. studies with original data or original analyses, not reviews without original analyses) were included in order to base our synthesis on evidence, not authors' interpretation of the evidence. In addition to peer-reviewed documents (articles in professional journals, graduate theses, and some government reports), we also included "gray literature" (e.g., unpublished reports) and manuscripts in review, because some of these studies are relevant to the review questions. We did not include undocumented data (e.g., personal communications), sources of raw data, or documents with insufficient information on methodology to allow assessment of the quality or relevance of the study (e.g., presentation abstracts, newsletters).

Articles found in our searches were evaluated for inclusion at three successive levels. In cases of uncertainty or insufficiency of information, the article was included in the next level of assessment. Inclusion was determined initially on viewing the titles of articles. If titles provide insufficient information, inclusion was based on reading abstracts (or summaries), if provided. Finally, each article found to be potentially relevant on the basis of the title or abstract was judged for inclusion by reviewing the full text. Studies that met all inclusion criteria were reviewed for quality and data extraction. For transparency, a list of all studies rejected on the basis of full-text assessment is provided in Appendix 5. If a thesis (or other unpublished document) met all inclusion criteria and also had a peer-reviewed publication associated with it, only the peer reviewed publication was included in the review. If other chapters of the thesis contained relevant information not mentioned in the publication, those chapters also were included in the review. In addition, papers that included analyses synthesizing data presented in earlier studies (e.g., final reports of multi-year studies, review papers) superseded the other studies if they included all relevant data pertaining to the question and provided sufficient information on methodology and a more robust analysis of the data. In cases where the same data (e.g., nest sites) were included in multiple studies, all studies containing novel analyses or unique information were included in the review.

To be included as a review paper for a particular question, a study was required to meet each of the inclusion criteria highlighted for that question in Appendix 6. A synopsis of those criteria was that each study must:

- provide data on Marbled Murrelets anywhere in their geographic range, and
- directly inform the particular question of interest.

A key element of all five questions is that they focus specifically on characteristics associated with identified Marbled Murrelet nests. An important inclusion criterion for all studies was that they include data identified with known nest locations (or locations were nests were likely absent for question 1) at the spatial scale of interest. Thus, studies that addressed the general questions based solely on indirect indicators of nesting (e.g., behaviors associated with "occupancy," inland flight activity patterns) were excluded from the review process, although we discuss comparative results of such studies where appropriate. We further acknowledge that some studies excluded on this basis do include data for areas with nests that were documented subsequently; however, we based our inclusion assessments on the merits of each paper individually and did not look for information (such as occurrence of known nests within the study area) that was not provided or cited in the focal study.

Data-Extraction Strategy

We extracted the primary results of studies from literature selected for inclusion in the data synthesis. Reviewers recorded this information in data-extraction tables for each question, with one table completed for each study (Appendix 7). These tables provided objective information for the assessment and synthesis of evidence and helped to identify gaps in knowledge pertaining to the questions. In addition to extraction tables for each study, we included an overall summary table for each question that summarized the key information from each study.

Critical Appraisal of Studies

When synthesizing data from the studies, it is important to consider both how much confidence we have in the results of the study as they apply to the SR question and their relevance to the review question. For example, a study might directly address the review question, yet have a weak design and power so low that it provides little confidence in the study's results. Conversely, a study may have strong design and power, yet provide results that have only weak relevance to the review question. Scores do not reflect an overall assessment of the study, but rather the relative value of its data as evidence for a particular question. Another factor to consider in this particular SR is that many of the studies are descriptive, so there is a need to consider additional specific factors that help quantify the relevance/confidence of those types of studies that may be important to include yet have no statistical components per se.

External reviewers applied information from the data-extraction tables (Appendix 7) to score each study on relevance and confidence factors by using the following scoring system to appraise each study critically:

Relevance Rating Factors:

- Study objectives: Was the study designed to address specifically the primary review question? (Scoring: 0 = no, but study contains relevant data; 2 = Yes).
- Nest habitat: How similar is the nesting habitat (i.e., forest structure and composition) to that found in Oregon? (Scoring: 0 = not similar [treeless or lacking trees with platforms]; 1 = forested habitat in Alaska, British Columbia, and/or California; 2 = forested habitat in Oregon and/or Washington).
- Continuous habitat: Are blocks of continuous habitat defined within the study area? (Scoring: 0 = no; 2 = yes, but continuity not defined; 3 = yes, with continuity defined). Note: applies to Questions 2 and 3 only.
- Nests: Does the study include data on real or artificial Marbled Murrelet nests? (Scoring: 0 = artificial murrelet nests/eggs/young only; 2 = includes real Marbled Murrelet nests). Note: applies to Question 5 only.

Confidence Rating Factors:

- Study design: Was the overall nature of the study qualitative (score = 0), or quantitative (score = 3) in regard to the review question?
- Sampling design: What was the sampling design as it pertains to the question of interest? (Scoring: 0 = anecdotal or peripheral observations; 1 = descriptive study without control groups, 2 = descriptive study with control/reference groups OR experimental study without replicates OR control groups; 3 = experimental study with replicates OR control groups; 4 = experimental study with replicated sampling AND control groups).
- Study methods: Were the study methods (e.g., audiovisual, radar, telemetry) appropriate for the question of interest? (Scoring: 0 = no; 1 = unknown; 4 = yes).
- Statistically robust: Were the statistical analyses that were conducted appropriate to address the objectives and the data collected? (Scoring: 0 = no; 1 = not applicable [i.e., for a descriptive study]; 5 = yes).
- Statistical power: Did the study present adequate power to detect significant differences if they occurred? (Scoring: 0 = no [power < 0.8]; 1 = not applicable or unknown; 4 = yes [power ≥ 0.8]). Note that power was considered adequate if significant results (at $\alpha = 0.05$) pertaining to the question of interest were reported.
- Study duration: How many years was the study conducted? (Scoring: 0 = 1 year, 1 = 2 years, 3 = ≥3 years).
- Within-season study duration: Were study efforts within seasons sufficient for the question of interest? (Scoring: 0 = no, sampling insufficient for seasonal variation; 1 = unknown or not applicable; 2 = yes, sampling adequate for seasonal variation).
- Sample size: How large was/were the sample size(s) of interest (e.g., number of nests, number of flight behaviors; number of sites)? (Scoring: 0 = single [1]; 1 = small [2–9]; 3 = medium [10–29]; 5 = large [≥ 30]).
- Spatial coverage: What was the relative spatial extent of data collection within each study area? (Scoring: 0 = low -- included <25% of suitable habitat within focal watershed, stand, site, etc.; 1 = unknown or not applicable; 2 = medium—included 25-75% of suitable habitat within focal watershed, stand, site, etc.; 3 = high—included >75% of suitable habitat within focal watershed, stand, site, etc.).
- Document type: Was the study document peer-reviewed? (Scoring: 0 = no [i.e., unpublished reports, articles in non-peer-reviewed serials, or manuscripts in review]; 2 = yes [i.e., published articles, agency peer-reviewed reports, Ph.D. or M.S. theses, or manuscripts in press that have undergone peer review]).

The minimal value for each factor was set at 0. The range of values for each factor reflected the relative importance of the factor in determining overall confidence (e.g., factors with four score levels are deemed more important than those with two levels, based on a survey of factor values among reviewers). Studies for which multiple responses were appropriate for a particular factor (e.g., nest habitat for a study including data across the species range) were assigned the highest appropriate value for that factor. The scores of all relevance and confidence factors were summed for a single Study Evaluation Score to help rank all review papers within each study question. Maximal Study Evaluation Scores for each question varied because some factors and responses were more or less relevant to certain questions than to others. For each question, scores of all included studies were listed and tallied in tables that enable quick, objective comparisons (Appendix 8).

Data Synthesis

Rating the strength of the body of evidence for each review question entailed not only evaluating study quality and the relevance of each study as described above but also included assessing the consistency of results among studies and assessing the comparability of study methodologies. Meta-analyses often are the preferred approach for evidence synthesis but were not conducted for this review because of the descriptive nature of some of the questions and inconsistencies in study methods that resulted in small samples of comparable studies for many of the questions. Thus, we provided a narrative synthesis for each question in this review.

Information from all included studies were summarized and, whenever possible, tabulated qualitatively. Narratives then were used to summarize that table or figure and discuss both the evidence relevant to the question and any gaps in that evidence. These tabulated study characteristics and narrative syntheses allow for comparisons of the degree of similarity among studies and illustrate how the reviewers arrived at an overall

assessment for each review question. Each narrative documents an organized, qualitative evaluation of the strength of the entire body of evidence based on the following criteria:
(1) Quality: the aggregate quality of the entire body of evidence (based on an average of the Study Evaluation Scores of all the individual studies); (2) Quantity: the number of studies, sample sizes, power, and magnitudes of effect; (3) Consistency: the extent to which similar findings are reported when using similar and different study designs; and (4) Coherence: do the findings of the body of evidence make sense as a whole? The narrative also documents how our evaluation may have been impacted by study characteristics and identifies potential effects modifiers (e.g., study locations, habitat type, year effects) that may contribute to variation in study results. We provide additional context for our results and their coherence by comparing them with results from other studies and reviews that provide syntheses following more traditional, non-systematic approaches to summarizing and evaluating results. Finally, based on the evaluation of the evidence, gaps in knowledge are identified.

Results and Discussion

Question 1. How are individual behaviors (subcanopy flight, circling, landing, vocalizations) of Marbled Murrelets indicative of nesting in the forest stand where those behaviors occur?

The ODF management approach for Marbled Murrelets relies heavily on the PSG protocol for helping in determining which forest stands are occupied by murrelets. The protocol provides standardized procedures for classifying survey sites and areas as having "probable absence" of murrelets, "presence" of murrelets flying over the area, or "occupancy" by nesting birds, based on observed flight behaviors (p. 22 of PSG protocol). The flight behaviors considered by the 2003 protocol to be associated with occupancy include: 1) subcanopy flights; 2) landings or attempted landings in trees; and 3) stationary vocalizations from within a stand. In addition, two above-canopy behaviors (i.e., circling and "jet" dives above the canopy) are considered by the protocol to be possible indicators of nesting, to be used to prompt additional survey efforts to detect subcanopy activities. Question #1 focuses on the evidence for whether these five Marbled Murrelet behaviors used by the PSG protocol to indicate occupancy are actual indicators of nesting. We acknowledge that forest habitats also may have value for murrelets beyond a direct association with nesting (e.g., prospecting for nest sites, pair-bonding, roosting), but in this review we focus only on the evidence that these behaviors are associated with the presence of active or inactive nests.

We used similar definitions for behaviors as used in the PSG protocol. Thus, subcanopy flights consisted of any flights below, through, into, or out of the forest canopy within or adjacent to the potential nesting habitat, including circling flights below canopy height. Subcanopy flights also included wing-beat sounds of murrelets heard below canopy. Detailed definitions of circling were lacking in most of the papers we reviewed, so we accepted all data reported as circling and acknowledge the potential for among-study differences in how circling was defined. Thus, circling behavior included any curving flights observed at any height above the canopy. We considered stationary calling to occur when three or more adult calls were heard coming from a single location within 100 m of the observer. "Jet" dives were considered to have occurred whenever diving behavior was observed or the "jet" sound produced by a diving bird was heard.

Papers Reviewed

A search and subsequent screening of available literature yielded 16 studies with primary data or analyses pertaining to these five behaviors at known nesting sites or sites with likely absence of nests (Appendix 8.1, Table 2). A site was considered to be a known nesting site if it contained either an active or inactive (i.e., historic) nest. A site was considered to have a likely absence of nests only if all potential nest trees were searched and no nests were found in the site, or if the habitat was deemed unsuitable for nesting and not closely adjacent to potential nesting habitat (e.g., an isolated stand of trees without nest platforms, or a large area of pastureland). Studies in which nesting suitability of habitat where behaviors were detected was unclear were omitted. Of the 16 studies we reviewed, 5 were articles in peer-reviewed journals, 5 were unpublished reports and papers, 3 were in agency technical reports, 2 were in graduate theses, and 1 was a book/book chapter. Seven of the studies were conducted in Oregon and Washington, 5 were conducted in British Columbia, 4 were conducted in California, and 0 were conducted in Alaska. Fifteen of the studies provided information from known nesting sites and one study provided information from sites with a likely absence of nests.

The mean Study Evaluation Score for the 16 studies was 17.9 points out of a possible 39 points, with scores ranging from 12 to 26 (Table 2, Appendix 8.1). None of the studies scored in the lowest quartile of possible scores (0–9); 10 studies scored in the second quartile (10–19), 6 studies scored in the third quartile (20–29), and no studies scored in the highest quartile (30–39; Figure 1). Just over half (56%) of the studies were in peer-reviewed publications and only half (50%) included methods specifically focusing on quantifying behaviors. The primary reason that no studies had a "high" score was because all 16 studies were either descriptive (n = 10 studies) or anecdotal (n = 6) and most (n = 9 studies) included behavioral information from <10 sites. Hence, they scored lower because they were not amenable to more than descriptive statistics and analyses.

Murrelet Behavior at Inland Sites

Murrelets are cryptic in their plumage and behavior and their nests are typically difficult to find. Therefore, a set of behavioral criteria was developed and incorpo-

Table 2. Summary of evidence for occurrence of "occupied" behaviors within and adjacent to sites with known active or inactive nests and occurrence of "occupied" behaviors at sites with likely absence of active or inactive nests. X indicates that a behavior was observed, but the number of observations was not provided. Study Evaluation Scores had a maximal value of 39.

			Number of times behavior was observed									
			Within or adjacent to a site with known nest(s)					At a site with likely absence of nests				
Citation	Study Evaluation Score	Sample size[2]	Sub-canopy	Landing	Stationary vocalization	Circling	Jet dive	Sub-canopy	Landing	Stationary vocalization	Circling	Jet dive
Dechesne and Smith 1997	12	92 occupied behaviors2 near 1 site with ≥1 active nest and 1 site with ≥1 inactive nest	51	0	0	33	0					
Hamer and Cummins 1990	16	0 occupied behaviors near 31 sites in non-nesting habitat (22 of those 31 sites had presence of murrelets, however)						0	0	0	0	0
Jones 2001	15	130 occupied behaviors near 3 active nests	104[3]	104	18	8	0					
Lougheed et al. 1998	18	Subcanopy flights observed near 16 of 27 nests (active and inactive); landings at 3 of 27 nests; circling near 6 of 27 nests	X	X	0	X	0					
Manley 1999	23	193 occupied behaviors near 7 active and 6 inactive nests	75	48	4	66	0					
Manley and Kelson 1995	14	>9 occupied behaviors near 2 active nests	X	7	X	0	0					

Table 2. Continued.

			Number of times behavior was observed									
			Within or adjacent to a site with known nest(s)					At a site with likely absence of nests				
Citation	Study Evaluation Score	Sample size[2]	Sub-canopy	Landing	Stationary vocalization	Circling	Jet dive	Sub-canopy	Landing	Stationary vocalization	Circling	Jet dive
Naslund 1993	20	Subcanopy flights and circling observed during 83–93% of surveys near 2 active nests and during 67–83% of surveys near 2 inactive nests	X	X	X	0	0					
Nelson and Wilson 2002	25	>1,000 occupied behaviors at 7 sites with active nests and 14 sites with inactive nests	1,631	X	X	117	0					
Nelson et al. 1994	20	>97 occupied behaviors near 1 active and 11 inactive nests	>34	5	4	54	0					
Singer et al. 1991	17	51 occupied behaviors observed near 2 active nests	513	51	1	0	0					
Singer et al. 1995	20	>113 occupied behaviors observed near 4 active nests	>683	43	2	0	0					
Suddjian 2003	18	>3,000 occupied behaviors observed over a 10-yr period in four areas that contained either active or inactive nests in any given year	X	X	X	0	0					

Table 2. Continued.

Citation	Study Evaluation Score	Sample size[2]	Number of times behavior was observed: Within or adjacent to a site with known nest(s)					At a site with likely absence of nests				
			Sub-canopy	Landing	Stationary vocalization	Circling	Jet dive	Sub-canopy	Landing	Stationary vocalization	Circling	Jet dive
Total number of times behaviors observed across all studies:			>2,132	>391	>41	>307	≥4	0	0	0	0	0
Total number of studies reporting this type of behavior:			15	13	9	11	2	0	0	0	0	0

1 Blanks indicate that those columns were not applicable to the study.

2 In this column, the term "occupied behavior" refers to subcanopy flights, landings, stationary vocalizations, circling, or jet dives. Number of nest sites reported based on the number of nest-years (e.g., a single nest site that was active in year 1, inactive in year 2, and active in year 3 would be reported as 2 active and 1 inactive nests).

3 Includes all landing observations because those birds also were observed flying subcanopy as they approached or departed the nest tree.

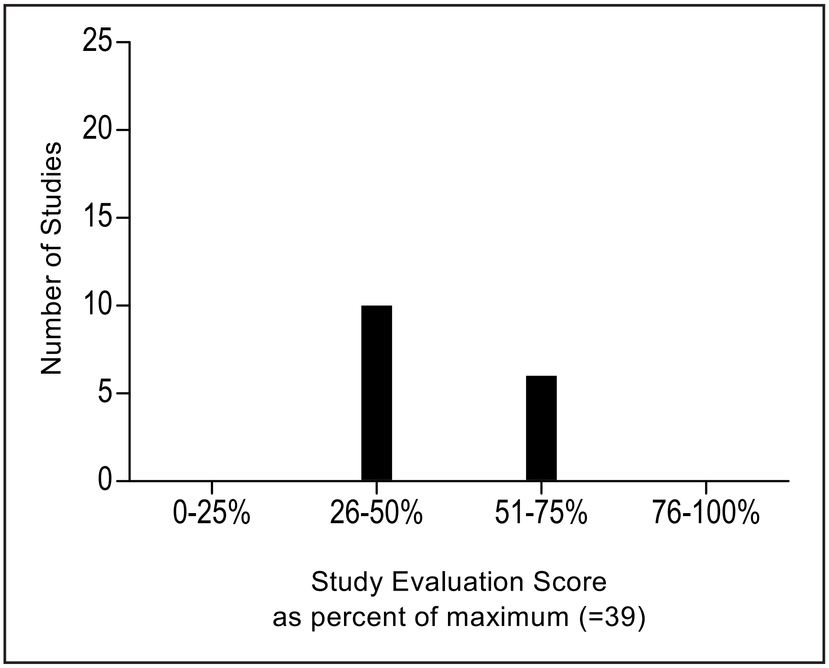

Figure 1. Distribution of study evaluation scores for 16 papers included in review for Question 1: "How are individual behaviors (subcanopy flight, circling, landing, vocalizations) of Marbled Murrelets indicative of nesting in the forest stand where those behaviors occur?"

rated into the PSG protocol to be used to determine if and how Marbled Murrelets use a site (Evans Mack et al. 2003). The PSG protocol cites documentation of certain behaviors (i.e., subcanopy flights, landings, stationary vocalizations, circling, and jet dives) at active nest sites as the rationale to use them as indicators strongly suggesting the occupancy of an area for nesting.

There is evidence that all five types of behaviors used by the PSG protocol to indicate occupancy or possible occupancy occur near nests. At least one of these behavior types was observed at all 15 studies conducted at known nesting sites (Table 2). These behaviors were observed in the vicinity of both active and inactive nests: 6 studies were conducted at active nests, 7 studies made observations near active and inactive nests (including one study where behaviors at active nests were not differentiated from behaviors at inactive nests; Suddjian 2003), and 2 studies had only an inactive nest (Table 3). Subcanopy flight was the most frequently observed behavior (>2,132 observations in 15 of 15 studies), followed by landing (>391 observations; 13 studies), circling (>307 observations; 11 studies), stationary vocalization (>41 observations; 9 studies), and jet dives (≥4 observations; 2 studies; Table 2). All behaviors of interest except jet dives were documented at known nesting sites in at least 5 of the 6 studies with Evaluation Scores ≥ 20 (i.e., >50% of maximum score; Figure 2).

Note that we provide total frequency of each behavior or occurrence by site rather than a mean number per day or per site because means (and variance) rarely were provided for the particular variables of interest in the review papers. The relative frequency of occurrence of all behaviors of interest has not been addressed by any individual study at sites with known nest presence; and differences among studies in methods, effort, and study objectives prevent summarization and direct comparisons across available studies. Efforts within studies also generally varied among sites, and frequencies were not standardized by effort (i.e., as rates), further limiting comparisons.

Only one study (a single-year study by Hamer and Cummins 1990) contained information on behavior at sites (lacking suitable habitat) with likely absence of nests. Behaviors used by the PSG protocol to indicate occupancy or possible occupancy were not reported at sites likely lacking nests (Table 2). The study included observations at 31 sites with likely absence of nests in Washington (i.e., in rock/talus, clearcut/meadow/sapling areas [<20 cm dbh], or small saw/pole forests [20-50 cm dbh]) and found no evidence for any of the five behaviors, despite the fact that murrelets were present at 22 of the 31 sites (Hamer and Cummins 1990).

Behavior as an Indicator of Nesting

Because both subcanopy flights and landings necessarily must occur at nest locations, the focal questions for

Table 3. Summary of evidence for occurrence of "occupied" behaviors within and adjacent to sites with known active or inactive nests. Study Evaluation Scores had a maximal value of 39.

		Number of sites with occurrence of behaviors at or adjacent to nest sites[1]											
		Known active nest(s)						Known inactive nest(s)[2]					
Citation	Study Evaluation Score	Sample size[3]	Sub-canopy	Landing	Stationary vocalization	Circling	Jet dive	Sample size[3]	Sub-canopy	Landing	Stationary vocalization	Circling	Jet dive
Dechesne and Smith 1997	12	1	1	0	0	1	0	1	1	0	0	0	0
Jones 2001	15	3	3	3	1	1	0						
Lougheed et al. 1998	18	3	3	3	0	?	0	27	15	3	0	6	0
Manley 1999	23	7[4]	4	4	1	1	0	6[4]	6	6	1	1	0
Manley and Kelson 1995	14	2	2	2	1	0	0						
Naslund 1993	20							2	2	1+	2	0	0
Nelson and Hardin 1993	13							1	1	1	0	1	0
Nelson and Peck 1995	22	9	9	9	9	1+	3	2	--	2	--	--	--
Nelson and Wilson 2002	25	7	7	3+	1+	5	0	14	6	2+	0	5	0
Nelson et al. 1994	20	1	1	1	0	0	0	4[4, 5]	1+	3	1	1	0
Singer et al. 1991	17	2	2	2	1	0	0						
Singer et al. 1995	20	3	3	3	2	0	0						
Varoujean et al. 1989	15	1	1	1	--	1	--						
Witt 1998	19	1	1	1	0	1	1						
Total number of sites:		40	37	32+	16+	11+	4	57	32+	18+	4	14	0

1 "?" indicates occurrence of behavior suggested by study but not clearly indicated. "--" indicates behavior not considered in study.

2 As identified by author(s) at time of observation.

3 Number of survey sites reported based on the number of nest-years (e.g., a single nest site that was active in year 1, inactive in year 2, and active in year 3 would be reported as 2 active and 1 inactive nests).

4 Focus of studies differed among nest sites; so not all behavior types reported for each nest.

5 Multiple old nests found at 4 sites, although uncertain if active nests undetected.

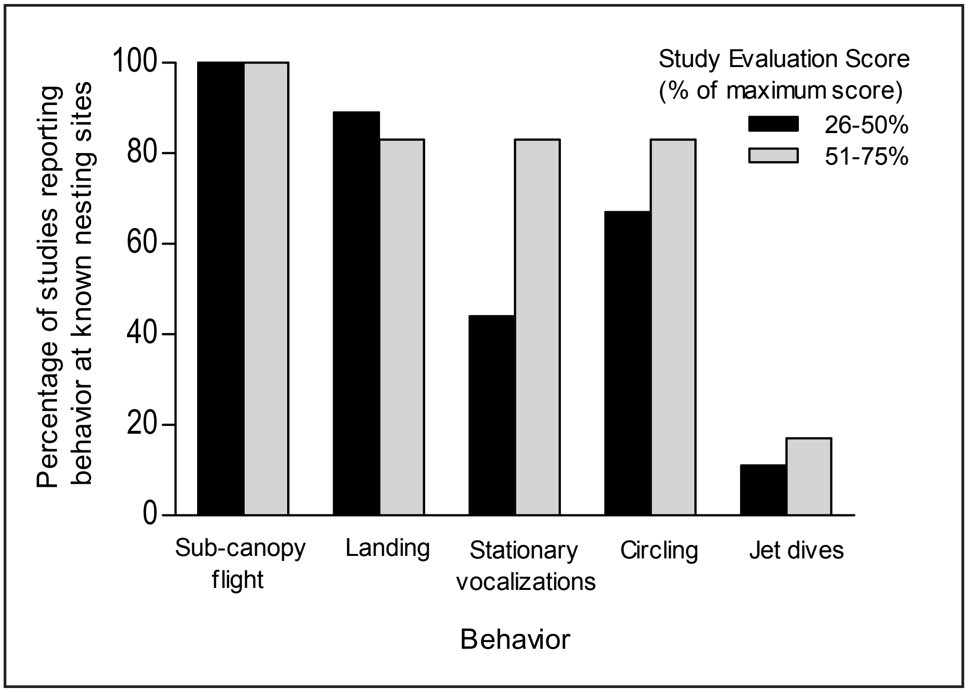

Figure 2. Studies containing evidence of "occupied" behaviors at Marbled Murrelet nesting sites relative to Study Evaluation Scores.

this review pertain to the relative degree to which other types of behaviors (i.e., vocalizations, circling, jet dives) are associated with nest locations, and how frequently do all behaviors considered to be indicative of nesting occur in areas lacking nests. Another question of interest is whether occupied behaviors occur at inactive nest sites and, if so, to what extent are they indicative of past or future nesting at those sites. Below, we address these questions for each of the five behavior types of interest.

Subcanopy Flights and Landings

In our review, 15 of 15 studies in known nesting sites observed some type of subcanopy flight. Subcanopy flights were reported near both active and inactive nests (Table 3). We found no evidence that subcanopy flights occur at sites with a likely absence of nests, but note that only one study (Hamer and Cummins 1990) had information for non-nesting sites, and that those sites lacked suitable nesting habitat.

In our review, 13 of our 15 studies in known nesting areas observed landings (Table 2). Eleven of 12 studies reported landings near active nests and 7 of 8 studies reported landings near inactive nests, although landings were reported less frequently at sites with inactive nests than at sites with active nests (Table 3). In addition, landings occurred at trees without nests that were in close proximity to nest trees (Manley and Kelson 1995, Nelson and Peck 1995). Hamer and Cummins (1991) found no evidence for subcanopy flights or landing at 31 sites lacking suitable nesting habitat. Thus, there is considerable and consistent evidence indicating that subcanopy flights and landings occur near both active and inactive nests; however, there is insufficient evidence at sites with a likely absence of nests, particularly in areas with suitable nesting habitat, to determine the extent to which these may behaviors occur away from nest sites.

Stationary Vocalizations

Stationary vocalizations at known nesting sites were reported in 9 of our 15 review papers at known nesting sites, including 5 of the 6 studies with Evaluation Scores ≥ 20 (Table 2). Stationary vocalizations were reported near active nests in 7 studies (including 4 of 5 studies with Evaluation Scores ≥ 20) and near inactive nests in 3 studies (3 of 4 studies with Evaluation Scores ≥ 20). In all studies, stationary vocalizations were reported at fewer sites than either subcanopy flights or landings. Stationary vocalizations were not reported at any sites with a likely absence of nests. Thus, the available evidence indicates that stationary vocalizations occur near active and inactive nest sites, but no evidence was found indicating that they occur at sites with a likely absence of nests, although no studies provided data for sites with suitable habitat that was known to lack nests.

Circling

Circling over nest sites was reported in 11 of the 15 studies in known nesting areas, including 4 of the 6 studies with Evaluation Scores ≥ 20 (Table 2). Seven studies (including 3 of 5 with Evaluation Scores ≥ 20) report circling near active nests and 5 studies (including 3 of 4 with Evaluation Scores ≥ 20) observed circling near inactive nests (Table 3). Circling behavior, however, was not reported for all sites in some studies where sub-canopy behaviors were observed (e.g., Lougheed et al. 1998). In contrast, Hamer and Cummins (1991) found no evidence for circling at the 31 sites with likely absence of nests (given a lack of suitable nesting habitat) that they studied. Overall, circling was recorded at fewer nest sites than were sub-canopy flights and landings (Table 3). Thus, the available data indicate that circling often occurs near nesting sites, although the relative frequency and consistency of occurrence was not determinable across studies (or a subset of studies with relatively higher Evaluation Scores).

Jet Dives

Jet dive flight displays were reported near four active murrelet nest sites in two studies (Table 3). There was no evidence of jet dives occurring over sites with a likely absence of nests in the single study that included observations at such sites. In most studies, however, it was unclear if jet dives were regularly and consistently recorded or reported, so it is possible that the number of jet dives reported is lower that what actually was observed.

Variation Among Studies

There generally was good consistency among studies in terms of how the different behaviors were defined. The one possible (but unknown) exception was for circling behavior: none of the papers fully defined both the amount of arcing that constituted circling and a maximum height above canopy. There are at least two reasons why it is important to consider the potential effect of how circling was defined, both in terms of the degree of arc required to constitute circling and the height at which circling occurred. First, if any deviation from a straight flight path was defined as circling (as in the PSG protocol), it raises the possibility of a study concluding that circling occurred when a bird was simply making a slight course adjustment on its way to a distant location. Secondly, if there were among-study differences in how circling was defined relative to canopy height, then studies that defined circling to include circling at all heights might have different results (i.e., be more likely to detect circling behavior and conclude that nesting may have occurred in the area) than a study that restricted circling to lower-level flights relative to the canopy. Unfortunately, the degree to which these scenarios may have occurred is impossible to determine due to the fact that detailed definitions or descriptions of circling were not provided for the review studies.

Another possible, but unknown, source of variation among studies was that it was not always known whether the behaviors were associated with active or currently inactive nests when both occurred. This was further complicated by the fact that because murrelet nests can be so difficult to find (particularly after early nest failure) and because exhaustive and repetitive nest searching of entire sites was rare, there could have been additional active and inactive nests in the area that were not found. Thus, we often were not able to compare the frequency of those behaviors between active and inactive nests; but clearly, there was consistency in the overall pattern that one or more of the overall group of behaviors thought to indicate occupancy or possible occupancy occurred near both active and inactive nest sites.

In addition, there was considerable variation among studies in how information on behaviors was collected and presented. Anecdotal observations of behaviors reported in many studies did not exclude the possibility that other behaviors also were observed but not reported. Because none of the relevant studies focused on systematic recording of all behaviors of interest or standardizing frequencies of detections, summarization and direct comparisons across available studies are severely limited, as are relative comparisons of behaviors within studies.

Effects Modifiers

There are several factors that may have influenced results across studies to an unknown degree, including but not limited to season, geography, and habitat. For example, there could have been a seasonal effect if studies made observations only during a small portion of the breeding season (e.g., there could have been differences in the relative proportions of different behavior types observed early in the breeding season when birds were beginning to nest vs. later in the season when breeding adults were feeding chicks and when more nonbreeding birds may have been present). This potential effect was minimized by the fact that most (14 of

17) studies made observations over the majority of the breeding season.

It also is possible (but unknown) if there were habitat differences among geographic areas that could have affected behavior (e.g., the possibility that birds could have had different flight behavior in redwood-dominated habitat in California vs. habitat further north in Oregon composed of other tree species). A redwood habitat effect, if one exists, would have been minimized by the fact that only 3 of the 20 studies (Naslund 1993; Singer et al. 1991, 1995) were conducted in redwood habitat.

Some habitat types are certain to have had an effect on the types of behavior that were observed. For example, birds flying over water, clearcuts, meadows, or other areas without trees obviously could not fly below canopy, land in trees, or vocalize from a nest, but they could circle or jet dive. The single study conducted in sites with a likely absence of nests made observations over unforested habitat and was affected in this manner. Similarly, local topography could have had an effect on observed behaviors. For example, birds flying up a narrow, steep canyon could have been considered to be subcanopy flights depending upon which of the surrounding trees were used as the baseline measure of the top of canopy height. Further, at such sites, birds could have been characterized as circling if they had curving flights that followed the winding course of a canyon.

It is worth noting that many of the studies included in our review were conducted during the first years of research on Marbled Murrelets, when the focus was on basic ecology and not hypothesis-driven research. Further, the current survey protocol (Evans Mack et al. 2003) was not yet in existence during some of the early studies, so murrelet study methodologies were still evolving. For example, some of the early studies included were based on single-season observations; before the ISP identified the need for multiple years of study to ascertain occupied status of habitat.

Comparison to Non-systematic Reviews

The following information is a non-systematic review of related publications and is provided for context only. The publications included have not been intensively reviewed according to the protocols described in our methods section.

Murrelets are highly vocal at inland nesting areas and are more vocal at sea compared to other alcids (Nelson 1997). The three general categories of murrelet calls are Keer Calls, Whistle Calls, and Groan Calls. All three types of calls occur at nests, but in general, vocalizations made in close proximity to a nest are soft and loud calls at nests are uncommon (e.g., Nelson and Hamer 1995b, Nelson and Peck 1995, Singer et al. 1995). In our review, we did not find any definitive evidence that stationary calling occurs at sites with a likely absence of nests. Thus, available evidence supports the use of locations of stationary calls to help locate nesting sites.

Circling and aerial displays are well-known in colonial alcids and can serve many purposes, including social interactions, courtship, and predator avoidance (Nettleship and Birkhead 1995, Gaston and Jones 1998, Schreiber and Burger 2002). We focused this review on murrelets, since one might expect to see some differences between Marbled Murrelets and other alcids. For example, Marbled Murrelets do not nest in dense colonies (relative to many alcids) and generally nest in trees (vs. treeless areas) in inland areas (vs. marine islands and cliffs).

Circling over nesting stands has been stated as a characteristic of Marbled Murrelets (Nelson 1997) and was reported for 11 of the 15 studies conducted at nesting sites (Table 2). Other evidence for circling over non-nesting habitat is provided by three studies reporting circling over lakes (Eisenhawer and Reimchen 1990, Reimchen 1991, and Rodway et al. 1991); however, in all three of those studies the lakes were surrounded by habitat that probably contained nests.

It is important to consider the spatial scale at which circling occurs. For instance, if circles tend to be large and non-nesting habitat was located close to the nesting habitat that the circling murrelet was associated with, one obviously would expect that birds occasionally circle over the non-nesting habitat. Radar studies have determined that murrelets sometimes fly in large circles (up to ~1 km in radius) from the site with which they appeared to be associated (Cooper and Blaha 2002), so this scenario is a possible explanation for observations of circling over non-nest sites (e.g., lakes).

Jet dives may function to maintain murrelet pair bonds or be used in territorial defense (Nelson 1997). Jet dive flight displays were reported near three active nests and one inactive nest in two of our review studies, but there was no evidence that jet dives occurred over sites with likely absence of nests (Table 2). Nelson and Hamer (1995b) state that jet dives have “been observed most often (67%) associated with known nest trees." This statement suggests that the dives also may occur at an unknown distance away from nests, if one is willing to assume that the 33% of dives observed away from known nests occurred in locations where non-nesting was verified (source data and sample sizes for this figure were not provided, however, so no firm conclusions can be drawn).

The PSG protocol cites examples of subcanopy flights, landings, stationary vocalizations, circling, and jet dives at active nest sites as a rationale to use them as indicators of occupancy, but also provides two examples of subcanopy flights occurring at likely non-nesting sites. In the first example, murrelets were observed flying just above the top of riparian hardwood trees when following stream channels, especially during foggy or overcast mornings. In the second example, low-flying birds were observed as they crossed ridgelines or in steep canyons over non-nesting habitat areas.

Conclusions and Data Gaps

In summary, there is consistent evidence indicating that subcanopy flights, landings, stationary vocalizations, and circling regularly occur in the vicinity of known Marbled Murrelet nest sites. Further, there are good reasons from a life history standpoint as to why each of these behaviors might be expected to occur near active nests. Currently, however, there are no studies that have systematically examined the relative frequencies of occurrence of these behaviors (as well as the less-frequently reported jet dives) at known nest sites. The studies that include data relevant to this specific question, therefore, were descriptive or anecdotal in nature and generally consisted of observations at a small number of sites, resulting in Study Evaluation Scores that ranged from 12 to 25 (of a maximum 39 points). In addition, there is very little information available on the spatial scale (i.e., distance from the nest) at which these behaviors might occur.

We also found studies providing evidence that all five types of occupied behaviors occurred at active nest sites and that four of the five types of occupied behaviors (i.e., all except jet dives) occurred at inactive nest sites. These data indicate that occupied behaviors occur not only at active nesting sites, but also suggest that they might be associated with past nesting attempts and potentially with future nesting attempts, assuming murrelets exhibit nest site fidelity (see Fidelity sections below). Here, again, however, studies are lacking that quantitatively and conclusively demonstrate the relationships between such behaviors and past, present, and future nesting at sites.

To demonstrate the usefulness of behaviors as indicators of nesting, it also is necessary to determine the degree to which those behaviors occur at non-nesting sites. However, we found only one study (with a low Study Evaluation Score) that included observations of Marbled Murrelet behaviors at a non-nesting site, and those sites were in habitat that was unsuitable for nesting. No occupied behaviors were observed among birds observed flying over the unsuitable habitat in that study.

The most pressing need in regards to addressing Review Question #1 is to collect more information on murrelet behavior from known non-nesting areas (particularly areas within suitable nesting habitat). Further, it would be valuable to publish results of those studies in appropriate peer-reviewed journals to help maximize their quality and accessibility. Such studies would need to consider effects of habitat type, season, and proximity to known nesting locations. A key goal would be to determine how commonly each of these occupied behaviors occurs in various configurations of non-nesting sites. Those data could then be used to help assess what the overall probability is for occurrence of occupied behaviors at non-nesting sites.

In addition to conducting studies in known non-nesting sites in otherwise suitable habitat, more information is needed on the frequency and relative frequency of occurrence of occupied behaviors at known nest sites and their associations with past, current, and future nesting activity at the site. Data for such analyses may already exist in raw data from protocol surveys at known nest sites; however, locating inactive nest sites remains problematic in most cases and would require extensive effort and cost to determine in future focused studies.

Question 2. To what extent do Marbled Murrelets exhibit nest-site fidelity at various spatial scales (i.e., at the scale of a watershed, forest stand, tree, branch, and platform), and how does the spatial extent of continuous potential habitat affect nest-site fidelity?

This question focuses on an aspect of Marbled Murrelet breeding ecology (site fidelity by the same or different individuals) that, at the level of the forest stand, is cited in the PSG protocol as supportive evidence for the importance of continuous habitat beyond the survey site. In the context of this study, the term "site fidelity" includes repeated use of a site (from a specific nest to a watershed containing known nests) within a year or among years by the same or different individuals. In effect, this question looks at whether birds reuse areas—is there site-fidelity at various scales, and do birds reuse the same area among years?

The analysis of survey effort required to classify occupancy correctly (Appendix A of the PSG protocol) was done at the survey-site level; however, the Protocol extends "site classification" beyond the survey-site to the entire survey area and recommends consulting with appropriate regulatory agencies regarding habitat beyond the survey area boundary. In this review, we also assessed the evidence for relationships between site fidelity and the extent of continuous potential habitat. In other words, we looked for evidence to help address the question "If birds nest in one part of a stand of what appears to be suitable habitat, is that indicative of current or future nesting in the same or other parts of the stand?"

We examine here the evidence for fidelity at a variety of scales. In this context, it is important to note that fidelity to small scales (e.g., nest-cup, nest-branch) also implies fidelity at larger scales, all the way up to that of a watershed. In addition, the issue of renesting is of interest in the context of fidelity in that it is worth knowing whether renesting occurs and whether failed birds that do attempt to renest do so in the same watershed/stand/tree/etc. or they go somewhere else. We also examine here the effects of continuity of habitat on fidelity.

Papers Reviewed

A search and subsequent screening of available literature yielded 23 studies with primary data or analyses pertaining to fidelity at any scale and/or the effects of continuity of habitat on fidelity. Of these studies, 11 were unpublished reports and papers, 9 were articles in peer-reviewed journals, 1 was in an agency technical report, 1 was a book chapter, and 1 was a graduate thesis. Four of the studies were conducted in Oregon and Washington, 10 were conducted in British Columbia, 5 were conducted in California, 3 were conducted in Alaska (including 1 exclusively in unforested habitat), and 1 was a synthesis of rangewide information. Note that selection criteria for pertinent literature was restricted to direct evidence of fidelity as indicated by observations at active nest sites or tracking radio-tagged birds to inland sites. Indirect evidence of nesting (e.g., radar surveys, observations of occupied behaviors) was not included for this critical review but we address these data in "Comparisons with Other Studies" (see below).

The mean Study Evaluation Score for these studies was 16.6 points out of a possible 42 points, with scores ranging from 10 to 25 (Table 4, Appendix 8.2). One study scored in the lowest quartile of possible scores (0–10); 21 studies scored in the second quartile (11–21), 1 study scored in the third quartile (22–31), and no studies scored in the highest quartile (32–42; Figure 3). Because of the difficulty in discovering murrelet nests (i.e., low sample-sizes) and the fact that many of these studies involved learning how to find nests or describing nests discovered by accident, many of these studies largely were descriptive or anecdotal and, hence, resulted in low scores primarily because they were not amenable to anything more than descriptive statistics and analyses. Because nearly all studies scored in the second quartile of potential scores, we do not highlight results of "high"-scoring studies in the following results.

Site Fidelity

Because many of the nests were found by following telemetered birds captured at sea, nests could be scattered over vast areas (e.g., Bloxton and Raphael 2009, Barbaree et al. 2014; see also Hull et al. 2001), making inferences about fidelity to a watershed difficult because birds may go to a large variety of locations. On the other hand, locating nests by extensively searching all branches of all possible nest-trees is extremely difficult and prohibitively expensive over large areas. As a result, none of the climbing studies reviewed were able to search an area approaching an entire watershed or even a large stand of trees. In addition, as some authors admit, nests that were rechecked in subsequent years may have been active in the second year but failed prior to nest-checks and hence may have been misclassified as non-active. Finally, only one bird studied in British Columbia (Burger et al. 2009) and one studied in northern California (Golightly and Schneider 2011) were known, marked birds; so evidence of nest fidelity of individuals is poorly known for all scales of fidelity.

In tabulating occurrences of fidelity, we assumed that fidelity at one spatial scale implied fidelity at larger scales as well, although the numbers were not cumulative across scales unless clearly stated as such. For example, demonstrated fidelity at two nest trees implied

Table 4. Summary of evidence of fidelity in nesting Marbled Murrelets in North America at various scales. For each scale, the number of observations of fidelity is indicated (total sample sizes are provided in parentheses). Study Evaluation Scores had a maximal value of 42.

	Scale[1]					
Elements	Study Evaluation Score	Watershed	Stand	Tree	Branch/ platform/ nest-cup	Source
OREGON						
Coast Range and Siskiyou Mountains	16	2 (≥2)	2 (7)	2 (7)	0 (9)	Nelson and Peck (1995)
Clatsop, Tillamook, and Elliott state forests (Coast Range)	19	≥3 (≥3)[2]	6 (13)[2]	1 (≥1)	--	Nelson and Wilson (2002)
WASHINGTON						
Olympic Peninsula (plus southern Vancouver Island and Cascades)	14	2 (≥2)	1 (1)	1 (1)	1 (1)	Bloxton and Raphael (2009)
Olympic Peninsula	17	4 (8)[3]	4 (8)[3]	4 (22)[3]	--	Meekins and Hamer (1999)
BRITISH COLUMBIA						
Carmanah–Walbran watersheds (southwestern Vancouver Island)	16	2 (2)	1 (1)	0 (6)	0 (6)	Burger (1994)
Southeastern Vancouver Island	14	1 (1)	1 (1)	1 (1)[3]	--	Burger et al. (2000)
Mainland and eastern and western Vancouver Island	25	≥4 (≥4)	≥5 (≥5)	26 (143)	5 (22)	Burger et al. (2009)[4]
Ursus Valley, Clayoquot Sound (southwestern Vancouver Island)	18	1 (1)	≥1 (≥1)	--	--	Conroy et al. (2002)
Desolation Sound and Bunster Range (mainland)	19	≥1 (≥1)	≥1 (≥1)	3 (9)	3 (9)	Drever et al. (1998)
Caren Range (mainland)	15	1 (1)	1 (1)	1 (1)	1 (1)	Jones (2001)
Desolation Sound	17	≥1 (≥1)[2]	≥1 (≥1)[2]	2 (21)[2]	1 (21)[2]	Lougheed et al. (1998)
Sunshine Coast, (mainland)	21	≥1 (≥1)	≥1 (≥1)	4 (36)	--	Manley (1999)
Desolation Sound and Clayoquot Sound (south-western Vancouver Island)	16	≥1 (≥1)	≥1 (≥1)	5 (5)	--	Manley (2003)
Chilliwack River (mainland)	10	1 (1)	1 (1)	--	--	Ryder et al. (2012)

Table 4. Continued.

Elements	Study Evaluation Score	Scale[1] Watershed	Stand	Tree	Branch/ platform/ nest-cup	Source
CALIFORNIA						
Redwood National and State parks (northern)	13	1 (1)	1 (1)	1 (1)	1 (1)	Golightly and Schneider (2011)
Redwood National and State parks (northern)	19	≥1 (≥1)	≥1 (≥1)	3 (10)	3 (10)	Hébert and Golightly (2006)
Redwood National and State parks (northern)	15	≥1 (≥1)	2 (2)	--	--	Hébert et al. (2003)
Big Basin Redwoods State Park (central)	21	1 (1)	1 (1)	1 (1)	1 (2)	Singer et al. (1995)
Prairie Creek Redwoods State Park (northern)	11	1 (1)	1 (1)	1 (1)	1 (1)	Spickler and Sillett (1998)
ALASKA						
Port Snettisham (Southeastern)	20	≥1 (≥1)	≥1 (≥1)	4 (≥4)	--	Barbaree et al. (2014)
Barren Islands (northern Gulf of Alaska)	12	1 (1)[5]	1 (1)[5]	1 (1)[5]	--	Hirsch et al. (1981)
Naked, Afognak, and Kodiak islands (northern Gulf of Alaska)	17	1 (≥1)	1 (2)	0 (5)	0 (5)	Naslund et al. (1995)
OTHER						
Rangewide	17	4 (4)	4 (4)	4 (4)	1 (13)	Divoky and Horton (1995)[6]

1 Fidelity at one spatial scale implied fidelity at larger scales, but the numbers were not cumulative across scales unless clearly stated as such. For example, demonstrated fidelity at two nest trees implied fidelity at ≥1 forest stand and ≥1 watershed, unless indicated that trees were in different stands/watersheds.

2 Additional cases of reuse suggested by "occupied" behaviors.

3 Multiple use; nest ages uncertain, so unclear if re-use or co-occurrence.

4 Includes results of Burger (1994), Burger et al. (2000), Manley (1999), Jones (2001), Conroy et al. (2002), and most of the tree and branch/platform/nest-cup data from Cooke (1999), Drever et al. (1998), and Lougheed et al. (1998).

5 Ground nest.

6 Unknown amount of overlap with Naslund et al. (1995), Singer et al. (1995), and Jones (2001).

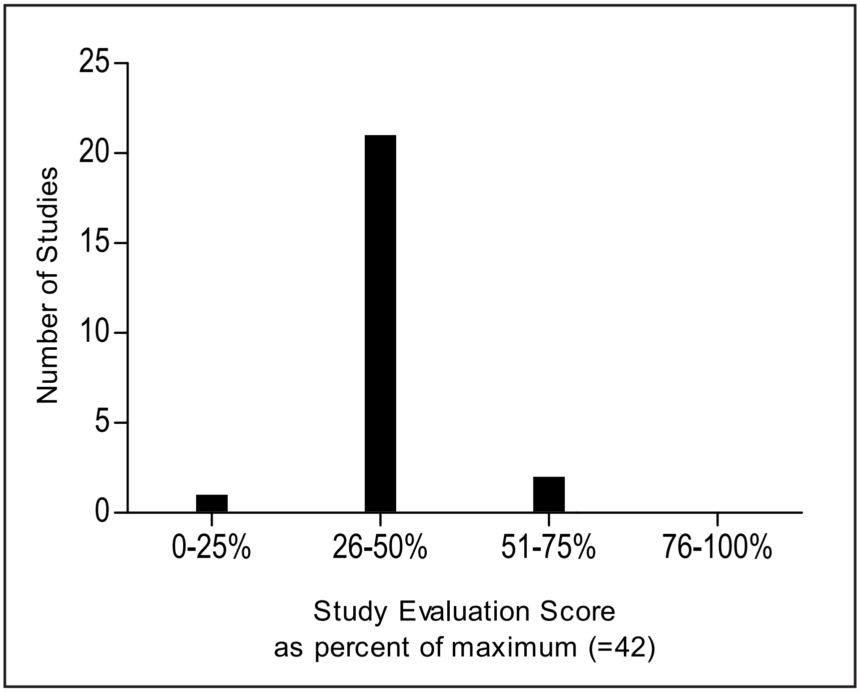

Figure 3. Distribution of study evaluation scores for 23 papers included in review for Question 2: "To what extent do Marbled Murrelets exhibit nest-site fidelity at various spatial scales (i.e., at the scale of a watershed, forest stand, tree, branch, and platform), and how does the spatial extent of continuous potential habitat affect nest-site fidelity?"

fidelity at ≥1 forest stand and ≥1 watershed, unless indicated that trees were in different stands/watersheds. In addition, while papers with duplicated results were omitted from the review, there remained some overlap in data presented in different studies (as indicated in Table 4). Because different studies also may have been conducted in the same locations (e.g., over different time periods), cumulative summaries do not accurately represent the total numbers of locations where fidelity was determined.

Fidelity at Scale of Watershed

There is consistent evidence of fidelity at the scale of a watershed, as indicated by each of the 23 studies reviewed (Table 4). These studies found evidence of fidelity at the watershed scale for all (n ≥37) watersheds examined. By region, this equates to fidelity in the following number of watersheds: ≥11 watersheds studied in Oregon and Washington, ≥15 watersheds studied in British Columbia, ≥3 watersheds studied in California, and ≥3 watersheds studied in Alaska. Nesting fidelity to the watershed was documented for six known individuals (one each in California and British Columbia, and four in Alaska); so all other cases of fidelity included here represent reuse by unknown (i.e., the same or different) individuals.

Fidelity at Scale of Stand

There also is evidence of fidelity at the scale of a stand, as indicated by each of the 23 studies reviewed (Table 4). Overall, fidelity was identified at ≥40 of the ≥57 stands studied (and at ≥5 stands in the one study with an Evaluation Score >50% of the maximum). By region, fidelity was observed in ≥13 of ≥29 stands studied in Oregon and Washington, ≥15 of ≥15 stands studied in British Columbia; ≥6 of ≥6 stands studied in California; and ≥3 of ≥4 stands studied in Alaska. Fidelity to the nest stand was documented for only six known individuals (one each in California and British Columbia, and four in Alaska); so all other cases of fidelity included here represent reuse by unknown individuals.

Only 10 studies specifically addressed renesting at the stand level. Nest stand fidelity, therefore, was implied by reuse of individual nest trees in most studies. Furthermore, fidelity/reuse was often inferred by the discovery of old nests during climbing of a suspected or known nest tree and/or a sample of trees with suitable nest platforms. Because all potential nest trees in a stand were not examined for evidence of nesting, actual rates of stand fidelity could not be determined and would provide conservative estimates at best.

Several studies recorded interesting aspects of stand-scale fidelity. For example, Manley (1999) found that 52% of 36 nest-sites in mainland British Columbia, where 80% of the original habitat is gone and nesting options are limited (Zharikov et al. 2006, Burger et al. 2009), were associated with another nest-tree within 100 m; for most of the clusters, nests were not active at the same time, but 2 pairs of active nests occurred 38 m and 58 m from each other. The author suggested that nest clusters may represent multiple nesting attempts within the same stand by a breeding pair and, hence, indicate fidelity to a nest-patch instead of a nest-tree or a nest-platform. Nelson and Wilson (2002) found 2 active nests ~30 m from each other at one site in the Coast Range of western Oregon, another area with extensive logging that may provide limited nesting options for murrelets.

Fidelity at Scale of Tree

Fidelity at the scale of a tree was indicated by evidence from 19 of the 23 studies reviewed (Table 4). Overall, this resulted in fidelity at the tree scale for ≥64 of ≥276 trees revisited by observers in multiple years. By region, fidelity was observed at 8 of ≥31 trees studied in Oregon and Washington, 43 of 222 trees studied in British Columbia; 6 of ≥13 trees studied in California; and 4 of ≥9 stands studied in Alaska. Finally, in a rangewide study of the species, fidelity was observed in 4 of 4 trees studied.

The best evidence for fidelity at a tree scale was multiple nests of various ages in 1 tree, although there sometimes was other evidence of reuse of a single nest in a tree (e.g., remains of old eggs or chicks that died in the nest in previous years). Altogether, 5 trees in Oregon have been found to contain multiple nests, indicating fidelity at a tree scale, with up to 3 nests in a tree (Nelson and Wilson 2002). Meekins and Hamer (1999) climbed 1,498 trees in Washington while searching for nests and found 27 nest-sites in 22 (1.5% of all trees searched) nest-trees, with 4 (18%) of the nest-trees each containing 2–4 nest-sites. The authors suggest that, because multiple nest-sites often were found in the same plot or the same tree, it is likely that pairs return to the same patch of forest to renest. The best evidence for fidelity at the tree scale comes from British Columbia, where 26 (18%) of 143 nest-trees showed evidence of fidelity (multiple nest-sites within the tree or multiple use of the same nest in different years; Burger et al. 2009).

Fidelity at Scale of Branch/Nest-Platform/ Nest-Cup

There is evidence of fidelity at the scale of a nest-branch, nest-platform, or nest-cup (Table 4). Overall, 13 of the 23 studies reviewed indicated fidelity at these smaller scales for 18 of the 101 nests examined. By region the cases of fidelity included: 1 of 10 nests studied in Oregon and Washington (2 studies); 31 of 59 nests studied in British Columbia (5 studies); 6 of ≥14 nests studied in California (4 studies); and none of the 5 nests revisited multiple times in Alaska (1 study). Small sample sizes preclude determining the extent or potential causes of geographic variation. One important data point comes from the work of Golightly and Schneider (2011) in California, where a banded female has returned to the same nest off and on for more than a decade.

Renesting and Fidelity

Renesting following failure of initial nests occurs frequently in at least some Marbled Murrelet populations. McFarlane et al. (2003) used a combination of telemetry data, blood protein analyses, and examination of brood patches in captured individuals to determine that females renested after 34% of 82 failed first nesting attempts in Desolation Sound, BC, although the extent of fidelity was not determined because they did not locate initial nests. If renesting at a failed nest occurs, it can occur at a variety of scales from the same watershed to the same nest-cup, as with nesting in general. All evidence of renesting indicates fidelity at these various scales, although only coarsely at the scale of the stand and watershed. Only 5 studies discuss renesting and fidelity explicitly.

Burger et al. (2009) discuss radio telemetry data from British Columbia that showed a tagged bird nesting within 200 m of a nest used 2 years earlier.

Barbaree et al. (2014) studied 35 nests in southeastern Alaska. Overall, 4 (16%) of 25 murrelets that failed in their first nest renested, but they did so only when the nest failed during the incubation stage. Renesting occurred in the same location (within the accuracy of the telemetry work) and nest-site type as did the first nesting attempts, but the reuse of exactly the same trees or nest-cups could not be determined because nests were too inaccessible to be visited.

Drever et al. (1998) climbed 355 trees in desolation Sound and the Bunster Range, BC. Murrelets attempted to renest at 2 sites in 1996, but both attempts apparently failed. Although it was assumed that the reuse of nesting sites was done by the same individuals, no conclusive evidence was obtained. The authors suggest that different individuals may attempt to reuse nest-sites when nesting habitat is limited and the competition for nests is high.

Hébert and Golightly (2006) studied 10 nests in northern California in 2001–2003, with Nest 1 being the same nest as that discussed with a longer time-series by Golightly and Schneider 2011). Of the 10 nest-sites examined, renesting was attempted at 2 (20%) of these nest-sites in a given year (note: a third nest-site was reused in different years; Table 4).

Hébert et al. (2003) studied renesting in a population of radio-tagged murrelets in northern California in 2001–2002. Based on radio-based movements, one bird (out of 5 birds that were radio-tagged) was suspected of renesting in 2001 after it failed, visiting the nesting area again after spending 9 days at sea. Unfortunately, neither nest was found; so it is unclear whether the same nest-site or nest-tree was reused. In addition, one bird (of 21 birds that were radio-tagged) was suspected of renesting in 2002 after it failed, visiting the nesting area again after spending time at sea. It renested successfully before losing the transmitter, but the nest was found. Unfortunately, its first nest was not found, so it is not clear whether the same nest was used for renesting; however, both nests certainly occurred in the same stand of trees.

Effect of Extent of Habitat Continuity on Fidelity

It would be valuable to know the extent of habitat one needs to keep intact when occupancy is determined at a location: in other words, does the occurrence of a nest at one location signify concurrent or future occurrence of nesting in the surrounding area? Specifically, if birds nest in one part of a stand or other area of habitat, is that indicative of current or future nesting in the same or other parts of the stand/habitat area? The PSG survey protocol defines potential habitat as mature and old-growth coniferous forests and younger coniferous forests with platforms for nesting; continuous potential habitat has no gaps in suitable forest cover wider than 100 m (page 3).

In British Columbia, patterns of fidelity vary geographically, in that trees in areas that had been heavily logged (i.e., where there were few or no large stretches of continuous habitat) were more heavily disturbed (southern mainland coast, eastern Vancouver Island) had higher rates of reuse (23% and 50%, respectively) than did areas that had low levels of (or no) logging or other disturbance (western Vancouver Island; 8%; Burger et al. 2009). The large number of trees climbed (1,628) and the large number of nest-trees found (143) among 8 different study areas provide compelling support for this hypothesis of the effect of habitat continuity on fidelity. On the other hand, low rates of logging in the northern Gulf of Alaska were accompanied by low rates of fidelity to nests, although stands of trees and landing-trees appeared to be used over multiple years (Naslund et al. 1995), whereas high rates of fidelity have been recorded at nests in heavily logged parts of California where studies were conducted (Golightly and Schneider 2011, Singer et al. 1995).

Although radar data only provide indirect evidence of nesting, it would be an oversight to not include some reference to ornithological radar studies that have documented numbers of probable murrelets entering a watershed during the breeding season and quantified the extent of potential habitat in these areas. We provide a general summary of this information and the limitations relative to the question of interest under "Comparisons with other Studies" (see below).

Variation Among Studies

The most important variation among studies involved vague terms referring to what exactly is a nest. Some authors clearly used "nest-cup" and others used "nest site", "nest branch", or "nest platform", whereas others used what we suspect meant a nest-tree when they used the term "nest."

Another source of variation was lack of clarity in some papers when referring to larger-scale aspects of fidelity. For example, it sometimes was difficult to determine whether the authors were referring to a stand of trees, a watershed, or something else (e.g., a "forest patch"). Some of the papers did not provide adequate maps of study areas and/or nests to determine with certainty that more than 1 pair of birds was nesting in the same stand or watershed or whether the birds nested in the same stand or watershed in the same or different years. This variation in the extent of areas surveyed permitted only broad generalizations across studies of fidelity at larger scales.

Effects Modifiers

Numerous factors may have influenced results across studies. Habitat differences among areas may have some effect on patterns of fidelity; however, the limited data for 2 nearby ground-nests at the Barren Islands in successive years (Hirsch et al. 1981) suggest fidelity, similar to what is seen in tree-nests (Table 4). Thus, this similarity between ground- and tree-nests suggests that the overall effect of this modifier was minimal.

The amount of continuous habitat in an area also may affect reuse or renesting and, hence, may affect comparability among studies. Burger et al. (2009) synthesized all available data at the time on the reuse of nests by murrelets in British Columbia, based on 1,628 trees climbed over multiple years; 26 (18%) of 143 nest-trees showed evidence of multiple nesting, although rates of reuse varied geographically: being highest in areas that had been logged heavily (e.g., mainland [23%], southeastern part of Vancouver Island [50%]) and lowest in areas with the least amount of logging of potential nesting habitat (e.g., outer coast of Vancouver Island [8%]). In a general sense, this pattern is repeated on a larger scale toward the ends of the species' range. For example, a set of studies in a part of California that has few areas with large stretches of continuous habitat has one nest/nest-tree that has been reused for >10 years (Hébert and Golightly 2006; Golightly and Schneider 2011), and a nest studied by Singer et al. (1995) in an area with little continuous habitat was used at least 4 years. In contrast, the limited number of nest-trees examined in a part of Alaska that had not been logged heavily had extremely low rates of renesting in subsequent years, although birds revisited some trees in subsequent years (Naslund et al. 1995). Data of Nelson and Peck (1995) recorded nest-tree fidelity rates of 29% (2 of 7 nests) from parts of Oregon with only patches of continuous habitat; and data from Meekins and Hamer (1999) from a part of Washington with little continuous habitat (other than in Olympic National Park) suggested that 18% of 22 nest-trees contained >1 nest-cup and possibly reuse of nest-cups.

Another factor that appears to cause differences among years is resampling nest-cups/nest-branches or nest-platforms/nest-trees. A lack of resampling effort presumably reflects changing priorities in subsequent years' funding levels or sampling strategies. Visiting some of these nests even one time in a subsequent year may be prohibitively expensive or logistically difficult, especially if money has not been set aside to answer such a basic question about the biology of this species. In addition, several of the authors who did resample nests in subsequent years included in discussion sections that they may not have sampled often enough within a subsequent year to have confidence that they detected all nesting efforts. Because murrelets may not nest every year, returning breeders may not be identified without multi-year (>2-year) studies.

The field method used to find nests also could have affected comparability among studies. Clearly, tree-climbing is a more effective means of detecting nests within a defined area (e.g., a stand) than is capturing and telemetering birds at sea (which may not). This relates to the fact that, because tree-climbing could be used to detect most if not all nests within a stand, it provides better information for looking at fidelity within a particular area than would a telemetry study. Hence, those studies relying only on radio-telemetry should be considered to do a poorer job than long-term, large-scale tree-climbing studies for detecting fidelity. Unfortunately, the costs of such tree-climbing studies often make them unfeasible from a financial standpoint.

The variability of search areas further affects comparability among studies and interpretation of results. The primary limitation of tree-climbing is the spatial scale that can be comprehensively surveyed. In most tree-climbing studies, either a search radius was defined around a known nest or observation point or the search area was constrained to an area smaller than the entire stand. As a result, stand-level site fidelity was largely extrapolated from fidelity at the level of the tree or patch, without providing information on nests that may occur elsewhere within a stand.

Comparison to Non-Systematic Reviews

The following information is a non-systematic review of related publications and is provided for context only. The publications included have not been intensively reviewed according to the protocols described in our methods section.

Alcid nest-site fidelity typically is high (generally >75%, and frequently exceeding 90%; Divoky and Horton 1995). Alcids also have strong fidelity to a nest (nest-ledge, burrow, rock crevice), as do most seabirds (Gaston and Jones 1998). Because most seabirds avoid or reduce predation by nesting colonially on inaccessible islands or mainland cliffs, a nest is a highly prized possession that is defended fiercely because it often is limited in availability. In some cases (e.g., northern fulmars Fulmarus glacialis in the North Sea, female murres Uria spp.), birds actually spend most of the year regularly visiting the colony, defending the nest and nest-site from other birds that are trying to usurp it. Similarly, Marbled Murrelets in some areas are found at inland sites throughout the year, presumably for the same reason (Naslund 1994, Sanzenbacher et al. 2014).

Similarly strong nest-site fidelity in murrelets has been posited by Divoky and Horton (1995), based on observations that murrelets have been recorded in the same forest stands in California, Oregon, and Washington for ≥20 years. Site-fidelity can reduce potential reproductive effort by (1) increasing the chances of breeding with the previous year's mate; (2) reducing the need to locate a suitable nest site every year; and (3) increasing the birds' familiarity with nearby marine and terrestrial environments. Divoky and Horton (1995) described many patterns of the biology of alcids and explained how Marbled Murrelets are likely to compare to other members of the family. However, none of the non-Brachyramphus alcids for which extensive data were available are cryptic, solitary nesters, so the assumption of comparability of aspects of life-history between murrelets and other alcids, especially important aspects such as fidelity, may not be correct.

Observed fidelity to the same nest-cup in successive years appears to be lower for murrelets than that for other alcids, possibly because of high rates of predation observed at murrelet nests (Nelson and Hamer 1995b). If nest-sites are limiting, the loss of nesting habitat reduces the long-term reproductive potential of a population; this problem could especially be relevant for murrelets, which generally nest in older trees that take many years to develop. Because the loss of old-growth nesting habitat results in the displacement of breeding birds until the habitat can re-grow and age, murrelets either must have some flexibility in nest-site fidelity or many in heavily logged or fire-prone areas must be nonbreeding birds. High nest-site fidelity makes it difficult for breeding murrelets to move to new areas and breed after habitat loss, whereas low nest-site fidelity may make them more adaptable to habitat loss; however, the effect of habitat loss on fidelity also depends on the scale of the fidelity (i.e., whether the fidelity is to a nesting branch, a nest-tree, a forest stand, or a watershed). On the other hand, low nest-tree fidelity also can have positive aspects, such as reduced probability of repeated predation by predators, especially corvids, which learn nests locations (Burger et al. 2009).

Multi-year radar and telemetry studies have provided evidence suggestive of reuse of watersheds and specific forest stands across years. Several radar studies have demonstrated high numbers of murrelets (presumably mostly nesting individuals) entering specific stands (Bigger et al. 2006) or watersheds (Burger 2001, Raphael et al. 2002, Burger et al. 2004, Cooper et al. 2006) in multiple years, but there is no evidence that these were the same individuals. A number of radar studies also provide insight on the relationship between the extent of potential habitat and densities of murrelets at inland sites, particularly at the watershed or landscape scale. Raphael et al. (2002) found a positive correlation between radar counts of murrelets and the amount of late-seral forest in drainages. Burger (2001) looked at numbers of murrelet radar targets per ha relative to the level of disturbance (i.e., recent logging activities) in 14 watersheds and found that murrelet numbers declined as habitat declined. Burger et al. (2002) documented that murrelets in watersheds on the mainland of British Columbia occurred at densities of 0.045 ± 0.039 birds/ha, whereas on west Vancouver Island densities were 0.090 ± 0.060 birds/ha; however, continuity of habitat was not quantified in this study. At the forest stand scale, Bigger et al. (2006) found that radar counts of murrelets in northern California were positively, but weakly correlated to the amount of unharvested old growth across a surveyed landscape.

Although informative, there are limitations to radar data that ultimately caused us to exclude these studies from the literature review. The primary issue was that radar cannot determine occupancy (i.e., nesting) at a site because birds flying near or below canopy are shielded from the radar. Similarly, radar counts do not differentiate between breeding birds and non-breeders simply prospecting in an area. Also, one does not know how many murrelets are associated with a particular radar target. In many cases the evidence for nesting of multiple individuals in a particular watershed based on radar studies is compelling; however, these studies generally do not have direct evidence of nesting based on observations at nest sites or from tracking of telemetered birds. Thus, although radar data are informative to the question, we ultimately excluded this information from the formal literature review due to the inherent limitations of these data.

Other scientists have discussed the importance of fidelity. Some have suggested that nest-sites could be limiting for murrelets because most large branches are not accessible—key to the suitability of a nesting platform (Hébert and Golightly 2006). Finding and claiming an appropriate nest-site takes much time in most alcids but may be even more difficult for murrelets, which typically have only a couple of hours of crepuscular light/day to search. These authors also pointed out that annual survival averages ~85%, so 15% of all nests would lose 1 member of a pair every year. Weather-caused downing of branches and aging of a tree also result in losses of appropriate nesting branches in subsequent years. Hence, new pairs must be being formed constantly, requiring a nearly constant search for appropriate nest-sites. Fidelity should be strongest in pairs that nest successfully, but it can be overridden by access to a nest-site, which can vary among years.

Conclusions and Data Gaps

Given the limited information that is available, an area (at a variety of scales) that is used for nesting by marbled murrelets frequently is occupied in future years by the same birds and/or other birds. Results are suggestive that fidelity at the scale of the tree and branch may be lower in areas with more continuous habitat, although data are currently too limited to identify the spatial extent of fidelity for individual birds within contiguous habitat at larger spatial scales. Studies specifically focusing upon the The studies that include data relevant to this specific question were descriptive or anecdotal in nature and generally consisted of observations of small numbers of nests at one or few sites (with exceptions such as Burger et al. 2009 and Manley 1999), resulting in Study Evaluation Scores that ranged from 10 (24%) to 25 (60%) of the maximum 42 points.

Perhaps the most pressing need is for a large sample of banded, known-sex, and radio-tagged birds over multiple years to determine whether the many levels of fidelity that have been found reflect the same birds or different birds—a problem admitted by many authors who saw evidence of fidelity. At this point, we have limited data that the same birds use the same nest or nearby areas (within or across stands) if renesting or returning in successive years. We also do not have studies or published analyses of existing data that indicate how many birds may use a stand of trees within a year and among years, although radar studies provide some inference on this. Some authors suggest that fidelity to a stand is caused by the same birds nesting in a variety of trees within a general area at a particular spatial scale; whereas others suggest that this level of fidelity is caused by multiple pairs using a stand that has appropriate nesting habitat. An intensive telemetry/marking study could help to determine the average likelihood of fidelity and the spatial distribution of nests utilized by individuals within and across years.

There also is a need for banded, known-sex, and radio-tagged birds to determine whether there is a sexual effect on whether birds can/do renest. Barbaree et al. (2014) found that 4 of 25 marked birds that failed in their first nesting attempt renested, all of whom happened to be males. Barbaree et al. (2014) stated that females may have been more affected by the transmitters which may explain why they did not see renesting for females. More studies on sex-based differences, if any, should be conducted to provide more information.

Finally, there is a need to determine whether renesting can occur only if nest-loss occurs during incubation, whether renesting can occur if loss occurs during chick-rearing, and whether these patters differ geographically. The limited evidence from Alaska and California suggests that renesting can occur if the nest-loss occurs during incubation (Barbaree et al. 2014, Hébert et al. 2003), but the occurrence of renesting over the breeding season requires more exploration.

Results from the study with the highest Study Evaluation Score in this review provided evidence from multiple study sites that suggested decreasing nest-site fidelity with increasing continuity of habitat; but overall, information is lacking on relationships between breeding fidelity and the extent of habitat. There is a need for studies in stands of various sizes to determine the effects of the spatial extent of continuous potential habitat on fidelity at the stand level. Identification of and adequate sample sizes for subsequent nest locations beyond the scale of the nest tree, however, is generally difficult. Currently, stand-level fidelity almost exclusively is inferred from studies focused at or below the scale of a habitat patch. Broader nest search efforts are required to determine fidelity rates across entire stands.

Similarly, there also is a need for studies of multiyear use of stands of various sizes and across a range of habitat types and levels of disturbance. This topic is a key part of the question that there were not adequate data to evaluate with confidence, although there is some evidence of decreasing fidelity of nest-sites with increasing continuity of habitat.

Although studies of marked birds are essential for understanding the processes that create patterns of fidelity as well as population dynamics, from a management point of view, population fidelity is as important as individual fidelity. As long as a stand or watershed is still being used by murrelets, it is important to the population. Hence, studies focused on quantifying repeated multiyear use across a range of habitat types, stand sizes, and levels of disturbance would be of great value for determining the effects of such factors on the probability of reuse at larger spatial scales. Because of the difficulty of finding nests, the value of identifying reliable behavioral indicators of nesting, as suggested in Question 1, cannot be overstated.

Question 3. How does the spatial extent of continuous potential habitat relate to the co-occurrence (i.e., nesting by multiple pairs) of murrelets in a forest stand and at other spatial scales?

This question focuses on an aspect of Marbled Murrelet breeding ecology (the distribution of nesting pairs at different spatial scales) that, at the level of the forest stand, is cited in the PSG protocol as supportive evidence for the importance of continuous habitat beyond the survey site. In the PSG protocol the 'survey site' is the scale at which surveys are conducted, while the 'survey area' is the scale at which survey results from one or more sites apply and are relevant. This extension of survey results (e.g., occupancy status) at a site to the larger survey area is based on explanations regarding the importance of continuous habitat for current and future nesting by one or more pairs of murrelets (pages 6 and 23). The protocol defines potential habitat as mature and old-growth coniferous forests and younger coniferous forests with platforms for nesting.

Question #3 focuses on the co-occurrence of nesting murrelets at the watershed and forest stand scales. In this context, co-occurrence is defined as nesting by multiple pairs (>1 pair) of murrelets within a defined area (i.e., watershed or forest stand) during the same breeding year. In effect, the question is: does the presence of an active murrelet nest at a site indicate possible nesting in the surrounding area by additional pairs of murrelets, and to what degree does the extent of continuous habitat affect this? It is important to note that co-occurrence at smaller spatial scales (e.g., adjacent nest trees) was considered an indicator of co-occurrence at larger scales, up to that of a watershed. For instance, adjacent nests separated by <100 m are assumed to occur within the same forest stand (as defined by the PSG protocol) and also within the same watershed. Also, examples of co-occurrence presented here do not necessarily indicate continuous habitat: in most studies, information on continuous habitat was qualitative or absent altogether.

Papers Reviewed

A search and subsequent screening of available literature resulted in 14 studies with primary data or analyses pertaining to the co-occurrence of nesting Marbled Murrelets at the watershed or forest stand scale; a small subset of these sources also included information on the extent of continuous habitat in areas with co-occurrence. Note that selection criteria for pertinent literature was restricted to direct evidence of co-occurrence indicated by observations at nest sites or tracking radio-tagged birds to inland sites. Because we focus our question specifically on nesting and not on other reasons for occurrence of birds at inland sites (e.g., prospecting, social circling), indirect evidence of nesting (e.g., radar surveys, audio-visual detections of "occupied" behaviors) was not included for this critical review but we address these data in "Comparisons with Other Studies" (see below).

Of the 14 studies summarized here, 5 were unpublished reports and papers, 6 were articles in peer-reviewed journals, 2 were agency technical reports, and one was a graduate thesis. The locations of these studies included the following: 5 in Oregon and Washington; 8 in British Columbia; 1 in southern California; and 2 in Alaska. One of these studies (Carter and Sealy 1987) summarized historical records from across the species range of hatch-year birds found grounded at inland sites and included pertinent data not presented elsewhere from British Columbia and Washington. Because murrelets have a clutch size of one egg per nesting attempt and young birds generally travel directly to the ocean at fledging, a grounded first-year bird found in potential nesting habitat was evaluated as an indicator of a nearby murrelet nest. Also of note, only 6 studies identified areas of continuous habitat around nest sites, with only one study quantifying the habitat area. Spatial scales (i.e., watershed, forest stand) often were not explicitly stated in studies; therefore, when appropriate, we conservatively inferred them from study figures. Nevertheless, co-occurrence within stands or watersheds for some or all nests within studies could not be determined from information provided; so, rates of co-occurrence could not be quantified.

The mean Study Evaluation Score for the 14 studies with pertinent information was 19.2 out of a possible 42 points, with scores ranging from 12 to 31 (Table 5, Appendix 8.3). No studies scored in the lowest quartile of possible scores (0–10); 10 studies scored in the second quartile (11–21), 4 studies scored in the third quartile (22–32), and no studies scored in the highest quartile (33–42; Figure 4). The primary reason that no studies scored in the highest quartile was that most were not designed to directly address the question of co-occurrence and therefore were either anecdotal (*n* = 10 studies) or descriptive (*n* = 4 studies) in nature. As a result these studies scored lower because they did not allow for anything more than descriptive statistics and analyses.

Co-Occurrence of Nesting Murrelets

Finding murrelet nests is extremely challenging due to the secretive nature of these birds at inland sites and difficulties in locating their cryptic nests in large trees. The studies we reviewed employed a range of methods and effort to locate nests, but no studies comprehensively surveyed and conclusively identified all active nests within an entire stand or watershed. Furthermore, nests located could not always be differentiated into those that were active concurrently (evidence of co-occurrence) and those that were active during different years or periods within a year (evidence of re-nesting or re-use). As a result, evidence of co-occurrence presented here provides minimal estimates that often underestimate the extent of co-occurrence in an area.

Co-Occurrence Within Watersheds

There is evidence of co-occurrence at the scale of a watershed, based on 13 of the 14 studies reviewed (Table 5). This included 13 examples with co-occurrence of 2 nests, 9 examples with co-occurrence of 3 nests, and 4 examples with co-occurrence of at least 5 nests within a watershed.

Co-Occurrence Within Forest Stands

There is evidence of co-occurrence at the forest stand scale from 8 of the 14 studies reviewed (Table 5). This included 11 examples with co-occurrence of 2 nests and 3 examples of co-occurrence of 3 nests. Stand-level co-occurrence was defined by nests found within identified stands in 4 studies, within large blocks of continuous habitat in 3 studies, and by discovery of two downy chicks falling from single trees (1 study).

Distance Between Nests

Inter-nest distances, explicitly stated or inferred from text and figures, were found in 11 of the 14 studies reviewed and came from all regions included in this review. These are crude estimates of the likely proximity of all active nests, given that none of the methods used (telemetry, tree-climbing) would reveal all the nests within the sampled area. This included 5 examples of nests <100 m apart, 4 different examples of nests 200–1,000 m apart, and another 5 examples of nests co-occurring at distances of >1–12 km from each other. Zharikov et al. (2007) provided overall mean nearest nest distances of 4.6 ± 4.0 km (mean ± SD) and 6.6 ± 4.2 km for two separate study areas in British Columbia, based on 157 nest locations identified from radio telemetry. They determined that these results were independent of the number of nests found each year and, at least at the Desolation Sound site, was stable among years. We did not report cases of inter-nest distances at larger scales (i.e., distance of >20 km), because all of these cases were likely to be beyond the scale of the watershed and thus not informative to the question and spatial scales of interest.

The inter-nest distances summarized in this review provide additional insight on the scale at which nests co-occur and allowed for determination of co-occurrence at the watershed or stand scale in a number of cases where this was not otherwise specified (Hamer and Cummins 1990, Kuletz et al. 1995, Manley 1999). For instance, we determined co-occurrence at the stand and watershed scale in two cases where nests were separated by distances of <200 m (Burger 1994) and <1 km (Kuletz et al. 1995) and habitat was contiguous based on reference descriptions (e.g., for Burger 1994) and other resources (e.g., Google Earth for Kuletz et al. 1995). However, not all studies provided information on the extent of continuous habitat, limiting our ability to determine co-occurrence in the same forest stands, particularly in areas with more extensive habitat modification. Further, it sometimes was unknown if nests with larger inter-nest distances (i.e., >1 km) even co-occurred in the same watershed.

Effect of Extent of Habitat Continuity on Co-Occurrence

Only one study that documented co-occurrence based on direct evidence of nesting also quantified the extent of continuous habitat in the area of interest. Naslund et al. (1995) found co-occurrence of 3 murrelet nests

Table 5. Summary of evidence of fidelity in nesting Marbled Murrelets in North America at various scales. For each scale, the number of observations of fidelity is indicated (total sample sizes are provided in parentheses). Study Evaluation Scores had a maximal value of 42.

Area/source	Location	Year(s)	Co-occurrence: Total number of nests[1]	Co-occurrence: Watershed (n)[2]	Co-occurrence: Stand (n)[2]	Co-occurrence: Inter-nest Distance[3] (n)[4]	Study Evaluation Score
OREGON							
Nelson and Peck 1995	Coast Range and Siskiyou Mountains	1990–1993	9 nests	2 nests (1)		1 km (2)	16
Nelson and Wilson 2002	Clatsop, Tillamook, Elliot State Forests (Coast Range)	1995–1999	37 nests	2 nests (2)	2 nests (1)	30 m (2)	28
WASHINGTON							
Bloxton and Raphael 2009	Olympic National Park, WA	2004–2008	19 nests	2 nests (1), 3 nests (1)			20
Carter and Sealy 19875	Sultan River Basin	1950s	2 grounded chicks	2 nests (1)	2 nests (1)		12
Hamer and Cummins 1990	Stillaguamish River Basin, Sloan Creek, Sauk River, (northwest)	1990	2 nests	2 nests (1)	2 nests (1)	46 m (2)	15
BRITISH COLUMBIA							
Bloxton and Raphael 2009	Carmanah and Walbran watersheds (southwestern Vancouver Island)	2004–2008	19 nests	2 nests (3), 3 nests (1)		5 km (2), 7 km (2)	20
Burger 1994	Carmanah and Walbran watersheds (southwestern Vancouver Island)	1990–1993	6 nests	3 nests (1)	-	<200 m (2), 5–6 km (3)	16
Carter and Sealy 19875	Gilltoyees Inlet and Holberg	1919, 1967	4 grounded chicks	2 nests (2)	2 nests (2)		12
Hull et al. 2001	Desolation Sound	1998	23 nests	≥5 nests (3)	-		15
Manley 1999	Sunshine Coast (mainland)	1994–1997	52 nest trees	2 nests (2)	2 nests (2)	38 m (2), 58 m (2)	28

Table 5. Continued.

Area/source	Location	Year(s)	Co-occurrence				Study Evaluation Score
			Total number of nests[1]	Watershed (n)[2]	Stand (n)[2]	Inter-nest Distance[3] (n)[4]	
Ryder et al. 2012	Elk Creek	1955	3 nests[6]	3 nests (1)	-	-	12
Waterhouse et al. 2011	Mathieson Channel	1992, 1999	14 nests	12 nests (1), 2 nests (1)	-	2–25 km (12), 7 km (2)	20
Zharikov et al. 2007[7]	Desolation Sound and Clayoquot Sound, (southwestern Vancouver Island)	1998–2001	157 nests		-	4.6 km, 6.6 km[8]	31
CALIFORNIA							
Suddjian 2003	South Fork Butano Creek, San Mateo County	1991–2001	12 nests[9]	3 nests (1), 2 nests (1)	2 nests (2)	500 m (2)	17
ALASKA							
Kuletz et al. 1995	Prince William Sound (northern Gulf of Alaska)	1994	6 nests	3 nests (1)	3 nests (1)	<1 km (3)[10], 6–12 km (3)[11]	14
Naslund et al. 1995	Naked, Afognak, and Kodiak islands (northern Gulf of Alaska)	1991–1992	14 nests	3 nests (1), 2 nests (1)	3 nests (1), 2 nests (1)	<50 m (2)	25

1 Includes actual nest sites, grounded chicks/fledglings, occurrences of eggshell fragments on forest floor, etc., which were evaluated from each study for determination of co-occurrence.
2 n = number of cases of co-occurrence.
3 Note that in most cases inter-nest distances provide a crude and minimal measurement of actual proximity of active nests, because few studies will find all nests in a study area.
4 n = number of nests.
5 Note that the Carter and Sealy (1987) is included twice because it provided data from both Washington and British Columbia.
6 2 nests inferred from egg-shell fragments on the ground.
7 Includes nests reported on by Hull et al. (2001) but different metrics presented (i.e., co-occurrence versus inter-nest distances).
8 Average within-year nearest neighbor distance of nests was 4.6 ± 4.0 (standard deviation) km at Desolation Sound (n = 23–38 nests/yr over 4 years) and 6.6 ± 4.2 km at Clayoquot Sound (n = 8–18 nests/year over 3 years).
9 Included nest sites (n = 1), grounded fledglings (n = 2), eggshell fragments on the ground (n = 2), and adults carrying fish (n = 9).
10 3 tree-nests within unfragmented forest unit.
11 3 ground nests.

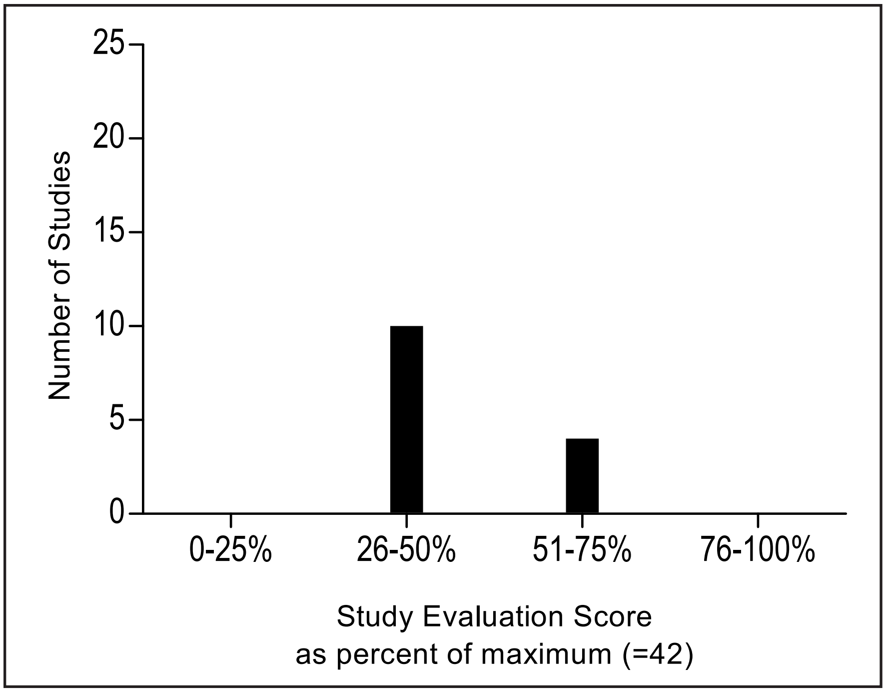

Figure 4. Distribution of study evaluation scores for 14 papers included in review for Question 3: "How does the spatial extent of continuous potential habitat relate to the co-occurrence (i.e., nesting by multiple pairs) of murrelets in a forest stand and at other spatial scales?"

within a 17.5 ha stand of continuous habitat on Naked Island in Alaska. Waterhouse et al. (2011) quantified habitat types in the ~40,000 ha catchment of Mussel Inlet in British Columbia and found large areas of mature/old forest; however, habitat quality was mixed and continuity was not specifically addressed. Although 9 of the 13 studies we summarized provided some qualitative information or description of the extent of continuous habitat in a study area (e.g., "old-growth forest", "unlogged", "highly fragmented"), none provided sufficient information to determine if there was continuous habitat in areas with co-occurrence at the watershed or forest stand scales.

Although radar data only provide indirect evidence of co-occurrence, it would be an oversight to not include some reference to ornithological radar studies that have documented numbers of probable murrelets entering a watershed during the breeding season and quantified the extent of potential habitat in these areas. We provide a general summary of this information and the limitations relative to the question of interest under "Comparisons with other Studies" (see below).

Variation Among Studies

We encountered considerable variation in the study design and methods and presentation of results among the studies reviewed for Question 3. In many cases this resulted from the fact that identifying and quantifying instances of co-occurrence was not a main study objective. Because many studies simply did not provide details on the spatial or temporal occurrence of active nests, it is clear that instances of co-occurrence were often under-reported. For instance, from Manley (1999) we identified co-occurrence at the watershed and forest stand scales in 1996 and 1997 along the Sunshine Coast of British Columbia, but this information could only be inferred from a table with inter-nest distances for some nests and likely underestimated the actual frequency of co-occurrence. Similarly, Waterhouse et al. (2011) reported on nests of radio-tagged individuals along the southwest coast of British Columbia, but based on a map of nest sites we could only determine co-occurrence at the watershed scale and there was insufficient information to determine if there was also co-occurrence at the forest stand scale. A number of studies were ultimately excluded from review because it was not possible to determine the spatial scale of co-occurrence. For instance, Drever et al. (1998) and Lougheed et al. (1998) identified cases of co-occurrence in the Bunster Range of British Columbia during the 1996–1997 breeding periods; however, neither study provided sufficient detail to determine if there was co-occurrence at scales smaller than the study area (e.g., at the watershed or forest stand scales).

Another source of variation among studies was determining the year in which nests were active. For telemetry studies that located nests based on activity and locations of tagged murrelets this obviously was not an issue, but for studies that relied on tree-climbing at the end of murrelet breeding activities to find nests this was at times more problematic. In many cases, the age of a murrelet nest can be dated if there is evidence at the nest (e.g., eggshells, fecal ring) and nest cups can remain visible for 4 or more years (Manley 1999, Burger et al. 2009). Thus, in some cases it can be extremely difficult to definitively determine that a nest was active in a given year and if not to provide an estimate of the year when last active. For nests with obvious signs of depredation (i.e., egg shells or murrelet carcass remains) or possible fledging (i.e., fresh fecal ring or down), it was much easier to determine that a nest was active during the current study year. However, for nests without conclusive evidence researchers often could not determine the year a nest was active or provided a range of possible years when last active. This was often the case for nests in areas where activity of adult murrelets was observed early in the breeding period but upon finding a nest at the end of the breeding season there was an empty nest cup and no other evidence of nesting. As a result it was not always possible for authors to discern if a nest was a failed nesting attempt or if the nest was not used for nesting during the year of the study. Clearly, the inability to definitively determine the age of certain nests resulted in lack of determination of co-occurrence in a several studies.

We attempted to compile nest densities as an additional source of inference on the scale at which co-occurrence happens, but we found that many studies did not calculate this metric and in other studies the methods used to calculate nest densities were not well-defined. In most cases, it appeared that nest densities were calculated based on the pooled sample of nests (both active and inactive) within a year or across multiple study years. For instance, Nelson and Wilson (2002) calculated nest densities of 0.1–3.0 nests/ha in the Coast Range of Oregon, but this included active and inactive nests pooled across multiple study years. Similarly, Manley (1999) calculated nest densities for four different clusters of nests on the Sunshine Coast of British Columbia, that ranged from 1.3–4.2 nests/ha, but did not specify if these nests co-occurred (i.e., were active in the same year). As presented, these nest densities do not provide strong inference on the scale of co-occurrence or the potential influence of the extent of continuous habitat. In at least one case it was possible to discern nest densities of co-occurring nests based on the information provided. Specifically, Naslund et al. (1995) provided sufficient information for us to calculate a nesting density of 5.83 nests/ha for 3 nests co-occurring in 17.5 ha of continuous habitat on Naked Island in Alaska.

Effects Modifiers

We identified a number of factors that might have influenced results across studies. For instance, the studies reviewed for co-occurrence included a range of survey methods that generally involved some combination of audio-visual surveys (10 studies), telemetry (6 studies), tree-climbing (10 studies), and egg-shell searches on the forest floor (4 studies). Carter and Sealy (1987) reported exclusively on anecdotal observations of grounded nestlings and fledglings. There was considerable variation among these studies in the overall sample size of nests (i.e., 2–157) but also the spatial extent at which nests were found. In general telemetry studies resulted in nests distributed over larger areas and eliminated habitat bias in searching for nests, whereas audio-visual surveys and intensive tree-climbing surveys were generally more focused on finding nests at smaller scales in more discrete areas of available habitat. The studies that reported co-occurrence also differed in duration of effort with 5 studies reporting on a single year of data and 9 studies with multiple years of data, presumably depending on the study objectives and availability of funding. Studies over multiple years generally had a larger sample of nests from which to look for co-occurrence and researchers often returned to nest sites in subsequent years, because murrelets often exhibit fidelity to an area and may occasionally reuse a nest tree or even nest cup among years (e.g., Burger et al. 2009).

We looked at studies from across the entire range of the species, thus introducing potential geographic and habitat-based modifiers across studies; but we found no reason to speculate that there would be inherent differences in co-occurrence across these different areas based solely on habitat types or tree species or other geographic factors. One exception might be that if habitat quality was so poor that it affected average nesting density in an area, it would affect the average distance among nests, and thus, the likelihood of nest co-occurrence at the smaller (e.g., forest stand) scales. In addition, if there was an effect of continuous habitat on co-occurrence, then clearly regions with a more extensive history of habitat modification resulting from fire or logging could differ from more "untouched" areas that likely exhibit less habitat fragmentation, etc. In general, the studies we reviewed were conducted in areas with a range of disturbance and we did not see any patterns in co-occurrence reported for studies with more intact versus modified habitats, but this would be another obvious area of interest for additional study.

As with studies of site fidelity, the variability of nest search areas also affects comparability among studies and interpretation of results relating to co-occurrence. The primary limitation of tree-climbing is the spatial scale that can be comprehensively surveyed. In most tree-climbing studies, either a search radius was defined around a known nest or observation point or the search area was constrained to an area smaller than the entire stand. As a result, stand-level co-occurrence was largely extrapolated from fidelity at the level of the tree or patch, without providing information on nests that may have been present elsewhere within a stand.

Comparison to Non-systematic Reviews

The following information is a non-systematic review of related publications and is provided for context only. The publications included have not been intensively reviewed according to the protocols described in our methods section.

Marbled Murrelets are considered solitary nesters (Nelson and Peck 1995, Nelson 1997), in contrast to most other alcids (non-*Brachyramphus*) that nest colonially (Nettleship and Birkhead 1985, Coulson 2002). As documented in this review, multiple pairs of nesting murrelets are known to co-occur within the same watershed or forest stand in a given year, and in some cases murrelets nest within very close proximity to each other. For example, there were five different cases of murrelet nests co-occurring within 100 m of each other. Manley (1999) found that murrelets showed a high degree of nest site aggregation during studies in British Columbia, with 52% of nests occurring within 100 m of at least one other nest. The actual level of aggregation was potentially higher but not all trees in an area were systematically searched for nests. However, in most cases these nests were not found to be active in the same year (i.e., co-occurring) and may represent fidelity and reuse of nest sites among or within years by the same pairs of breeding murrelets. Carter and Sealy (1987) reported observations of 2 chicks falling from the same nest tree in both Washington and British Columbia, indicating that co-occurrence also happens within the same nest tree. In fact, we found additional evidence indicating that multiple nests within the same tree may not be such a rare occurrence in areas where there has been severe loss of habitat and nesting options are limited. For example, Drever et al. (1998) noted that 8 of 32 nest trees searched in Desolation Sound, where 80% of the potential suitable habitat has been lost (Zharikov et al. 2006), had >1 nest. Similarly, Meekins and Hamer (1999) found 4 different nest trees with 2–4 nests each on the Olympic Peninsula of Washington and Nelson and Wilson (2002) found 1 tree with 2 old nests in the Tillamook State Forest of Oregon. Again it must be noted that none of these studies established co-occurrence of active nests in the same tree.

The PSG survey protocol cites co-occurrence among nesting murrelets as evidence for the importance of maintaining areas of continuous habitat where murrelets nest. The distribution of available habitat is one possible explanation for the density of nesting murrelets within an area, but there are other possible influencing factors. For example, Waterhouse et al. (2011) reported on two radio-telemetry studies of nesting murrelets on the central coast of British Columbia, in an area with largely undisturbed forest. It was assumed that nests would be found throughout the larger study area, but of the birds captured, most nests were concentrated within just a quarter of the area. Alternatively, Lougheed et al. (1998) radio-tagged murrelets in a single area of Desolation Sound, but tracked these birds to nests across a wide area and in all directions from the capture site. The reasons for these differences among studies are not well understood, but suggest that there are a range of factors other than or in addition to continuity of forest that influence the distribution of nesting murrelets in an area.

Ornithological radar is an effective tool for surveying murrelets traveling over a site and in some cases can provide indirect but convincing evidence for the frequency of co-occurrence in a defined area (e.g., watershed). A number of radar studies (e.g., Burger 2001, Raphael et al. 2002)have also documented a correlation between the number of murrelets entering an area and the amount of potential habitat. Ultimately the limitations of radar data and lack of direct evidence of nesting led us to exclude these studies from the literature review; however, it is worth summarizing some of this information here and also discussing in more detail the reasons for excluding this data from the formal review process.

Raphael et al. (2002) used radar to document the mean number of murrelets per morning entering 10 river drainages on the Olympic Peninsula of Washington. Across three study years these counts ranged from 15–143 murrelets per morning at each drainage. Assuming these data indicated multiple murrelet nests per drainage then the documented frequency of co-occurrence was 100% for these watersheds. Similarly, Burger et al. (2004) combined radar survey data from five studies that covered 101 different watersheds totaling over 2 million hectares in British Columbia. Radar counts of murrelets in these studies ranged from 11–1,012 murrelets per morning across these watersheds, thus suggesting the frequency of co-occurrence was also 100% for these 101 watersheds. In contrast, a related metric from our review of the literature with direct evidence of nesting indicated that 20.7% of all nests found co-occurred with other nests at the watershed scale (i.e., 73 co-occurring nests from 353 total nests). This necessarily is a minimal estimate, because it is based on the flawed assumption that all nests were found and all areas searched in these studies. The actual frequency of co-occurrence likely lies somewhere between these results but the discrepancy between these metrics highlights the difficulty in finding murrelet nests and perhaps differences among studies in the quality and extent of habitat. However, those radar data suggest that the current direct evidence from observations of nesting murrelets clearly underestimates the frequency of co-occurrence.

A number of radar studies also provide insight on the relationship between the extent of potential habitat and densities of murrelets at inland sites. Raphael et al. (2002) found a positive correlation between radar counts of murrelets and the amount of late-seral forest in drainages. Burger (2001) looked at numbers of murrelet radar targets per ha relative to the level of disturbance (i.e., recent logging activities) in 14 watersheds and found that murrelet numbers declined as habitat declined. Burger et al. (2002) documented that murrelets in watersheds on the mainland of British Columbia occurred at densities of 0.045 ± 0.039 birds/ha, whereas on west Vancouver Island densities were 0.090 ± 0.060 birds/ha; however, continuity of habitat was not quantified in this study. At the forest stand scale, Bigger et al. (2006) found that radar counts of murrelets in northern California were positively, but weakly correlated to the amount of unharvested old growth at a site.

Although informative, there are limitations to radar data that ultimately caused us to exclude these studies from the literature review. The primary issue was that radar cannot be used to determine occupancy (i.e., nesting) at a particular site because birds flying near or below canopy are shielded from the radar. As a result it generally is not possible to definitively determine from radar data that a murrelet radar target is using the watershed of interest and not simply passing over to nest in an adjacent watershed. A number of radar studies in British Columbia recognize this issue but state that the study sites were narrow drainages that funneled birds into discrete areas of potential habitat so it is highly likely that murrelets observed entering these drainages on radar were indeed using these areas. Similarly, radar counts do not differentiate between breeding birds and non-breeders simply prospecting in an area. There is a precedent in some studies to assume one breeding pair per three murrelets observed on radar (COSEWIC 2012) but again, there is no direct evidence of nesting in these cases. Also, one does not know how many murrelets are associated with a particular radar target. A general correction factor of 1.5 murrelets per radar target has been derived based on visual observations of murrelet targets (B. Cooper, unpubl. data). Thus, although radar data are informative to the question we ultimately excluded this information from the formal literature review due to the inherent limitations of these data.

Conclusions

In summary, our review of the literature found evidence for co-occurrence of nesting murrelets at the scale of the watershed and forest stand. No studies comprehensively surveyed an entire stand or watershed for nests; so direct evidence of co-occurrence presented here provides only minimal frequencies of co-occurrence and is insufficient for assessing relationships between the extent of habitat and the probability of co-occurrence or the breeding density within stands or watersheds. Although indirect evidence of co-occurrence was not addressed in this review, data from radar studies in particular provide additional support that nesting by multiple breeding pairs of murrelets within the same watershed is a common phenomenon.

A main finding of this review was that there have been few studies designed to specifically address co-occurrence of nesting Marbled Murrelets and in particular the potential influence of continuous habitat on the likelihood or extent of co-occurrence. As a result, the Study Evaluation Scores ranged from 12 to 31 (of a maximum 42 points) with most falling into the second quartile (11–21 points). Several studies described nests within large areas of continuous habitat, in which only a small fraction of nests were likely detected and which, therefore, did not add to the determination of how the extent of habitat affects the probability of co-occurrence or the breeding density within an area. In fact, we found only one study that quantified and reported the extent of continuous habitat at watershed and forest stand scales in areas with co-occurrence. The studies we reviewed spanned a range of intact versus disturbed (e.g., logged) sites but ultimately there was not sufficient evidence to determine patterns of co-occurrence based on the extent of continuous habitat.

Data Gaps

A main finding from our literature review was that there have been few studies designed to specifically address co-occurrence of murrelets and the potential influence of continuous habitat on co-occurrence. To more fully address the question would require further large-scale, intensive tree-climbing efforts to locate all active nests within large sampling areas of contiguous and non-contiguous habitat. However, it is possible that several of the existing studies, if revisited, could likely provide further important information on the question of co-occurrence and continuous habitat. For instance, many studies reported active nests but did not provide locations of these nests in a manner (e.g., detailed maps, coordinates, or descriptions) that allowed for determination of co-occurrence at the watershed or forest stand scale. This information is available within state databases but has yet to be included in a comprehensive analysis. Another issue that we encountered in the literature review process was that detailed information on co-occurrence often was provided in interim reports of studies but excluded from final reports or peer-reviewed publications. As a result, in a number of cases we cite the interim reports rather than the final reports or publications from these studies.

Another large data gap is the lack of good information on density of concurrently active nests. This review provides evidence that nests co-occur, but did not find evidence supporting estimates of the likelihood of co-occurrence because of insufficient detectability of concurrently active nests in most studies. Another potential bias was the fact that studies where only a single active nest was located tended to be excluded because it was unknown whether or not additional active nests were present in the watershed or stand; if those areas truly only had the single active nest, then the exclusion of those data result in a negative bias of the overall frequency of co-occurrence.

Potentially the largest data gap was that only one study quantified and reported the extent of continuous habitat at watershed and forest stand scales in areas with co-occurrence. In some cases resolving this data gap would require a large effort, but with advances in mapping and remote sensing this information should be more readily available for future analyses. Information on the extent of continuous habitat in areas with co-occurring nests would help provide a basis for determining the amount of intact habitat surrounding a nest that supports additional active nests in an area. In particular, using data from patchy landscapes to determine the nature of the relationship (linear or non-linear) between stand size and nest densities would help determine the likelihood of co-occurrence within nest stands of various sizes.

Question 4. How is the occurrence of Marbled Murrelet nest sites related to the number and size of potential nest platforms and platform-tree density within stands of different age-classes (young, mature, and old growth)?

The PSG protocol defines Marbled Murrelet nesting habitat as older-aged forests or young forests that include trees with platforms, and it notes that the presence of platforms is "the most important stand characteristic for predicting murrelet presence in an area (Hamer et al. 1994)" (p. 3.). A platform is defined as "a relatively flat surface at least 10 cm (4 in) in diameter and 10 m (33 ft) high in the live crown of a coniferous tree" (p. 2). Question #4 focuses on examining the evidence for how platform size and density are associated with the occurrence of nests. We acknowledge that forest habitats also may have value for murrelets in addition to a direct association with nesting; for this question, however, we focus specifically on an assessment of the evidence that these characteristics are associated specifically with the presence of active or inactive nests.

Papers Reviewed

A search and subsequent screening of available literature yielded 25 studies with primary data or analyses pertaining to relationships between nest platform sizes or densities and the occurrence of Marbled Murrelet nests. Data also were extracted from additional studies (i.e., from Binford et al. 1975; Grenier and Nelson 1995; Hamer and Cummins 1991; Jordan and Hughes

1995; Kerns and Miller 1995; Manley and Kelson 1995; Nelson 1992; Nelson and Hardin 1993; Nelson et al. 1994; Singer et al. 1991, 1992), but these later were excluded from consideration because all of pertinent information from those studies was synthesized by either Hamer and Nelson (1995) or Baker et al. (2006). Of the 25 studies, 11 were unpublished reports and papers, 10 were articles in peer-reviewed journals, 3 were in agency technical reports, and one was a graduate thesis. Four of the studies were conducted in Oregon and Washington, 12 were conducted in British Columbia, 5 focused on California sites, 3 occurred in forested habitat of Alaska, and 1 was from across the species range.

The mean Study Evaluation Score for the included studies was 22.3 (out of a possible 36 points), with scores ranging from 9 to 34 (Table 6, Appendix 8.4). One study scored in the lowest quartile of possible scores (0–9); 8 studies scored in the second quartile (10–18), 9 studies scored in the third quartile (19–27), and 7 studies scored in the highest quartile (28–36; Figure 5). Study Evaluation Scores were strongly correlated with sample size scores ($r = 0.89$, $n = 25$, $p < 0.001$), and many studies contained information on single nests ($n = 8$) or small numbers (2–9, $n = 5$) of nests. Most studies (15 of 25, 60%) were either descriptive or anecdotal and not amenable to more than descriptive statistics.

Platform Variables

Platform Size

Twenty studies provided information on the diameter of limbs supporting murrelet nests (Table 6). One study (Hamer and Nelson 1995) provided summarized information on nests (both reported elsewhere and unpublished) for each state and province; and one study (Manley 2003) provided separate summaries for each of two study areas. Limb diameters were reported for measurements nearest the trunk in 10 studies. For 9 studies, diameters were reported for limb measurements at the nest, and for 3 studies, the location along the limb where measurements were made was not specified.

Nest limb diameters ranged from 7–81 cm. Mean nest limb diameters ranged from 16 to 50 cm (weighted means = 26 cm at the bole and 28 cm at the nest), with smallest mean diameters recorded in Alaska and in Oregon (Table 6). Mean diameters were the same when studies with sample sizes <10 (and Study Evaluation Scores <60% of the maximum) were excluded from the analysis. Although sample sizes within studies and numbers of studies within different regions were generally low, results suggest geographic variation in mean nest limb size (Table 6). Notably, the study with the highest Evaluation Score (Nelson and Wilson 2002) had one of the lowest mean nest limb diameters reported (17 cm at the bole, 20 cm at the nest). Several factors influenced the range of limb diameters reported (see Effects Modifiers below) and limit comparisons across studies. Many studies measured diameters that included moss layers on the branches, while others (including those reporting the smallest diameter nest limbs in Oregon) excluded moss cover. Overall, mean limb diameters did not differ between measurements taken at the bole and nest (Mann-Whitney $U = 28.5$, $p = 0.3$, $n = 9$ studies), although differences varied among studies from 3 cm greater to 13 cm smaller at the nest than at the bole. Minimal limb diameters recorded in each state/province ranged from 7 cm (Oregon) to 21 cm (California) at the bole and from 10 cm (Oregon) to 16 cm (California) at the nest. The smallest limbs were reported in studies with larger (≥10) sample sizes. Two studies (Meekins and Hamer 1999, Nelson and Wilson 2002; Study Evaluation Scores = 28 and 34 of 36, respectively) reported that diameters of limbs containing nests were larger than randomly selected limbs with suitable platforms.

Twelve studies provided information on the width of murrelet nest platforms (Table 7). Mean platform widths of tree nest platforms varied from 12 to 28 cm (weighted mean = 23 cm). Minimal platform widths recorded in each state/province ranged from 6.5 cm (California) to 10 cm (Washington). One study (Meekins and Hamer 1999) reported that nest platforms were larger (area = length X width) than randomly selected platforms and that sample plots with nests had larger mean platform diameters than plots where no nests were found.

Platform Density

Eleven studies provided information on the number of potential nest platforms in trees containing Marbled Murrelet nests (Table 8). Three studies (Manley 2003, Naslund et al 1995, Silvergieter and Lank 2011a) provided separate results for each of two study areas. Two studies (Manley 2003, Silvergieter and Lank 2011a) included data on the same nest trees, following different methods for counting platforms (tree-climbing and ground-based counts, respectively); while one study (Burger et al. 2000) reported comparative results using each of the two methods. In addition to variation

Table 6. Summary of reported diameters of limbs supporting Marbled Murrelet tree nests (n = number of nest limbs). Study Evaluation Scores had a maximal value of 36.

		Diameter of nest limb (cm)					
	Study Evaluation	At bole		At nest		Unknown	
Area/Citation	Score	Mean ± SD (n)	Range	Mean ± SD (n)	Range	Mean ± SD (n)	Range
OREGON							
Hamer and Nelson 1995	26	31 ± 11 (19)	14–56	34 ± 18 (20)	10–81	--	--
Nelson and Wilson 2002	34	17 ± 6 (37)	7–37	20 ± 6 (37)	12–36	--	--
Witt 1998	16	17 (1)	--	--	--	--	--
WASHINGTON							
Hamer and Nelson 1995	26	36 ± 12 (5)	14–49	29 ± 13 (4)	11–46	--	--
Meekins and Hamer 1999	28	--	--	26 ± 13 (29)	11–58	--	--
BRITISH COLUMBIA							
Burger 1994	16	--	--	--	--	18 (1)	--
Burger et al. 2000	17	50 (2)	42–57	50 (2)	42–57	--	--
Conroy et al. 2002	23	36 ± 25 (5)	14–74	23 ± 12 (5)	14–43	--	--
Dechesne and Smith 1997	9	--	--	--	--	33 (1)	--
Hamer and Nelson 1995	26	32 ± 9 (9)	18–43	27 ± 9 (7)	15–38	--	--
Jordan et al. 1997	12	--	--	27 (1)	--	--	--
Manley 1999	29	25 ± 8 (62)	11–62	--	--	--	--
Manley 2003[1]	23	29 ± 13 (24)	--	--	--	--	--
Manley 2003[2]	23	27 ± 12 (38)	--	--	--	--	--
CALIFORNIA							
Baker 2006	27	--	--	47 ± 12 (12)	29–70	--	--
Golightly and Schneider 2009	15	--	--	--	--	36 (1)	--
Golightly et al. 2009	25	36 ± 12 (10)	--	29 ± 9 (10)	--	--	--
Hamer and Nelson 1995	26	35 ± 13 (8)	21–61	34 ± 13 (10)	16–61	--	--
ALASKA							
Naslund et al. 1995	27	16 ± 5 (12)	9–27	19 ± 5 (12)	12–28	--	--
Quinlan and Hughes 1990	15	18 (1)	--	--	--	--	--
PACIFIC NORTHWEST TOTAL							
Hamer and Nelson 1995	26	32 ± 11 (41)	14–61	32 ± 16 (41)	10–81	--	--

1 Clayoquot Sound area.
2 Desolation Sound area.

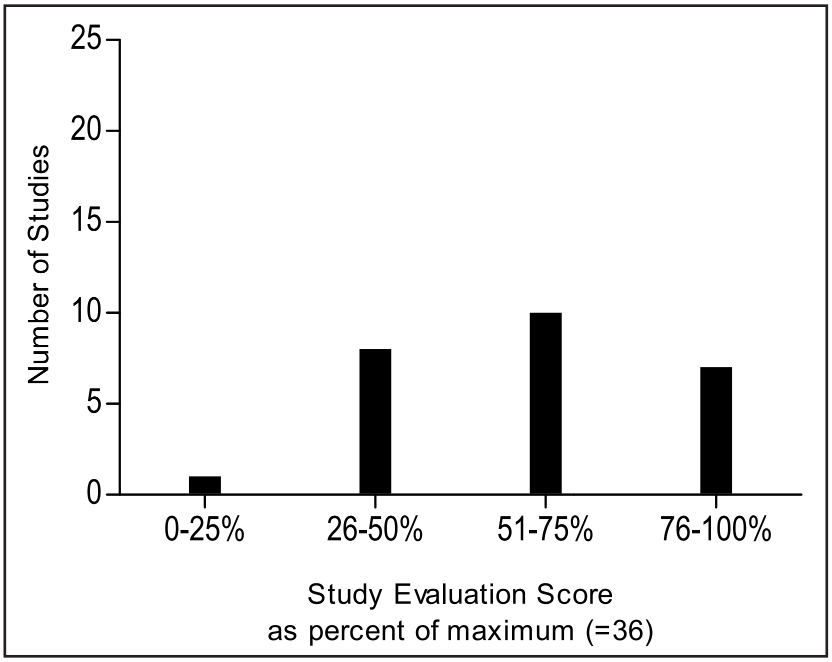

Figure 5. Distribution of study evaluation scores for 25 papers included in review for Question 4: "How is the occurrence of Marbled Murrelet nest sites related to the number and size of potential nest platforms and platform-tree density within stands of different age-classes (young, mature, and old growth)?"

in count methods, comparisons and summary statistics across studies are confounded by variation in the minimal diameter of platforms considered suitable for nesting, which ranged from 10 to 18 cm. Nests have been reported in trees containing just one suitable platform (Manley 1999), while other studies (Nelson and Wilson 2002, Silvergieter and Lank 2011a) found that nest trees contained a minimum of 3–4 platforms.

Several studies compared the number of potential nesting platforms present in nest trees to those in randomly selected or adjacent trees. Nest trees were found to contain more platforms than non-nest or randomly-selected trees in 6 studies (Study Evaluation Scores range: 23–34 of maximum 36; Naslund et al. 1995, Manley 1999, Meekins and Hamer 1999, Nelson and Wilson 2002, Baker et al. 2006, Silvergieter and Lank 2011a). In contrast, no significant differences ($p > 0.05$) were found between the two groups in two studies (Study Evaluation Scores: 23 and 29; Grenier and Nelson 1995; Conroy et al. 2002).

Stand-level platform densities were measured in terms of the number of potential nesting platforms per hectare (five studies) and the number of potential nesting platforms per canopy tree within the stand (four studies; Table 9). Two studies (Burger and Bahn 2001, Manley 2003) provided separate results for each of two study areas. Platform densities within nest stands were highly variable both within and across studies. Although the number of studies was too small to suggest any geographic differences, most studies of platform densities (which include 80% of the total number of nest stands examined) were conducted in British Columbia. Furthermore, the minimal diameter of platforms considered suitable for nesting varied among studies from 10 to 18 cm, which again prevented comparisons across studies for either measure of platform density.

Platform Tree Density

Six studies provided information on the density of trees with potential nesting platforms within stands containing murrelet nests (Table 10). Two studies (Burger and Bahn 2001, Manley 2003) provided separate results for each of two study areas. The minimal diameter of platforms considered suitable for nesting varied among studies from 10 to 18 cm. All results are from studies conducted in British Columbia except for a study of 21 nesting stands in Washington (Meekins and Hamer 1999). The mean number of platform trees in nesting stands ranged from 22 to 123 trees/ha, with a minimal stand density of 5 platform trees/ha reported.

Two studies (Manley 1999, Waterhouse 2007; respective Study Evaluation Scores: 29 and 22) reported that densities of platform trees in plots containing nests were higher than in randomly-selected plots; however,

Table 7. Summary of reported widths of Marbled Murrelet nest platforms (*n* = number of nest platforms). Study Evaluation Scores had a maximal value of 36.

Area/Citation	Study Evaluation Score	Nest Platform width (cm) Mean ± SD (*n*)	Range
OREGON			
Hamer and Nelson 1995	26	28 ± 12 (21)	7–51
Nelson and Wilson 2002	34	22 ± 6 (37)	7–44
Witt 1998	16	22 (1)	--
WASHINGTON			
Hamer and Nelson 1995	26	24 ± 11 (5)	10–39
Meekins and Hamer 1999	28	27 ± 13 (29)	10–75
BRITISH COLUMBIA			
Burger et al. 2000	17	18 ± 3 (3)	14–20
Conroy et al. 2002	23	24 ± 8 (4)	14–20
Hamer and Nelson 1995	26	12 ± 3 (6)	9–19
Jordan et al. 1997	12	20 (1)	--
CALIFORNIA			
Hamer and Nelson 1995	26	15 ± 7 (10)	6–23
ALASKA			
Ford and Brown 1995	13	35[1] (1)	--
PACIFIC NORTHWEST TOTAL			
Hamer and Nelson 1995	26	22 ± 12 (42)	6–51

1 Moss platform on exposed roots of hemlock at edge of cliff.

two studies (Meekins and Hamer 1999; Waterhouse 2009; respective Study Evaluation Scores: 28 and 32) found no differences. Silvergieter and Lank (2011b) determined that nesting probabilities increase in relation to platform tree densities up to 100 trees/ha and level off at higher densities.

Stand Age

There essentially were no studies available to address the portion of the review question pertaining to stands of different age-classes (young, mature, and old growth), although results of Nelson and Wilson (2002) are suggestive of stand-age effects. In that study, nests found in younger stands often were found on platforms at branch forks or created by deformities associated with mistletoe, located further from the bole. Mean nest branch diameters in this study were among the smallest reported.

Variation Among Studies

Nesting platforms and potential nesting platforms have been defined variously, confounding comparisons of results across studies, particularly regarding counts and densities. Minimal diameters of limbs considered suitable as nesting platforms and the minimal height (above ground) of limbs considered suitable have varied among regions and studies. In many studies, counts of platforms and platform trees focus solely upon limbs as potential nesting platforms; whereas other studies include all tree structures (e.g., witch's brooms, other deformities) of suitable diameter. In addition to variation in the defining characteristics of nest platforms,

Table 8. Summary of number of potential nest platforms in trees containing Marbled Murrelet nests. Study Evaluation Scores had a maximal value of 36.

Citation	Study Evaluation Score	Number of trees (*n*)	Mean ± SD number of platforms/nest tree (range)	"Platform" Diameter[1] (cm)	Assessment method
OREGON					
Nelson and Wilson 2002	34	33	25.8 ± 20 (4–92)	≥15	Tree-climbing
WASHINGTON					
Meekins and Hamer 1999	28	21	28 ± 13 (10–52)	>10	Tree-climbing
BRITISH COLUMBIA					
Burger et al. 2000	17	2	8 ± 2.8 (6–10)	>18	Tree-climbing
Burger et al. 2000	17	2	6.5 ± 4.9 (3–10)	>18	Ground-based
Conroy et al. 2002	23	5	9.8 ± 5.2 (4–18)	>18	Tree-climbing
Jordan et al. 1997	12	1	62	Not defined	Tree-climbing
Manley 1999	29	52	9 ± 7 (1–30)	≥15	Tree-climbing
Manley 2003[4]	23	27	14.9 ± 9.7	>15	Tree-climbing
Manley 2003[5]	23	39	22.5 ± 14.3	>15	Tree-climbing
Silvergieter and Lank 2011a[2]	31	27	8 ± 5	≥15	Ground-based
Silvergieter and Lank 2011a[3]	31	32	8 ± 6	≥15	Ground-based
CALIFORNIA					
Baker 2006	27	13	7.4 ± 4.9	>10	Ground-based
Golightly et al. 2009	25	10	364	>10	Ground-based
ALASKA					
Naslund et al. 1995[5]	27	9	8 ± 4	≥15	Ground-based
Naslund et al. 1995[6]	27	1	18	≥15	Ground-based

1 Diameter of limb or other platform qualifying as potential nesting platform.
2 Clayoquot Sound area.
3 Desolation Sound area.
4 Combined "small" (10–19.9 cm) and "large" (≥20 cm) platforms.
5 Naked Island.
6 Kodiak Island.

Table 9. Summary of potential nest platform densities in stands containing Marbled Murrelet nests. Study Evaluation Scores had a maximal value of 36.

Density variable	Citation	Study Evaluation Score	Number of Stands (*n*)	Mean ± SD number of platforms (range)	"Platform" Diameter[1] (cm)
Platforms/ha	WASHINGTON				
	Meekins and Hamer 1999	28	21	600.6 ± 104.6 (300–1,066)	>10
	BRITISH COLUMBIA				
	Burger and Bahn 2001[2]	21	7	1,513 ± 633	>18
	Burger and Bahn 2001[3]	21	11	1,181 ± 1,180	>18
	Manley 1999	29	32	128 ± 79 (5–321)	≥15
	Manley 2003[4]	23	27	223.7 ± 140.8	>15
	Manley 2003[5]	23	39	237.7 ± 262.2	>15
	Manley et al. 2001	17	7	126 ± 45 (53.3–181.7)	>18
Platforms/tree sampled	OREGON				
	Grenier and Nelson 1995	29	10	6.7 ± 3.2 (0–11)	≥18
	BRITISH COLUMBIA				
	Dechesne and Smith 1997	9	1	0.2	Not defined
	Manley 2003[4]	23	26	4.4 ± 2.5	>15
	Manley 2003[5]	23	35	5.6 ± 2.9	>15
	Manley et al. 2001	17	7	4.5 ± 1.5 (2.9–6.7)	>18

1 Diameter of limb or other platform qualifying as potential nesting platform.
2 Lower Carmanah Valley.
3 Upper Carmanah/Walbran watersheds.
4 Clayoquot Sound area.
5 Desolation Sound area.

Table 10. Summary of the density of platform trees (trees containing potential nest platforms) in stands containing Marbled Murrelet nests. Study Evaluation Scores had a maximal value of 36.

Citation	Study Evaluation Score	Number of stands (*n*)	Mean ± SD number of platform trees/ha (range)	"Platform" Diameter [1] (cm)
WASHINGTON				
Meekins and Hamer 1999	28	21	51.0 ± 10.0 (15–92)	>10
BRITISH COLUMBIA				
Bradley and Cooke 2001	19	1	66	>18
Burger and Bahn 2001[2]	21	7	123 ± 48	>18
Burger and Bahn 2001[3]	21	11	98 ± 65	>18
Manley 1999	29	32	32 ± 22 (5–66)	>15
Manley 2003[4]	23	26	53.6 ± 20.7	>15
Manley 2003[5]	23	38	40.4 ± 29.1	>15
Manley et al. 2001	17	7	21.9 ± 9.9 (18.3–43.3)	>18

1 Diameter of limb or other platform qualifying as potential nesting platform.
2 Lower Carmanah Valley.
3 Upper Carmanah/Walbran watersheds.
4 Clayoquot Sound area.
5 Desolation Sound area.

the dimensions provided for platforms varied among studies and included both nest structures and nest cups, as well as the flat surface supporting them.

Platforms were counted either by ground-based observers or by individuals climbing into tree canopies. Nelson and Wilson (2002) and Burger et al. (2000) compared results of counts using these two methods and found that ground-based observers counted fewer platforms than did observers counting from within the canopy. Meekins and Hamer (1999) also compared platform counts of ground-based and tree-climbing observers and found that climber counts of "small" (10–19.9 cm diameter) and "large" (20+ cm diameter) platforms were higher than ground-based counts by factors of 2 and 4, respectively. In studies reviewed here, Silvergieter and Lank (2011a) reported substantially fewer platforms within nest trees using ground-based observers than did Manley (2003) using tree-climbers to count platforms in most of the same trees. Thus, results of all three of the above studies suggest that platform-counting methodology could have been an effects modifier for this review question.

For most studies that provided information on nest limb diameters, values were presented for measurements taken closest to the bole or both adjacent to the bole and at the nest platform. In three studies, however, only limb diameters at the nest were presented; and the locations along the limb where diameters were measured were not specified. Another variant among studies where nest limb diameters have been measured was the inclusion of moss or other epiphyte layers in the measurements. Although indicated for many studies, this factor often was not addressed in descriptions of methods or results. As thickness of moss layers may be substantial in many nesting habitats, inclusion of these layers can inflate diameter measurements relative to studies that exclude them.

Effects Modifiers

Although tree species has not been found to be a factor directly influencing choice of nest sites within study areas (Burger 2002, Nelson et al. 2006, Silvergieter 2011a), several authors (e.g., Naslund et al. 1995, Manley 1999, Meekins and Hamer 1999, Bradley and Cooke 2001, Nelson and Wilson 2002, Burger et al. 2010) noted differences in platform counts associated with tree species. Regional differences, therefore, are likely to occur in the association between platform density, and dominant tree species present. Similarly, there could be inherent differences among tree species in average size of limbs that could have affect average nest limb or platform size. Other regional differences in forest structure and other characteristics (e.g., elevation, climate) also may influence overall densities of potential platforms and platform trees and limit comparisons across regions.

Nearly all nest sites included in this review were associated with older-aged forest (variously defined or undefined), so stand age probably did not have a large effect on variation among the studies that we reviewed. Stand age certainly could affect average platform sizes and densities in a stand, however, and was addressed as a correlate with platform densities in one study (Nelson and Wilson 2002). In that study, nests found in younger stands often were found on platforms at branch forks or created by deformities associated with mistletoe, located further from the bole. Mean nest branch diameters in this study were among the smallest reported.

Comparison to Non-systematic Reviews

The following information is a non-systematic review of related publications and is provided for context only. The Nelson et al (2006) publication included was not intensively reviewed according to the protocols described in our methods section.

Hamer and Nelson (1995) first compiled range-wide results of habitat characteristics associated with 61 tree nests found throughout the breeding range through 1993. Excluding nests in Alaska, mean nest limb diameters were 32 cm measured at both the bole and the nest (n = 41). With the addition of nests found since that time and included in this review, mean diameters of nest limbs found from California to British Columbia have decreased to 27 cm (at the bole; n = 220) and 29 cm (at the nest; n = 137). Minimal nest limb diameters of non-Alaskan nests through 1993 were 14 cm at the bole and 10 cm at the nest, while nests discovered more recently have been on limbs as small as 7 cm in diameter at the bole. Mean platform width of 42 nests found outside of Alaska through 1993 was 22 cm (Hamer and Nelson 1995) and increased to 23 cm with the addition of nests discovered subsequently (total = 117 nests), with no decrease in the minimal platform width (6.5 cm) since 1993.

Studies currently available for inclusion in this review do not include data for any nests found after 2003. Therefore, the range-wide summaries of known nest measurements, platform and platform tree densities, and relative measures with non-nest or random sites that were presented by Nelson et al. (2006) remain current, based on studies available for this review. Further analyses of Silvergieter & Lank (2011a), however, have indicated that apparent selection of nest trees containing more platforms in fact may be an artifact of selection occurring at the individual platform level, as trees with greater numbers of platforms were not selected with greater frequency than expected based on the distribution of platforms within the study patch.

Conclusions

Variability in methods and platform definitions limited the comparability of platform characteristics across studies and the analysis of regional and sub-regional patterns. Platform and platform tree densities could not be adequately summarized because of these differences. In addition, studies did not address variability in nest platform sizes and numbers in relation to factors such as stand age and elevation, which could provide further insight into conservation and management strategies. Lastly, there were essentially no studies available that addressed the portion of the review question pertaining to stands of different age-classes (young, mature, and old growth). Instead, nearly all nest sites included in this review were associated only with older-aged forests.

Minimal and mean nest limb diameters across all studies (and when studies with small sample sizes and low Evaluation Scores were excluded) were 7 and 26 cm (measured at the bole) and 10 and 28 cm (measured at the nest), respectively. Mean limb diameters were variable across studies, however; and the study with the highest Evaluation Score had one of the smallest limb diameters (7 cm). Minimal and mean platform widths were 6.5 and 23 cm, respectively, with or without low-scoring studies excluded. Most studies indicated that nest trees typically contained more potential nesting platforms than non-nest or randomly selected trees, although at least one study indicated that trees were selected in the proportion expected based on the distribution of platforms within a patch. Overall, evidence for the density of trees containing potential nest platforms as an important factor in predictive models of nesting probabilities is equivocal. Study Evaluation Scores, which largely reflected sample sizes within studies, were not sufficiently different among studies with contrasting results to lend support to a particular conclusion.

Data Gaps

As the number of murrelet nests discovered has increased, habitat characteristics associated with nests (such as aspects of nest platform size) have become better defined; however sample sizes and the number of studies that have addressed covariance and other interrelationships among factors remains small. Furthermore, while there has been increasing standardization of terminology associated with nesting platforms, historical differences and other variability create limitations to meta-analyses of study results across and within regions.

Studies currently are not available to assess variability in nest platform sizes and numbers in relation to factors such as stand age and elevation, which could provide further insight into conservation and management strategies. Recent data collected at nest platforms but not provided in the literature, may provide opportunities for further analyses. For example, no nests discovered and measured since 2003 were described in studies available for this review; additional information from raw data associated with currently available studies could possibly be useful for further analyses pertaining to these questions.

There essentially were no studies available to address the portion of the review question pertaining to stands of different age-classes (young, mature, and old growth), although results of Nelson and Wilson (2002) are suggestive of stand-age effects. This data gap results from the fact that relatively few nests have been found in trees and stands considered younger than "old growth" (except for mature [≥80-year-old] stands in Oregon) and at higher (> 3,500 m) elevation sites (McShane et al. 2004, USFWS 2009). Unbiased sampling efforts (e.g., radio-tracking of birds captured at sea) suggest that the vast majority of nests currently occur in older-aged stands at lower elevations. Burger et al. (2010) identified tree and stand characteristics (including elevation and age-associated tree size measures) that correlated with the presence and density of potential nest platforms; however, variation in actual nest platform sizes and densities of platforms within known nesting stands relative to stand age and elevation is largely unknown.

Question 5. How is Marbled Murrelet nesting success affected by habitat characteristics?

Unlike the previous four review questions, this question does not pertain directly to the PSG survey protocol, but instead focuses on factors associated with Marbled Murrelet nesting success that can inform forest management decisions in locations where murrelets occur or potentially occur. Attributes considered include those that are associated with patches, stands, and landscapes; such as habitat quality and quantity, habitat continuity and configuration, and corvid abundance. Also included were abiotic factors that described the location of nest trees and stands in relation to topography and distances from landscape features. This question focuses only on habitat associations with nest success and not on the much broader question of habitat associations with the presence of nests (i.e., nest site selection).

Papers Reviewed

A search and subsequent screening of available literature yielded 40 studies with primary data or analyses pertaining to murrelet nest success and habitat. Of these studies, 18 were articles in peer-reviewed journals, 15 were unpublished reports and papers, 3 were books or book chapters, 3 were theses/dissertations, and 1 was an agency technical report. Three studies originally included were omitted because they only contained data on nests that failed due to human disturbance at nests (Harris 1971, Singer and Verardo 1975, Carter and Sealy 1985). Several other studies that met search criteria subsequently were omitted because they were superseded by other studies.

Sixteen studies included analyses of habitat associations with nesting success. The remaining 24 papers included habitat descriptions associated with nests with known fates but did not have sufficient sample sizes or conduct analyses to examine associations between fates and habitat characteristics (Table 11). Among the studies that examined habitat correlations with nest success, 9 focused upon nest success at identified murrelet nests, while 5 were artificial nest studies of predation where surrogate eggs or nestlings were placed on platforms (limbs) and monitored (Table 11). One study (Malt and Lank 2007) compared results of monitoring both artificial and natural nests. Sample sizes were generally low for descriptive studies (including 8 studies of single nests with known fates) and higher for analytical studies of nest success associations (14 of 16 studies with ≥30 nests). Studies of artificial nests provided the largest sample sizes (range: 40–1,043).

Table 11. Summary of evidence of nest fate and cause of failure for studies also including information on habitat characteristics at the forest stand or tree scales for nesting Marbled Murrelets in North America. Values in brackets indicate cases where nest fate was speculated. Study Evaluation scores had a maximal value of 42.

			Known nest fate			Causes of failure			
Area/source	Year(s)	Study Evaluation Score	Success	Failure	Total	Nest predation	Other (*N*)	Unknown	Analysis of nest fate and habitat relationship?
Marbled Murrelet Nests									
OREGON									
Nelson 1992	1991	17	2	3	5	3			No
Nelson and Hardin 1993	1992	14	1	[2]	3				No
Nelson and Peck 1995	1990–1992	19	3	6	9	5	death of chick (1)		No
Nelson and Wilson 2002	1995–1999	20	4	6	10	3, [1]	death of chick (1)	1	No
Witt 1998	1994	18	1	0	1				No
WASHINGTON									
Hamer and Cummins 1991	1990–1991	15	2	[1]	3		chick fell from nest (1)		No
Bloxton and Raphael 2009[1]	2004–2008	24	3, [1]	16	20	[1]	death of chick (2), nest abandoned (1)	12	No
BRITISH COLUMBIA									
Bradley 2002[2]	1998–2001	31	15	69	84			69	Yes
Bradley and Cooke 2001[2]	1999	16	1	1	2			1	No
Burger 1994	1990–1993	15	[4]	[0]	4				No
Burger et al. 2000	1998–1999	14	[0]	[1]	1			1	No
Drever et al. 19982	1996	22	4, [4]	33	41	33			No
Jones 2001	1991–1994; 1996–1997	16	3	0	3				No
Malt and Lank 2007[2]	2004–2005	28	37	19	56			19	Yes
Manley 1999	1994–1997	30	7	14	21	14			No
Manley 2003	1998–2002	32	35	35	70			35	Yes

Table 11. Continued.

			Known nest fate			Causes of failure			
Area/source	Year(s)	Study Evaluation Score	Success	Failure	Total	Nest predation	Other (*N*)	Unknown	Analysis of nest fate and habitat relationship?
Manley et al. 2001	2000	16	0	3	3			3	No
Silvergieter 2009[2]	1999–2002	31	31	27	58	7	death of chick (1), abandonment (2), egg not viable (1)	16	Yes
Waterhouse et al. 2008[2]	1998–2002	31	18	11	29			11	Yes
Zharikov et al. 2006[2]	1998–2002	33	88	49	137			49	Yes
Zharikov et al. 2007[2]	1998–2001	31	71	36	107			36	Yes
CALIFORNIA									
Becking 1991	1988	12	0	[1]	1			1	No
Golightly et al. 2009	2001–2003	27	7	4	11			4	Yes
Kerns and Miller 1995	1992	18	0	1	1		death of chick (1)	1	No
Singer et al. 1991	1989	14	0	2	2	2			No
Singer et al. 1995	1991–1994	20	2	1, [1]	4	1, [1]		2	No
Suddjian 2003	1992–2001	17	0	2, [3]	5	1, [3]	death of adult (1)		No
ALASKA									
Barbaree et al. 2014	2007–2008	23	39	34	73		death of adult (3)		
Ford and Brown 1995	1993	13	0	1	1	1			
Hirsch et al. 1981	1979	14	1	0	1				
Kuletz et al. 1994	1993	10	0	1	1		death of adult (1)		
Marks and Naslund 1994	1991	13	0	1	1		death of adult (1)		
Naslund et al. 1995	1991–1992	17	0	7	7	1	abandonment (1)/[2], death of adult (1)		
RANGEWIDE	1998–2001								
Nelson and Hamer 1995[3]	1974–1993	36	9	23	32	10	abandonment (4) death of chick (1), chick fell from tree (3)		

Table 11. Continued.

Area/source	Year(s)	Study Evaluation Score	Known nest fate: Success	Known nest fate: Failure	Known nest fate: Total	Causes of failure: Nest predation	Causes of failure: Other (*N*)	Causes of failure: Unknown	Analysis of nest fate and habitat relationship?
Artificial Nests[4]									
OREGON									
Marzluff et al. 1999	1997–1998	27	29	194	223	110	disturbance by non-predator (32)	52	Yes
WASHINGTON									
Luginbuhl et al. 2001	1995–1998	31	200	705	905	705			Yes
Marzluff and Neatherlin 2006	1995–2000	31	212	837	1,049	837			Yes
Raphael et al. 2002	1995–1999	31	185	738	923	738			Yes
BRITISH COLUMBIA									
Burger et al. 2004	1994–2000	36	27	13	40	8	wind storm (5)		Yes
Malt and Lank 2007	2004–2005	28	71	65	136	65			Yes

1 Five of the nests occurred in British Columbia.
2 All part of related studies conducted by Simon Fraser University so considerable overlap in data but considered different aspects of habitat. Overall total number of nests were: Desolation Sound (including Toba Inlet) = 121 nests, Clayoquot Sound = 36 nests, and Mussel Inlet = 14 nests.
3 Includes some data presented elsewhere.
4 Nests were surrogate eggs and/or nestlings instead of actual murrelet nests. Disturbance at artificial nests was classified as failed nests due to predation unless otherwise noted.

The mean Study Evaluation Score for the included studies was 22.2 (out of a possible 42 points), with scores ranging from 10 to 36 (Table 11, Appendix 8.5). One study scored in the lowest quartile of possible scores (0–10); 20 studies scored in the second quartile (11–21), 15 studies scored in the third quartile (22–32), and 4 studies scored in the highest quartile (33–42; Figure 6). Study Evaluation Scores were strongly correlated with sample size scores ($r = 0.92$, $n = 40$, $p < 0.001$).

Nest Fates

Across 36 studies, nesting success was reported for a proportion of nests in each of these studies (Table 11). Success was variously defined based upon camera recordings of fledgings, presence of well-defined fecal rings at nests, presence of chicks until time of anticipated fledging, or documented nest visitation of adults (typically radio-tagged individuals) through the mid-chick-rearing period. The success rate of nests among these studies, when not 0% or 100%, ranged from 20–66%. However, we do not present an overall success rate because differences among definitions of success notwithstanding, individual nests often were included in multiple studies (focusing on different habitat associations) and some regions are disproportionately represented in studies.

Evidence for the cause of nest failure was reported in 18 different studies and included nests that failed as a result of predation of eggs or nestlings, failed due to death of the chick (not depredated), failed due to nest abandonment, failed as a result of predation of an adult, or the egg was determined to be non-viable. Although identification of specific nest predators was rarely documented in most regions, current evidence indicates that corvids (jays, crows, and ravens) are the primary predators of eggs and nestlings, based on direct observations of predation and also abundance of corvids in areas with high predation rates (Nelson 1992, Nelson and Hamer 1995, Peery et al. 2004, Singer et al. 1991).

For the 6 studies that monitored predation rates at artificial murrelet nests, 78% of 3,276 nests were disturbed (equating to nest failure) during the monitoring period. Disturbance of nests was determined or presumed to be by nest predators in most studies; however, in Marzluff et al. (1999) disturbance by unspecified non-predators was identified as a cause of failure at 23% of nest with identified causes of failure. Studies of predation at artificial nests lend additional support to the prevalence of corvids as murrelet nest predators. For instance, Marzluff and Neatherlin (2006) found that Gray Jays and Steller's Jays preyed on 27% of artificial nests and were responsible for 82% of corvid predation.

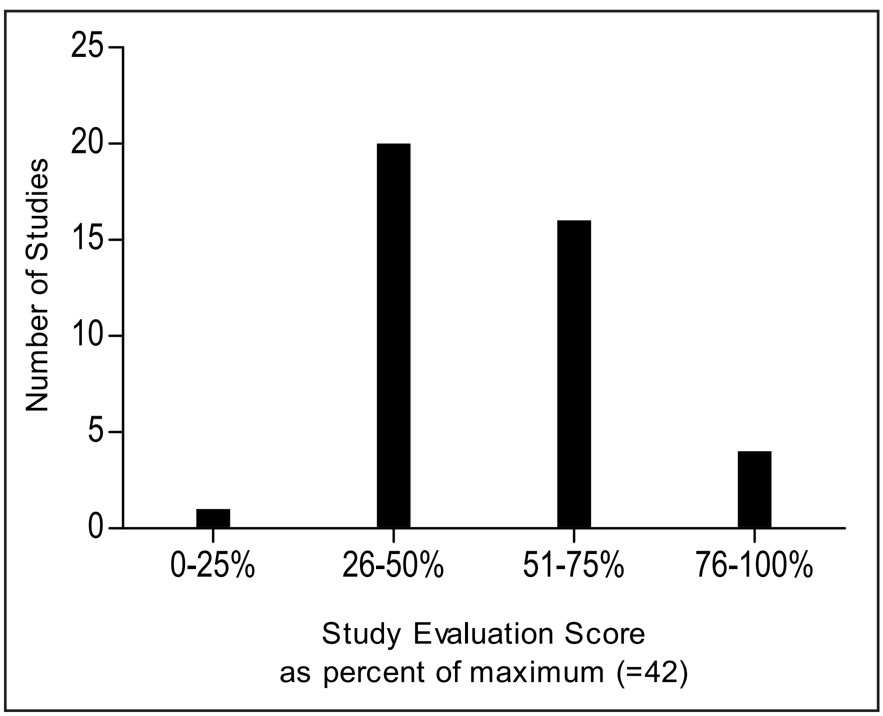

Figure 6. Distribution of study evaluation scores for 40 papers included in review for Question 5: "How is Marbled Murrelet nesting success affected by habitat characteristics?"

Associations of Habitat Characteristics and Nest Tree Locations with Nesting Success

Many studies measured habitat characteristics associated with nests of known fates but only a subset (16) analyzed these data relative to nest success (Table 12). These analytical studies had higher Study Evaluation Scores (mean = 30.3, range = 23–36) than did descriptive studies (mean = 16.8, range = 10–30). Differences in scores among comparable studies were generally small, often reflecting tradeoffs between study design (e.g., artificial vs. actual nests) and sample sizes. A total of over 30 variables pertaining to nest tree locations and habitat characteristics of nest patches, stands, and landscapes have been examined with univariate and multivariate analyses and considered in the construction and selection of models predicting nest success. Of these, 16 variables were included in two or more studies that focused on habitat correlations with nest success (Table 13). None of the studies included the same suite of variables in their analyses, which varied extensively in applications of univariate and multivariate methodologies.

General Habitat Characteristics

Ten general habitat characteristics of nest stands or landscapes were analyzed for relationships with nesting success in two or more studies (Table 13). Nest success was not significantly associated with stand size, platform density, tree density, or canopy height in any studies that included those variables in their analyses. Single studies reported significant associations between nesting success and patch shape (positive association with compact [rather than linear] shape), percent canopy cover (negative), and canopy complexity (positive); however other studies found no significant relationship between these variables and nest success. Among studies that included variables pertaining to stand age or size of trees, no significant relationships were found with nest success for most (n = 4 studies at actual nests; Study Evaluation Scores: 27–32); however, two studies reported contrasting significant age effects at the landscape scale. Malt and Lank (2007; Study Evaluation Scores: 28) found increased predation rates at artificial murrelet nests in landscapes with greater percentages of old-growth habitat. Alternatively, Zharikov et al. (2007; Study Evaluation Scores: 31) reported that nest success at murrelet nests (defined as nest attendance of radio-tagged adults through the midpoint of the chick-rearing period) was negatively associated with the proportion of a landscape characterized by young (<60-year-old) forest.

The abundance of corvids was directly or indirectly (as a covariate of other habitat variables) negatively associated with nest success in three studies of artificial nests and one study at actual murrelet nests (Study Evaluation Scores: 28–36). In two other artificial nest studies, corvid densities varied in relation to other habitat characteristics. Raphael et al. (2002; Study Evaluation Scores: 31) reported a positive correlation between corvid abundance and predation at artificial murrelet nests in stands surrounded by continuous forest but not in fragmented stands, where edge effects and distance from human activity may be more important factors. Marzluff and Neatherlin (2006; Study Evaluation Scores: 31) also reported a positive relationship between crow densities and predation rates at artificial nests, but only for nests within 1 km of human settlements; and no associations were found between numbers of jays (the primary corvid predator) and nest predation rates.

Effects of habitat type adjacent to nest stands were significant in all six studies that included such variables in analyses of habitat associations with murrelet nesting success, although the relationships varied extensively among studies. In five studies, the type of adjacent habitat impacted edge effects (i.e., the relationship between nest success and the distance of nests from the stand edge). In two artificial nest studies in Oregon and Washington (Marzluff et al. 1999; Raphael et al. 2002; Study Evaluation Scores: 27 and 31), edge effects were associated with stands near human activity areas but not in more remote areas. Malt and Lank (2007; Study Evaluation Scores: 28) found that murrelets nesting closer to stand edges where contrast between nest stand and adjacent habitat was greater (i.e., nesting near "hard edges", such as those between forests and recent clearcuts) had lower nest success. In contrast, Zharikov et al. (2006; Study Evaluation Scores: 33) found greater nest success in this situation. Contrasting and opposite effects also were also found in the two studies for nest success in stands where the adjacent habitat was more similar to the nest stand (i.e., in stands with a "soft" or "fuzzy" edges, such as those between mature forests and later regenerating vegetation or younger forests). At a landscape level, one study (Zharikov et al. 2007; Study Evaluation Scores: 31) indicated that nests in areas with more contrast between adjacent habitat units had lower success than in landscapes with less contrast between neighboring units. When not explicitly demonstrated, these edge effects on nesting success generally were assumed to be associated with predator, particularly corvid, densities (although other factors, such as

Table 12. Summary of habitat attributes described during studies of nest success at real and artificial Marbled Murrelet nests in North America. Symbols for habitat characteristics indicate whether (A) association was tested (see Table 13 for results) or (X) habitat characteristics were measured but not analyzed relative to nest success. Blanks indicate habitat characteristics were not described.

		General habitat characteristic													Habitat at nest tree location							
Area/source	Study Evaluation Score	Stand size	Patch shape	Edge/adjacent habitat type	Platform density	Percent canopy cover	Canopy complexity	Tree size/classes	Mean tree/canopy height	Tree density	Corvid abundance	Dominant vegetation	Vegetative area/cover	Presence mistletoe or witch's broom	Distance inland	Distance to disturbance[1]	Distance to edge of stand	Distance to stream	Elevation	Slope or position on slope	Aspect	Distance to canopy gap
OREGON																						
Marzluff et al. 1999	27	A	A	A							X						A					
Nelson 1992	17									X				X								
Nelson and Hardin 1993	14	X				X	X			X			X		X	X	X	X	X	X	X	
Nelson and Peck 1995	19														X							
Nelson and Wilson 2002	20					X	X		X	X				X				X		X		X
Witt 1998	18	X					X			X					X			X	X	X		X
WASHINGTON																						
Hamer and Cummins 1991	15											X			X				X			
Luginbuhl et al. 2001	31										A											
Marzluff and Neatherlin 2006	31										A					A						
Raphael et al. 2002	31	A		A							A					A	A					
Bloxton and Raphael 2009 (WA/BC)	24														X				X	X		
BRITISH COLUMBIA																						
Bradley 2002	31			A							X				A	A	A		A	A		
Bradley and Cooke 2001	16				X					X					X				X	X		
Burger 1994	15									X		X	X	X	X	X	X	X	X	X	X	

Table 12. Continued.

Area/source	Study Evaluation Score	General habitat characteristic: Stand size	Patch shape	Edge/adjacent habitat type	Platform density	Percent canopy cover	Canopy complexity	Tree size/classes	Mean tree/canopy height	Tree density	Corvid abundance	Dominant vegetation	Vegetative area/cover	Presence mistletoe or witch's broom	Habitat at nest tree location: Distance inland	Distance to disturbance[1]	Distance to edge of stand	Distance to stream	Elevation	Slope or position on slope	Aspect	Distance to canopy gap
Burger et al. 2000	14	X				X		X		X	X	X		X	X	X		X	X	X	X	
Burger et al. 2004	36										A						A	X				
Drever et al. 1998	22				X		X	X														
Hull et al. 2001	26														A				A			
Jones 2001	16											X							X			
Malt and Lank 2007	28			A	X	A		A			A	X				X	A					
Manley 1999	30																X		X	X		
Manley 2003	32				A	A		A		A				A					A	A		
Manley et al. 2001	16				X			X				X			X				X	X		
Silvergieter 2009	31	X			A			A	A	A									A	A	X	
Waterhouse et al. 2008	31					A	A	A	A				A							A		X
Zharikov et al. 2006	33	A		A											A	A	A	A	A	A		
Zharikov et al. 2007	31	A	A	A				A				A			A							
CALIFORNIA																						
Becking 1991	12									X		X	X	X				X	X	X		
Golightly et al. 2009	27					A	A	A	A	A		X			A	A		A	A	A	A	A
Kerns and Miller 1995	18	X						X							X	X			X		X	
Singer et al. 1991	14					X				X		X	X	X		X				X	X	
Singer et al. 1995	20					X						X	X			X		X				
Suddjian 2003	17															X	X					

Table 12. Continued.

Area/source	Study Evaluation Score	General habitat characteristic													Habitat at nest tree location							
		Stand size	Patch shape	Edge/adjacent habitat type	Platform density	Percent canopy cover	Canopy complexity	Tree size/classes	Mean tree/canopy height	Tree density	Corvid abundance	Dominant vegetation	Vegetative area/cover	Presence mistletoe or witch's broom	Distance inland	Distance to disturbance[1]	Distance to edge of stand	Distance to stream	Elevation	Slope or position on slope	Aspect	Distance to canopy gap
ALASKA																						
Barbaree et al. 2014	23														A							
Ford and Brown 1995	13							X							X				X	X		
Hirsch et al. 1981	14														X						X	
Kuletz et al. 1994	10											X	X		X				X	X	X	
Marks and Naslund 1994	13					X									X				X			
Naslund et al. 1995	17	X				X		X		X		X	X		X			X	X	X	X	
RANGEWIDE																						
Nelson and Hamer 1995	36	A				A											A					

1 Includes roads, trails, other noise sources, etc.

Table 13. Summary of studies relating nest success to habitat attributes for nesting Marbled Murrelets in North America. Symbols refer to positive associations (+), negative associations (-), and/or no apparent association with nest success (0). Study Evaluation Scores had a maximal value of 42.

		General habitat characteristic										Habitat at nest tree location					
Area/source	Study Evaluation Score	Stand size	Patch shape	Edge/adjacent habitat type	Platform density	Percent canopy cover	Canopy complexity	Tree size/ age class	Mean tree/canopy height	Tree density	Corvid abundance	Distance inland	Distance to disturbance[1]	Distance to edge of stand	Distance to stream	Elevation	Slope /position on slope
OREGON																	
Marzluff et al. 1999	27	0	+	+													
WASHINGTON																	
Luginbuhl et al. 2001	31										-						
Marzluff and Neatherlin 2006	31										0/-		+[2]				
Raphael et al. 2002	31	0		+							0/-		+	0/+			
BRITISH COLUMBIA																	
Bradley 2002	31			+							-[3]	+	0	0/-		+	+
Burger et al. 2004	36										-[3]			+			
Hull et al. 2001	26											0				0	
Malt and Lank 2007	28			+		-		-			-[3]			+			
Manley 2003	32				0	0		0		0						0	+
Silvergieter 2009	31				0			0	0	0				0		0	0
Waterhouse et al. 2008	31					-	+	0									+
Zharikov et al. 2006[4]	33	0		+								0	0	+/-	0	0	0
Zharikov et al. 2007	31	0	0	+				+				+				+	

Table 13. Continued.

Area/source	Study Evaluation Score	General habitat characteristic: Stand size	Patch shape	Edge/adjacent habitat type	Platform density	Percent canopy cover	Canopy complexity	Tree size/ age class	Mean tree/canopy height	Tree density	Corvid abundance	Habitat at nest tree location: Distance inland	Distance to disturbance[1]	Distance to edge of stand	Distance to stream	Elevation	Slope /position on slope
CALIFORNIA																	
Golightly et al. 2009	27					0	0	0	0	0		0	0		0	0	0
ALASKA																	
Barbaree et al. 2014	23											0					
RANGEWIDE																	
Nelson and Hamer 1995	36	0				0								+			

1 Includes roads, trails, other noise sources, etc.
2 Relationship with corvid abundance varies with distance from human settlement.
3 Indirect association with corvid abundance described.
4 Note that interpretation of results and conclusions of this study have been challenged by Burger and Page (2007).

exposure to wind and other disturbance also could be associated with stand edges). In addition, nest stands adjacent to areas providing additional food resources for corvids (e.g., near human settlements or regenerating stands with berry-producing vegetation) were found to have higher nest failure rates or have stronger edge effects on predation rates than was found for other stands in four studies.

One additional habitat attribute was found to have a significant correlation with murrelet nesting success but was considered as a variable in only one study (thus not shown in Table 13). Waterhouse et al. (2008) found higher nest success in habitat with more dispersed dominant trees rising above adjacent canopy than in habitats with more uniform canopy; however, probable correlations of this attribute with other significant variables (e.g., slope, dominant trees, crown closure) confound interpretation of this result.

Habitat Characteristics Measured at the Nest Tree Location

Six attributes describing the location of nest trees relative to landscape or topographic features were analyzed for relationships with nesting success in multiple studies (Table 13). As described above, the distance of nests from stand edges were variably correlated with nest success, often in relation to the adjacent habitat type. Positive associations between distance to edge or disturbance and nest success were found in 5 of 9 studies, including the two studies with the highest Evaluation Scores (36). Nest success was found to be higher closer to edges in two studies, but only with particular edge types. Bradley (2002; Study Evaluation Score: 31) found that nests closer to "natural" edges (i.e., those not resulting from human activities) were more successful than those found either further from edges or near edges resulting from human habitat alterations.

The distance of nests from coastlines or foraging areas was not associated with nest success in four studies in which it was analyzed (Study Evaluation Scores: 23–33; Table 13). Two studies did find positive associations between distance inland and nest success (Bradley 2002, Zharikov et al. 2007; Study Evaluation Scores: 31 and 31); however, the distance from ocean was not independent of nest site elevation, which also had a positive correlation with nest success in these studies. Elevation was not associated with success in five other studies (Study Evaluation Scores: 26–33), although one study found higher nest success at sites that were higher on the local slope (Waterhouse et al. 2008; Study Evaluation Score: 31). Two studies (Bradley 2002, Manley 2003; Study Evaluation Scores: 31 and 32) reported higher nest success associated with steeper slopes, although no relationships between slope and success were found in three other studies.

Effects Modifiers

We identified a number of factors that might have influenced results across studies. We looked at studies from across the entire range of the species, which introduces geographic and habitat-based modifiers among these studies. For example, the structure of more northern forest communities in Alaska clearly differs from the redwood-dominated habitats of California, and these differences may occur at both the forest stand and patch scales. However, it is less likely that there are inherent differences in forest structure and habitat characteristics among studies in Oregon and Washington, and likely British Columbia. One notable exception is that forest harvest practices among regions may introduce additional variation in forest communities, even among neighboring areas, with some experiencing greater habitat modification from fire or logging and others remaining more "untouched". Thus, the relationships between nest success and habitat characteristics will differ across certain parts of the species range based on inherent differences in forest communities and also on land use practices that will vary with political boundaries and land ownership (e.g., federal, state/provincial, and private lands). Similarly, predator communities likely differ to some degree among regions based upon the above-noted differences in habitats and forest practices, as well as distance to human activities (e.g., camp grounds, settlements).

The methods used to locate nests and determine nest success differed among studies and introduces variation among study results. For instance, numerous studies used radio-telemetry to locate nests and in some cases these nests were in areas inaccessible from the ground. As a result these studies often used nest attendance patterns of telemetered birds to classify nest fate based on mid-rearing success of nests during the chick-rearing period, as opposed to using actual fledging success from direct observations of nests. It is important to note, however, that some studies (Withey et al. 2001, Peery et al. 2004, Bloxton and Raphael 2009), suggest that telemetry may reduce likelihood of nesting and nest success of individual murrelets. Also, in many cases telemetry studies were not able to locate the actual nest tree/cliff and the spatial accuracy of nest site locations was generally estimated at 10–100 m. Similarly, studies varied in manner that the different habitat variables were measured and in the scales used to characterize habitats. One methodological difference was that most studies collected ground-based measurements of habitat variables but a smaller set of studies relied on GIS-based measurements (e.g., Bradley 2002; Zharikov et al. 2006, 2007) or interpretation of aerial photos (e.g., Waterhouse et al. 2008) to characterize habitats. Finally, nest predation was identified in 72% (13 of 18) of the studies with known causes of nest failure, but occurred in 100% of the studies that used artificial nests with fake eggs or nestlings to document and describe predation specifically. Clearly, some factors associated with other causes of nest failure (e.g., nest abandonment, non-viable egg, death of adult) will not be represented by studies of artificial nests. Further, there also could be differences in the rates of nest discovery by predators at artificial versus real murrelet nests, as factors such as presence of adult birds and species-specific characteristics of eggs and nests may influence results. In the one study that compared results of artificial and real nests, however, habitat (edge) effects did not differ between the two methodologies (Malt and Lank 2007).

Conclusions and Data Gaps

Because of its association with increased edge effects on predator abundance and nest predation rates in Pacific Northwest and other forests (Paton 1994, Brand and George 2000), forest fragmentation has been suggested as a cause of murrelet nest failure and other population changes (Nelson and Hamer 1995, USFWS 1997, 2009). Raphael (2002) and Zharikov et al. (2007) found evidence for increased nest predation rates and predator abundance associated with some specific habitat characteristics associated with landscape fragmentation (including edges, amount of young forest, human habitation, and the presence of berry-producing plants), although interactions among variables limited assessment of general fragmentation effects on nest success. Our review found that, while there was some overlap in the model variables considered as potential correlates for nest success (especially with distance from stand edge), many of the variables considered varied among regions and models. As corvid predation is assumed to be the primary cause of nest failure in tree-nesting murrelet populations, geographic variation in the relative distribution and abundance of these and other predators across the range will likely affect nest success correlates in different regions. More comparable studies are needed in different parts of the species range to better understand general and regional patterns of nest success correlates.

Model selection analyses have helped to focus on attributes that contribute to predictive models of murrelet nesting success and to build a body of evidence for eliminating others as important variables. In addition, they have identified novel habitat features associated with success that should be considered at other sites. For example, Waterhouse et al. (2008) found higher success rates for nests in plots with scattered large trees than in those with higher densities of large trees, a finding that has implications for nesting success in remnant old-growth trees within a matrix of younger forest. This habitat variable has not been included in other models or analyses, so further studies would be valuable to gain more insights into its effect on nest success.

Although the overall range of Study Evaluation Scores for this question was broad (10–36 of a maximum 42 points), the range for the 16 studies that directly assessed associations between habitat characteristics and nest success was considerably less broad (23–36), with only one score <27. Scores among studies that reported differences in associations of habitat characteristics with nest success were generally similar. Assessment of evidence for consistent correlates of nest success was hampered by potential or identified intercorrelations and interactions of habitat variables and the variation among study methods, including whether and how such relationships are addressed.

We identified a number of studies (marked with "X" in Table 12) that determined nest success and also provided habitat information but had insufficient sample sizes or otherwise did not provide analysis of relationships between habitat and nest success. Data from these studies and other unpublished sources, however, may be useful as the basis of a meta-analysis to increase our understanding of the relationship between nest success and habitat.

An early review of the few known Marbled Murrelet nests in North America suggested that nest success was correlated with the distance of a nest to the edge of the nesting stand (Nelson and Hamer 1995). Our systematic review has demonstrated that, as more nests have been found and monitored and artificial nest experiments have been conducted, such a relationship is not straightforward. For example, considerable variation exists across studies in the relationships of habitat attributes to nesting success, suggesting geographic and/or landscape-level differences in these relationships. There is need for studies to better identify the interactions between habitat variables and to identify critical variables among those that tend to co-vary within studies. For example, several studies of artificial nests suggest that the type of edge bordering the nest stand may be important, with nest success likely to be higher at natural edges (e.g., along streams or avalanche chutes) than at hard edges bordering roads or recent clearcuts; and with local predator densities varying with habitat (and associated food abundance) adjacent to nesting stands.

References

Baker, L. M., M. Z. Peery, E. E. Burkett, S. W. Singer, D. L. Suddjian, and S. R. Beissinger. 2006. Nesting habitat characteristics of the Marbled Murrelet in central California redwood forests. Journal of Wildlife Management 70:939–946.

Barbaree, B. A., S. K. Nelson, B. D. Dugger, D. D. Roby, H. R. Carter, D. L. Whitworth, and S. H. Newman. 2014. Nesting ecology of Marbled Murrelets at a remote mainland fjord in southeast Alaska. Condor 116:173–184.

Becking, R. W. 1991. Eggshell fragments of the Marbled Murrelet (Brachyramphus marmoratus) in San Mateo County, California. Northwestern Naturalist 72:74–76.

Bernes C., K. A. Bråthen, B. C. Forbes, A. Hofgaard, J. Moen, and J. D. M. Speed. 2013. What are the impacts of reindeer/caribou (Rangifer tarandus L.) on arctic and alpine vegetation? A systematic review protocol. Environmental Evidence 2:1–7.

Bigger, D., M. Z. Peery, S. Chinnici, and S. P. Courtney. 2006. Efficacy of audiovisual and radar surveys for studying Marbled Murrelets in inland habitats. Journal of Wildlife Management 70:505–516.

Binford, L. C., B. G. Elliot, and S. W. Singer. 1975. Discovery of a nest and the downy young of the Marbled Murrelet. Wilson Bulletin 87:303–319.

Bloxton, T. D., Jr., and M. G. Raphael. 2009. Breeding ecology of the Marbled Murrelet in Washington state: five year project summary (2004–2008). Report by USDA Forest Service, Pacific Northwest Research Station, Olympia, WA. 41 pp.

Bradley, R. W. 2002. Breeding ecology of radio-marked Marbled Murrelets (Brachyramphus marmoratus) in Desolation Sound, British Columbia. M.Sc. Thesis, Simon Fraser University, Burnaby, BC. 102 pp.

Bradley, R. W., and F. Cooke. 2001. Cliff and deciduous tree nests of Marbled Murrelets in southwestern British Columbia. Northwestern Naturalist 82:52–57.

Brand, L. A., and T. L. George. 2000. Predation risks for nesting birds in fragmented coast redwood forest. Journal of Wildlife Management 64:42–51.

Burger, A. E. 1994. Analysis of terrestrial and marine activities of Marbled Murrelets breeding on southwest Vancouver Island, 1990–1993. Report by Biology Department, University of Victoria, Victoria, BC. 35 pp. + appendices.

———. 2001. Using radar to estimate populations and assess habitat associations of Marbled Murrelets. Journal of Wildlife Management 65:696–715.

———. 2002. Conservation assessment of Marbled Murrelets in British Columbia: review of the biology, populations, habitat associations, and conservation of this threatened species. Technical Report Series No. 387, Canadian Wildlife Service, Delta, BC.

Burger, A. E. and V. Bahn. 2000. Habitat requirements of Marbled Murrelets on SW Vancouver Island and the effects of forest harvest practices. Unpublished report, Department of Biology, University of Victoria, Victoria, BC. 19 pp.

———. 2001. Habitat requirements of Marbled Murrelets on Vancouver Island and the effects of forest harvest practices: Final report—30 April 2001. Unpublished report, Department of Biology, University of Victoria, Victoria, BC. 19 pp.

Burger, A. E., V. Bahn, and A. Young. 2000. Assessment of nesting habitat for Marbled Murrelets in the coastal Douglas-fir forests of southeast Vancouver Island in 1998 and 1999. Report by Department of Biology, University of Victoria, Victoria, BC. 51 pp.

Burger, A. E., Manley, I. A., M. P. Silvergieter, D. B. Lank, K. M. Jordan, T. D. Bloxton, and M. G. Raphael. 2009. Re-use of nest sites by Marbled Murrelets (Brachyramphus marmoratus) in British Columbia. Northwestern Naturalist 90:217–226.

Burger, A. E., M. N. M. Masselink, A. R. Tillmanns, A. R. Szabo, M. Farnholtz, and M. J. Krkosek. 2004. Effects of habitat fragmentation and forest edges on predators of Marbled Murrelets and other forest birds on southwest Vancouver Island. Pp. 1–19 in T. D. Hooper, Editor. Species at Risk 2004: Pathways to Recovery Conference, Victoria, BC.

Burger, A. E., R. A. Ronconi, M. P. Silvergieter, C. Conroy, V. Bahn, I. A. Manley, A. Cober, and D. B. Lank. 2010. Factors affecting the availability of thick epiphyte mats and other potential nest platforms for Marbled Murrelets in British Columbia. Canadian Journal of Forest Research 40:727–746.

Carter, H. R., and S. G. Sealy. 1987. Inland records of downy young and fledgling Marbled Murrelets in North America. Murrelet 68:58–63.

Collaboration for Environmental Evidence (CEE). 2013. Guidelines for systematic review and evidence synthesis in environmental management. Version 4.2. Environmental evidence: www.environmentalevidence.org/Documents/Guidleines/Guidelines 4.2.pdf

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2012. COSEWIC assessment and status report on the Marbled Murrelet Brachyramphus marmoratus in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xii + 82 pp. <www.registrelep-sararegistry.gc.ca/default_e.cfm>

Conroy, C. J., V. Bahn, M. S. Rodway, L. Ainsworth, and D. Newsome. 2002. Estimating nest densities for Marbled Murrelets in three habitat suitability categories in the Ursus Valley, Clayoquot Sound. Pp. 121–137 in A. E. Burger and T. A. Chatwin, Editors. Multi-scale studies of populations, distribution, and habitat associations of Marbled Murrelets in Clayoquot Sound, British Columbia. Report by Ministry of Water, Land, and Air Protection, Victoria, BC.

Cooke, F. 1999. Population studies of Marbled Murrelets (Brachyramphus marmoratus) in British Columbia. Pp. 43–51 in A. W. Diamond and D. N. Nettleship, Editors. Biology and conservation of forest birds. Society of Canadian Ornithologists, Fredericton, NB. Society of Canadian Ornithologists Special Publication No. 1.

Cooper, B. A., and R. J. Blaha. 2002. Comparisons of radar and audio-visual counts of Marbled Murrelets during inland forest surveys. Wildlife Society Bulletin 30:1182–1194.

Coulson, J. C. 2002. Colonial breeding in seabirds. Pp. 87–113 in E. A. Schreiber and J. Burger, Editors. Biology of Marine Birds. CRC Press, Boca Raton, FL.

Czarnomski, N., and H. Hale. 2013. Effectiveness of riparian buffers at protecting stream temperature and shade in Pacific Northwest Forests: a systematic review. Report prepared by Environmental Science Associates, Portland, OR, and Nutter and Associates, Athens, GA, for Oregon Dept. of Forestry, Salem, OR. 258 pp.

Dechesne, S. B. C., and J. L. Smith. 1997. Wildlife inventory: Queen Charlotte Islands/Haida Gwaii, 1994–1996. Unpublished report to Husby Group of Companies, Delta, BC, by Coast Forest Management Ltd., Victoria, BC. 49 pp.

Divoky, G. J., and M. Horton. 1995. Breeding and natal dispersal, nest habitat loss, and implications for Marbled Murrelet populations. Pp. 83–87 in C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, and J. F. Piatt, Technical Editors. Ecology and conservation of the Marbled Murrelet. USDA Forest Service, Pacific Southwest Research Station, Albany, CA. General Technical Report PSW-GTR-152.

Drever, M. C., C. Lougheed, I. A. Manley, B. A. Vanderkist, W. D. Beauchamp, W. S. Boyd, G. W. Kaiser, L. W. Lougheed, and F. Cooke. 1998. Demography and ecology of Marbled Murrelets in Desolation Sound, British

Columbia (1996). Report by CWS/NSERC Wildlife Ecology Chair, Simon Fraser University, Burnaby, BC. CWS/NSERC Wildlife Ecology Chair Technical Report No. 002. 46 pp.

Eisenhawer, A. E., and T. E. Reimchen. 1990. Inland flight patterns of Marbled Murrelets, Brachyramphus marmoratus, on the Queen Charlotte Islands, British Columbia. Canadian Field-Naturalist 104:439–444.

Evans Mack, D. M., W. P. Ritchie, S. K. Nelson, E. Kuo-Harrison, P. Harrison, and T. E. Hamer. 2003. Methods for surveying Marbled Murrelets in forests: a revised protocol for land management and research. Pacific Seabird Group Technical Publication Number 2. Available from http://www.pacificseabirdgroup.org.

Ford, C. ,and M. Brown. 1995. Unusual Marbled Murrelet nest. Wilson Bulletin 107:178–179.

Franklin, J. F., and T. A. Spies. 1991. Ecological definitions of old-growth Douglas-fir forests. Pp. 61–69 in L. F. Ruggiero, K. B. Aubry, A. B. Carey, and M. H. Huff, Technical Editors. Wildlife and vegetation of unmanaged Douglas-fir forests. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, General Technical Report no. PNW-285. Portland, OR.

Gaston, A. J., and I. L. Jones. 1998. The Auks, Alcidae. Oxford University Press, Oxford, UK. 388 pp.

Golightly, R. T., C. D. Hamilton, and P. N. Hébert. 2009. Characteristics of Marbled Murrelet (Brachyramphus marmoratus) habitat in northern California. Report by Department of Wildlife, Humboldt State University, Arcata, CA. 49 pp.

Golightly, R. T., and S. R. Schneider. 2009. Observations of incubation in Year 8 of a long-term monitoring effort at a Marbled Murrelet nest in northern California. Report by Department of Wildlife, Humboldt State University, Arcata, CA. 37 pp.

———. 2011. Years 9 and 10 of a long-term monitoring effort at a Marbled Murrelet nest in northern California. Report by Department of Wildlife, Humboldt State University, Arcata, CA. 22 pp.

Grenier, J. J., and S. K. Nelson. 1995. Marbled Murrelet habitat associations in Oregon. Pp. 191–204 in C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, and J. F. Piatt, Technical Editors. Ecology and conservation of the Marbled Murrelet. USDA Forest Service, Pacific Southwest Research Station, Albany, CA. General Technical Report PSW-GTR-152.

Hamer, T. E., W. P. Ritchie, E. B. Cummins, and C. W. Turley. 1994. Forest habitat relationships of Marbled Murrelets in western Washington. Unpublished report, Wildlife Management Division, Nongame Program, Washington Department of Wildlife, Olympia, WA. 51 pp.

Hamer, T. E., and E. B. Cummins. 1990. Forest habitat relationships of Marbled Murrelets in northwestern Washington. Unpublished report by Wildlife Management Division, Nongame Program, Washington Department of Wildlife, Olympia, WA. 54 pp. + unpaginated material.

———. 1991. Relationships between forest characteristics and the use of inland sites by Marbled Murrelets in northwestern Washington. Unpublished report by Wildlife Management Division, Nongame Program, Washington Department of Wildlife, Olympia, WA. 47 pp.

Hamer, T. E., and S. K. Nelson. 1995. Characteristics of Marbled Murrelet nest trees and nesting stands. Pp. 69–82 in C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, and J. F. Piatt, Technical Editors. Ecology and conservation of the Marbled Murrelet. USDA Forest Service, Pacific Southwest Research Station, Albany, CA. General Technical Report PSW-GTR-152.

Harris, R. D. 1971. Further evidence of tree nesting in the Marbled Murrelet. Canadian Field-Naturalist 85:67–68.

Hébert, P. N., H. R. Carter, and R. T. Golightly. 2011. Extra-pair visitations to a Marbled Murrelet nest in northern California. Northwestern Naturalist 92:95–100.

Hébert, P. N., H. R. Carter, R. T. Golightly, and D. L. Orthmeyer. 2003. Radio-telemetry evidence of re-nesting in the same season by the Marbled Murrelet. Waterbirds 26:261–265.

Hébert, P. N., and R. T. Golightly. 2006. Appendix B: Nest-site fidelity in Marbled Murrelets nesting in northern California. Pp. 257–282 in P. N. Hebert and R. T. Golightly. Movements, nesting, and response to anthropogenic disturbance of Marbled Murrelets (Brachyramphus marmoratus) in Redwood National and State parks, California. Unpublished report to California Department of Transportation, Sacramento, CA, by Department of Wildlife, Humboldt State University, Arcata, CA. California Department of Fish and Game Report No. 2006-02.

Hirsch, K. V., D. A. Woodby, and L. B. Astheimer. 1981. Growth of a nestling Marbled Murrelet. Condor 83:264–265.

Hull, C. L., G. W. Kaiser, C. Lougheed, L. Lougheed, S. Boyd, and F. Cooke. 2001. Intraspecific variation in commuting distance of Marbled Murrelets (Brachyramphus marmoratus): ecological and energetic consequences of nesting further inland. Auk 118:1036–1046.

Jones, P. H. 2001. The Marbled Murrelets of the Caren Range and Middlepoint Bight. Western Canada Wilderness Committee, Vancouver, BC. 150 pp.

Jordan, K. M., and S. K. Hughes. 1995. Characteristics of three Marbled Murrelet nest trees, Vancouver Island, British Columbia. Northwestern Naturalist 76:29–32.

Jordan, K. M., R. Toochin, and A. E. Burger. 1997. Marbled Murrelet nest in Bulson Valley, Clayoquot Sound, 1996. Pp. BN1-BN5 in A. E. Burger, B. A. Beasley, and T. A. Chatwin, Editors. Clayoquot Sound Marbled Murrelet inventory for 1996. Unpublished report to Ministry of Environment, Lands and Parks, Vancouver Island Regional Office, Nanaimo, BC.

Kaiser, G. W., and G. A. Keddie. 1999. Locating nest sites of the Marbled Murrelet (Brachyramphus marmoratus): a pilot project in radio-telemetry on the central coast of British Columbia. Unpublished report, Canadian Wildlife Service, Pacific and Yukon Region, Delta, BC. 37 pp.

Kerns, S. J., and R. A. Miller. 1995. Two Marbled Murrelet nest sites on private commercial forest lands in northern California. Northwestern Naturalist 76:40–42.

Kuletz, K. J., D. K. Marks, D. Flint, R. Burns, and L. Prestash. 1995. Marbled Murrelet foraging patterns and a pilot Productivity Index for murrelets in Prince William Sound, Alaska. Exxon Valdez Oil Spill Restoration Project Final Report (Restoration Project 94102). 110 pp. + unpaginated material.

Kuletz, K. J., D. K. Marks, N. L. Naslund, N. J. Goodson, and M. B. Cody. 1994. Information needs for habitat protection: Marbled Murrelet habitat identification. Exxon Valdez Oil Spill Restoration Project Final Report (Restoration Project 93051B). Report by U.S. Fish and Wildlife Service, Anchorage, AK. 41 pp. + unpaginated material.

Kuletz, K. J., N. L. Naslund, and D. K. Marks. 1994. Identification of Marbled Murrelet nesting habitat in the Exxon Valdez oil spill zone. Exxon Valdez Oil Spill Restoration Project Final Report (Restoration Study R15-2). Report by U.S. Fish and Wildlife Service, Anchorage, AK. 70 pp.

Lougheed, L. W., C. Lougheed, B. A. Vanderkist, S. Webster, R. Bradley, M. Drever, I. A. Manley, W. S. Boyd, G. W. Kaiser, and F. Cooke. 1998. Demography and ecology of Marbled Murrelets in Desolation Sound, British Columbia (1997). Report by CWS/NSERC Wildlife Ecology Chair, Simon Fraser University, Burnaby, BC. CWS/NSERC Wildlife Ecology Chair Technical Report No. 003. 43 pp.

Luginbuhl, J. M., J. M. Marzluff, J. E. Bradley, M. G. Raphael, and D. E. Varland. 2001. Corvid survey techniques and the relationship between corvid relative abundance and nest predation. Journal of Field Ornithology 72:556–572.

Malt, J., and D. Lank. 2007. Temporal dynamics of edge effects on nest predation risk for the Marbled Murrelet. Biological Conservation 140:160–173.

Manley, I. A. 1999. Behaviour and habitat selection of Marbled Murrelets nesting on the Sunshine Coast. M.Sc. Thesis, Simon Fraser University, Burnaby, BC. 163 pp.

———. 2003. Characteristics of Marbled Murrelet nest sites in Desolation Sound and Clayoquot Sound, BC. Unpublished report. Simon Fraser University, Burnaby, BC. 27 pp.

Manley, I. A, A. Harfenist, and G. Kaiser. 2001. Marbled Murrelet telemetry study on Queen Charlotte Islands/Haida Gwaii. Unpublished report to BC Ministry of Environment, Lands, and Parks, Smithers, BC. 31 pp.

Manley, I. A., and J. D. Kelson. 1995. Description of two Marbled Murrelet tree nests in the Walbran Valley, British Columbia. Northwestern Naturalist 76:26–29.

Marks, D. K., and N. L. Naslund. 1994. Sharp-shinned Hawk preys on a Marbled Murrelet nestling in old-growth forest. Wilson Bulletin 106:565–567.

Marzluff, J. M., J. M. Luginbuhl, J. E. Bradley, E. Neatherlin, M. G. Raphael, D. M. Evans, D. E. Varland, L. S. Young, S. P. Horton, and S. P. Courtney. 1999. The influence of stand structure, proximity to human activity, and forest fragmentation on the risk of predation to nests of Marbled Murrelets on the Olympic Peninsula. Unpublished report by Sustainable Ecosystems Institute and College of Forest Resources, University of Washington, Seattle, WA. 75 pp. + unpaginated material.

Marzluff, J. M., and E. Neatherlin. 2006. Corvid response to human settlements and campgrounds: causes, consequences, and challenges for conservation. Biological Conservation 130:301–314.

McFarlane Tranquilla, L., R. Bradley, N. Parker, D. Lank, and F. Cooke. 2003. Replacement laying in Marbled Murrelets. Marine Ornithology 31:75-81.

McShane, C., T. Hamer, H. Carter, G. Swartzman, V. Friesen, D. Ainley, R. Tressler, K. Nelson, A. Burger, L. Spear, T. Mohagen, R. Martin, L. Henkel, K. Prindle, C. Strong, and J. Keany. 2004. Evaluation report for the 5-year status review of the Marbled Murrelet in Washington, Oregon, and California. Report prepared by EDAW, Inc., Seattle, WA, for the U.S. Fish and Wildlife Service, Region 1, Portland, OR. 370 pp.

Meekins, D. J. and Hamer, T. E. 1999. Marbled Murrelet nest site selection in relation to habitat characteristics in western Washington. Unpublished report to Washington Department of Natural Resources, Olympia, WA. U.S. Fish and Wildlife Service, Lacey, WA, and Rayonier Northwest Forest Resources, Hoquiam, WA, by Hamer Environmental, Mt. Vernon, WA. 27 pp.

Naslund, N. L. 1993. Breeding biology and seasonal activity patterns of Marbled Murrelets (Brachyramphus marmoratus) nesting in old-growth forests. M.S. Thesis, University of California, Santa Cruz, CA. 146 pp.

Naslund, N. L., K. J. Kuletz, M. B. Cody, and D. K. Marks. 1995. Tree and habitat characteristics and reproductive success at Marbled Murrelet tree nests in Alaska. Northwestern Naturalist 76:12–25.

Naslund, N. L. 1993. Why do Marbled Murrelets attend old-growth forest nesting areas year-round? Auk 110:594–602.

Nelson, S. K. 1989. Development of inventory techniques for surveying Marbled Murrelets (Brachyramphus marmoratus) in the central Oregon Coast Range. Unpublished report to the Oregon Nongame Wildlife Research Program, Oregon Department of Fish and Wildlife, Portland, OR, by Oregon Cooperative Wildlife Research Unit, Oregon State University, Corvallis, OR. 104 pp.

———. 1992. Intensive searches for nests of the Marbled Murrelet through the use of visual observations and sophisticated audio equipment. Unpublished report to the Oregon Nongame Wildlife Research Program, Oregon

Department of Fish and Wildlife, Portland, OR, by Oregon Cooperative Wildlife Research Unit, Oregon State University, Corvallis, OR. 13 pp. + unpaginated material.

———. 1997. Marbled Murrelet (Brachyramphus marmoratus). In A. Poole and F. Gill (eds.). The Birds of North America, No. 276. Academy of Natural Sciences, Philadelphia, PA, and American Ornithologists' Union, Washington, D.C.

Nelson, S. K., and T. E. Hamer. 1995a. Nesting biology and behavior of the Marbled Murrelet. Pp. 57-67 in Ralph, C. J., G. L. Hunt, Jr., M. G. Raphael, and J. F. Piatt, Technical Editors. Ecology and conservation of the Marbled Murrelet. USDA Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR-152, Albany, CA.

———. 1995b. Nest success and the effects of predation on Marbled Murrelets. Pp. 89-97 in C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, and J. F. Piatt, Technical Editors. Ecology and conservation of the Marbled Murrelet. USDA Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR-152, Albany, CA.

Nelson, S. K., and J. G. Hardin. 1993. Landscape patterns and Marbled Murrelet occupancy: a pilot study (with notes on murrelet behavior and new nest trees). Report to Oregon Department of Fish and Wildlife, Portland, OR, Bureau of Land Management, Portland, OR, and U.S. Forest Service, Pacific Northwest Research Station, Olympia, WA, by Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR. 75 pp.

Nelson, S. K., and R. W. Peck. 1995. Behavior of Marbled Murrelets at nine nest sites in Oregon. Northwestern Naturalist 76:43–53.

Nelson, S. K., R. W. Peck, and T. L. De Santo. 1994. Searches for Marbled Murrelet nests using ground-based and tree climbing techniques. Pp. 1–36 in S. K. Nelson, R. W. Peck, J. J. Grenier, T. L De Santo, and M. M. Shaughnessy. Characteristics of Marbled Murrelet nests and occupied sites in Oregon. Report to Oregon Department of Fish and Wildlife, Portland, OR, and Bureau of Land Management, Portland, OR, by Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR.

Nelson, S. K., and A. K. Wilson. 2002. Marbled Murrelet habitat characteristics on State lands in Western Oregon. Report to Oregon Department of Forestry, Salem, OR, Oregon Department of Fish and Wildlife, Portland, OR, U.S. Fish and Wildlife Service, Portland, OR, and National Council for Air and Stream Improvement, Corvallis, OR, by Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR. 154 pp.

Nelson, S. K., M. H. Huff, S. L. Miller, M. G. Raphael. 2006. Marbled Murrelet biology: habitat relations and populations. Pp. 9–32 in M. H. Huff, M. G. Raphael, S. L. Miller, S. K. Nelson, and J. Baldwin (Technical Coordinators), Northwest Forest Plan—The First 10 years (1994–2003): Status and Trends of Populations and Nesting Habitat for the Marbled Murrelet. General Technical Report PNW-GTR-650. U. S. Forest Service, Pacific Northwest Research Station, Portland, OR.

Nettleship, D.N., and T. R. Birkhead. 1985. The Atlantic Alcidae. Academic Press, New York, NY. 574 pp.

O'Donnell, B.P., N.L. Naslund, and C.J. Ralph. 1995. Patterns of seasonal variation of activity of Marbled Murrelets in forested stands. Pp. 117-128 in C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, and J. F. Piatt, Technical Editors. Ecology and conservation of the Marbled Murrelet. USDA Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR-152, Albany, CA.

Paton, P. W. C. 1994. The effect of edge on avian nesting success: how strong is the evidence? Conservation Biology 8: 17-26.

Peery, M. Z., S. R. Beissinger, S. H. Newman, E. B. Burkett, and T. D. Williams. 2004. Applying the declining population paradigm: diagnosing causes of poor reproduction in the Marbled Murrelet. Conservation Biology 18:1088–1098.

Piatt, J. F., K. J. Kuletz, A. E. Burger, S. A. Hatch, V. L. Friesen, T. P. Birt, M. L. Arimitsu, G. S. Drew, A. M. A. Harding, and K. S. Bixler. 2007. Status review of the Marbled Murrelet (Brachyramphus marmoratus) in Alaska and British Columbia: U.S. Geological Survey Open-File Report No. 2006-1387.

Quinlan, S. E., and J. H. Hughes. 1990. Location and description of a Marbled Murrelet tree nest site in Alaska. Condor 92:1068–1073.

Ralph, C. J., G. L. Hunt Jr., M. G. Raphael, and J. F. Piatt (Technical Editors). 1995. Ecology and conservation of the Marbled Murrelet in North America. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, General Technical Report No. PSW-GTR-152, Albany, CA.

Raphael, M. G., D. E. Mack, J. M. Marzluff, and J. M. Luginbuhl. 2002. Effects of forest fragmentation on populations of the Marbled Murrelet. Studies in Avian Biology 25: 221–235.

Raphael, M. G., S. K. Nelson, P. Swedeen, M. Ostwald, K. Flotlin, S. Desimone, S. Horton, P. Harrison, D. Prenzlow Escene, and W. Jaross. 2008. Recommendations and supporting analysis of conservation opportunities for the Marbled Murrelet long-term conservation strategy. Report by Washington State Department of Natural Resources, Olympia, WA. 337 pp.

Raphael, M. G., G. A. Falxa, K. M. Dugger, B. M. Galleher, D. Lynch, S. L. Miller, S. K. Nelson, and R. D. Young. 2011. Northwest Forest Plan—the first 15 years (1994–2008): status and trend of nesting habitat for the Marbled Murrelet. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR. General Technical Report No. PNW-GTR-848. 52 pp.

Reimchen, T. E. 1991. Appendix 16: Marbled Murrelet habitat use near lakes in the Queen Charlotte Islands. Pp. 120–139 in M. S. Rodway, J.-P. L. Savard, and H. M. Regehr. Habitat use and activity patterns of Marbled Murrelets at inland and at-sea sites in the Queen Charlotte Islands, British Columbia. Canadian Wildlife Service, Pacific and Yukon Region, BC. Technical Report Series No. 122.

Rodway, M. S., J.-P. Savard, and H. M. Regehr. 1991. Habitat use and activity patterns of Marbled Murrelets at inland and at-sea sites in the Queen Charlotte Islands, British Columbia. Canadian Wildlife Service, Pacific and Yukon Region, Delta, BC. Technical Report Series No. 122. 152 pp.

Ryder, G. R., R. W. Campbell, H. R Carter, and S. G. Sealy. 2012. Earliest well-described tree nest of the Marbled Murrelet: Elk Creek, British Columbia, 1955. Wildlife Afield 9:49–58.

Sanzenbacher, P. M., B. A. Cooper, J. H. Plissner, and J. Bond. 2014. Intra-annual patterns in passage rates and flight altitudes of Marbled Murrelets (Brachyramphus marmoratus) in northern California. Marine Ornithology 42:169–174.

Schreiber, E. A., and J. Burger (Editors). 2002. Biology of Marine Birds. CRC Marine Biology Series, CRC Press, NY. 722 pp.

Silvergieter, M. P. 2009. Multi-scale analyses of nest site selection and fledging success by Marbled Murrelets (Brachyramphus marmoratus) in British Columbia. M.Sc. Thesis, Simon Fraser University, Burnaby, BC. 149 pp.

Silvergieter, M. P., and D. B. Lank. 2011a. Marbled Murrelets select distinctive nest trees within old-growth forest patches. Avian Conservation and Ecology 6(2):3. <http://dx.doi.org/10.5751/ACE-00462-060203>

———. 2011b. Patch scale nest-site selection by Marbled Murrelets (Brachyramphus marmoratus). Avian Conservation and Ecology 6(2):6. <http://dx.doi.org/10.5751/ACE-00483-060206>

Singer, S. W., N. L. Naslund, S. A. Singer, and C. J. Ralph. 1991. Discovery and observations of two tree nests of the Marbled Murrelet. Condor 93:330–339.

Singer, S. W., D. L. Suddjian, and S. A. Singer. 1992. Discovery, observations, and fledging of a Marbled Murrelet from a redwood tree nest. Unpublished report to Santa Cruz Museum of Natural History, Santa Cruz, CA. 7 pp. + unpaginated material.

———. 1995. Fledging behavior, flight patterns, and forest characteristics at Marbled Murrelet tree nests in California. Northwestern Naturalist 76:54–62.

Singer, S. W., and D. R. Verardo. 1975. The murrelet's nest discovered. Pacific Discovery 28: 18–21.

Spickler, J. C., and S. C. Sillett. 1995. Evidence of Marbled Murrelet nest fidelity in the redwood rain forest canopy of Humboldt County, California. Proposal for Save-the-Redwoods League, San Francisco, CA, by Eco-Ascension Research, Arcata, CA, and Department of Biological Sciences, Humboldt State University, Arcata, CA. 2 pp.

Suddjian, D. B. 2003. Ten years of monitoring Marbled Murrelets at the south fork of Butano Creek, San Mateo County, California, 1992–2001. Unpublished report for Big Creek Lumber Company, Davenport, CA. 42 pp. + unpaginated material.

U.S. Fish and Wildlife Service (USFWS). 1992. Endangered and threatened wildlife and plants determination of threatened status for the Washington, Oregon, and California population of the Marbled Murrelet. Federal Register 61: 26,256–26,320.

———. 1997. Recovery Plan for the Marbled Murrelet (Washington, Oregon, and California population). U.S. Fish and Wildlife Service, Portland, OR. 202 pp. + appendices.

———. 2009. Marbled Murrelet (Brachyramphus marmoratus): 5-year review. U.S. Fish and Wildlife Service, Lacey, WA. 85 pp. + appendices.

Varoujean, D. H., W. A. Williams, and D. R. Warrick. 1989. Nest locations and nesting habitat of the Marbled Murrelet (Brachyramphus marmoratus) in coastal Oregon. Nongame Wildlife Program, Oregon Department of Fish and Wildlife, Portland, OR. Technical Report #88-6-02. 48 pp.

Waterhouse, F. L., A. E. Burger, A. Cober, A. Donaldson, and P. Ott. 2007. Assessing habitat quality of Marbled Murrelet nest sites on the Queen Charlotte Islands/Haida Gwaii by algorithm, airphoto interpretation, and aerial survey methods. Research Section, Coast Forest Region, BC Ministry of Forests and Range, Nanaimo, BC. Technical Report No. TR-035. 20 pp.

Waterhouse, F. L., A. E. Burger, D. B. Lank, P. K. Ott, E. A. Krebs, and N. Parker. 2009. Using the low-level aerial survey method to identify Marbled Murrelet nesting habitat. BC Journal of Ecosystems and Management 10(1):80–96. <www.forrex.org/publications/jem/ISS50/vol10_no1_art8.pdf>

Waterhouse, F. L., A. Donaldson, D. B. Lank, P. K. Ott, and E. A. Krebs. 2008. Using air photos to interpret quality of Marbled Murrelet nesting habitat in south coastal British Columbia. BC Journal of Ecosystems and Management 9(1):17–37. <http://www.forrex.org/publications/jem/ISS47/vol9_no1_art3.pdf>

Waterhouse, F. L., A. Donaldson, P. K. Ott, and G. Kaiser. 2011. Interpretation of habitat quality from air photos at Marbled Murrelet nest sites in Mussel Inlet on the British Columbia central coast. BC Ministry of Forests, Mines and Land, Victoria, BC. Technical Report 061. 20 pp. <www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr061.htm>

Withey, J. C., T. D. Bloxton, and J. M. Marzluff. 2001. Effects of tagging and location error in wildlife radiotelemetry studies. Pp. 43–75 in J. J. Millspaugh, and J. M. Marzluff, Editors. Radio Tracking and Animal Populations. Academic Press, San Diego, CA.

Witt, J. W. 1998. Notes on activity and characteristics of an inland Marbled Murrelet nest site in Douglas County, Oregon. Northwestern Naturalist 79:27–32.

Zharikov, Y., D. B. Lank, and F. Cooke. 2007. Influence of landscape pattern on breeding distribution and success in a threatened alcid, the Marbled Murrelet: model transferability and management implications. Journal of Applied Ecology 44:748–759.

Zharikov, Y., D. B. Lank, F. Huettmann, R. W. Bradley, N. Parker, P. P.-W. Yen, L. A. McFarlane-Tranquilla, and F. Cooke. 2006. Habitat selection and breeding success in a forest-nesting alcid, the Marbled Murrelet, in two landscapes with different degrees of forest fragmentation. Landscape Ecology 21:107–120. <DOI.10.1007/s10980-005-1438-5>

Appendix 1—Modifications to protocol for this Marbled Murrelet Review

After submission of a final draft version of the protocol for this review, the following modifications to the protocol were determined to be appropriate, based upon information gathered during the literature search, data extraction, and synthesis portions of the review. Modified sections of the final draft proposal are highlighted in Appendix 9. Modifications were suggested or approved by ODF.

Confidence rating factors:

1. We revised values to set minimum for each factor = 0; however we did not change the overall range of values within each question.

2. Study methods:

   "Were the study methods (e.g., audiovisual, radar, telemetry) appropriate for the question of interest? (Scoring: 0 = no; 1 = unknown; 4 = yes)."

   We combined categories that distinguished between appropriate methods that were considered optimal and sub-optimal because such distinction may be considered subjective.

3. Sample size:

   "How large was/were the sample size(s) of interest (e.g., number of nests, number of flight behaviors; number of sites)? (Scoring: 0 = single [1]; 1 = small [2–9]; 3 = medium [10–29]; 5 = large [≥ 30])."

   We modified categories to reflect minimum sample sizes commonly considered adequate for assessment of statistical power or significance.

Data synthesis:

After generating Study Evaluation Scores and completing the synthesis of results, we found that many of the proposed tables and figures were unsuitable or uninformative for the results obtained.

Appendix 2—List of stakeholders and other interested parties solicited for input on drafts of review questions, protocol, and synthesis reports

Bill Ritchie, U.S. Fish and Wildlife Service
Bill Snyder, California Dept. of Forestry
Bob Sallinger, Portland Audubon
Bridget Moran, U.S. Fish and Wildlife Service
Bridget Tuerler, U.S. Fish and Wildlife Service
Bruce Hollen, Bureau of Land Management
Carolyn Scafidi, U.S. Fish and Wildlife Service
Chris Jarmer, Oregon Forest Industries Council
Colleen McShane, Seattle City Light
Dan Edge, Oregon State University - Dept. Fisheries & Wildlife
Daniel Varoujean
Dave Huber, Bureau of Land Management
Deanna Lynch, U.S. Fish and Wildlife Service
Dominick DellaSala, Geos Institute
Doug Robinson, Oregon State University - Dept. Fisheries & Wildlife
Gary Falxa, U.S. Fish and Wildlife Service
Gary Miller, U.S. Fish and Wildlife Service
Geoff Huntington, Oregon State University - College of Forestry
Ian Parnell, Canadian Wildlife Service
Jake Verschuyl, NCASI
Jeff Light, Plum Creek
Jennifer Bakke, Hancock Forest Management
Jennifer Weikel, Oregon Dept. of Forestry - Private Forests
Jim Heaney, Bureau of Land Management
Jim Rivers, Oregon State University - College of Forestry
Joan Hagar, Oregon State University - U S. Geological Survey
Jody Caicco, U.S. Fish and Wildlife Service
John Chatel, U.S. Forest Service
John Marzluff, University of Washington
Kate Engel, Confluence Environmental Company
Katie Dugger, Oregon State University - Oregon Cooperative Fish and Wildlife Research Unit
Ken Berg, U.S. Fish and Wildlife Service
Kerry Palermo, Bureau of Land Management
Kim Nelson, Oregon State University - Dept. Fisheries & Wildlife
Kyle Blum, Washington Dept. Natural Resources

Lee Folliard, Bureau of Land Management
Lisa Gaines, Oregon State University - Institute for Natural Resources
Louise Waterhouse, B.C. Ministry of Forests
Martin Nugent, Oregon Dept. of Forestry
Matt Betts, Oregon State University - College of Forestry
Meryl Redisch, Portland Audubon
Mike Rochelle, Weyerhaeuser
Nick Palazzotto, Oregon Dept. of Forestry-State Forests
Pat Kennedy, Oregon State University - Dept. Fisheries & Wildlife
Paul Henson, U.S. Fish and Wildlife Service
Peter Harrison, Washington Dept. Natural Resources
Phyllis Reed, U.S. Forest Service
Rex Sallabanks, Idaho Dept. Fish & Game
Rich Szlemp, U.S. Fish and Wildlife Service
Rod Krahmer, Oregon Dept. of Forestry
Rosemary Mannix, Oregon Dept. of Forestry-State Forests
Scott Pearson, Washington Dept. Fish and Wildlife
Sean McAllister, Mad River Biologists
Seth Barnes, Oregon Forest Industries Council
Sherri Miller, U.S. Forest Service
Steve Desimone, Washington Dept. Fish and Wildlife
Steve Holmer, American Bird Conservancy
Steve Tesch, Oregon State University - College of Forestry
Steven Courtney, WEST
Sue Sniado, California Dept. Fish and Game
Terry Frueh, Oregon Dept. of Forestry- Private Forests
Thomas Manness, Oregon State University - College of Forestry
Tim McBride, Hancock Forest Management
Tom Hamer, Hamer Environmental
Tom Williamson, Turnstone Environmental

Appendix 3—Reviewer Comments and Responses

Appendix 3.1. External comments and responses to these comments on draft Marbled Murrelet review questions

This section documents comments from external reviewers (i.e., stakeholders and others with interest in Marbled Murrelet policy), whose input on draft review questions was solicited and received during the period, May 2–19, 2014. Original document text is in serif font; reviewers' comments are provided in sans serif font, with general comments followed by those pertaining to specific questions. Reviewers' comments are followed (in italics) by responses provided by ODF and the ABR review team. Unless indicated below, typographic/grammatical errors and unclear wording that were indicated by reviewers are not addressed here but were corrected as suggested for the study plan.

GENERAL COMMENTS

Draft Systematic Review Questions

The objective of this section is to state the review questions. The context given before each question is provided to guide how the question is to be addressed and to provide some background so that the reader understands the Oregon Department of Forestry's intent behind the question and some key concepts embodied in the question. It is our intent that each question be addressed via scientific studies conducted in forests similar to those found in W. Oregon (i.e., not nests on rocky sites in e.g., Alaska). Reviewers are asked to consider the context and intent, along with the importance of well-constructed questions within Systematic Reviews, when providing any suggested improvements to the questions.

From Dominick DellaSala, Geos Institute (May 5, 2014):

"I would like the group to consider some additional questions related to ODF management of murrelet habitat:

1. to what extent does habitat fragmentation effect nesting success of murrelets, particularly in relation to nest predation?
2. do forest fragments act as population sinks for murrelets (this could be a subset of #1)?
3. to what extent is habitat continuity between state-managed lands and adjacent federal lands important to murrelet recovery goals?
4. what effect does clearcut logging, thinning, and post-fire logging have on murrelet nest site occupancy?"

ABR RESPONSE: *These are all good questions. We do not have the capacity to add additional questions to our review efforts at this time; and obviously there are numerous topics of interest and importance relating to the biology of and implementation of management recommendations for Marbled Murrelets that we cannot address. As previously indicated, ODF has identified the topics of highest priority for the review; and after considerable discussion, we arrived at these five questions and the contextual supplements, which we are revising (based on input from reviewers) for clarification and appropriate scope before we finalize a study plan for the review.*

While your questions #3 & 4 fall outside the scope of any of the current questions; #1 will be addressed in our review of our Question #4. In the context for the question, we use the terms "continuity" and "configuration" as specific aspects of fragmentation to be included and certainly will be addressing predation, as it has been the primary focus of studies that provide information on nest success for the species. As you indicate, the question of population sinks is strongly associated with the answer to the question as well and is, in fact, part of the rationale for the focus of this question on nest success rather than simply presence of nests. We are trying to frame questions that focus on aspects of the biology and ecology of the species that are useful for addressing various management issues and therefore often cover multiple spatial scales where feasible.

From Gary Falxa, U.S. Fish and Wildlife Service (May 7, 2014, with input from Deanna Lynch and Lynn Roberts):

"The first paragraph of the Draft Systematic Review Questions discusses excluding scientific studies conducted in areas that differ from western Oregon forests, giving the example of studies of murrelets nesting on rocky sites in Alaska. This is a mistake, in our view, and would exclude studies with relevant data. While studies of ground nesting murrelets will not be relevant for question related to nest-stand forest characteristics, those studies are relevant to questions of basic breeding biology and behavior, including questions 1 (e.g., circling behavior and vocalizations) and 2a (nest-site fidelity). Similarly, data from other alcid species may be relevant in certain aspects, particularly where data from Marbled Murrelets is lacking or limited. An example is for evaluating circling behavior.. if most alcids display circling behavior over nest sites, and if the data from Marbled Murrelets is limited, information from congeners and other alcids is relevant to evaluating whether MAMU circling above a stand is likely indicative of nesting there."

ABR RESPONSE: *We will remove the general comment about limiting inclusion geographically. We have decided not to include data from other alcids in this review for reasons addressed in the protocol. Although information from other alcid species may be useful from a policy standpoint, the relevance for these questions is highly uncertain given differences in breeding habitats and social systems.*

From Kim Nelson, Oregon State University (May 15, 2014):

(regarding statement: "It is our intent that each question be addressed via scientific studies conducted in forests similar to those found in W. Oregon [i.e., not nests on rocky sites in e.g., Alaska].")

"But hopefully will include forests of Alaska, California, and BC. These forests are different from W. OR but they are applicable to the murrelet and its biology. Leaving these out is definitely not appropriate."

ABR RESPONSE: *Agreed. Inclusion criteria regarding geography and nesting habitat will be question-specific and for the most part will be assessed as part of the relevance scoring rather than in the determination of whether or not to include specific studies in the review.*

(regarding Table 1 assertion about synthesis of study results within traditional reviews: "*Often do not differentiate between methodologically sound and unsound studies.*")

"This is really not true. I don't know any scientist who would knowingly use/cite unsound studies in their reports, manuscripts or reviews."

ABR RESPONSE: *Good point. The point to be made here is that there is a clearly defined and repeatable method used to generate the conclusions of SRs, whereas traditional reviews do not necessarily provide detailed analyses that objectively, rigorously, and consistently weigh the strengths and weaknesses of the supporting evidence.*

From Jake Verschuyl, National Council for Air and Stream Improvement (May 16, 2014):

"[C]oncerns with Question #1, #2a and #2b stem from the likelihood of ignoring that low p-values or high r-squared values do not necessarily constitute a high strength of evidence. The strength of evidence wording should make it clear that studies are weighed by their effect sizes, 95% confidence intervals and other elements of rigor, including the use of alternate data sets for model validation.

ABR RESPONSE: *As we indicate in the study protocol, the variable methodologies and numbers of pertinent studies anticipated for these questions lend to a narrative synthesis of results rather than a weighted meta-analysis. Nevertheless, to the extent that they are appropriate and described in studies, we will document and address elements of statistical power, variability, and study design in developing confidence scores and synthesizing results.*

From John Chatel, U.S. Forest Service (May 17, 2014):

"We would be interested in seeing other comments and receiving any next versions of your review questions."

ABR RESPONSE: *All comments and responses are included here, and the revised questions are provided in the draft study plan that will be sent to stakeholders for review at the same time that this document is sent.*

QUESTION 1

QUESTION 1. TO WHAT EXTENT ARE INDIVIDUAL BEHAVIORS (I.E., SUBCANOPY FLIGHT, CIRCLING, LANDING, VOCALIZATIONS) OF MARBLED MURRELETS INDICATIVE OF NESTING IN THE FOREST STAND WHERE THOSE BEHAVIORS OCCUR?

Context for question 1: This question addresses the current information on understanding the significance of various Marbled Murrelet behaviors to indication of nesting, and related to information on pages 20–21 of the 2003 protocol.

From Gary Falxa, U.S. Fish and Wildlife Service (May 7, 2014, with input from Deanna Lynch and Lynn Roberts):

"Comment: The general comment above applies here—should consider data from any murrelet study, as well as other alcids (weighting MAMU data more heavily)

Suggested rewording: 'What is the evidence, and how strong is that evidence for each individual murrelet behavior (i.e., subcanopy flight, circling, landing, vocalizations) that indicates nesting in the forest stand where those behaviors occur?'"

ABR RESPONSE: *See above regarding consideration of other alcid species.*

Other reviewers also seemed to object to starting questions with "To what extent ...." The rewording seems unnecessarily wordy; however, we have rephrased as "How are individual behaviors (subcanopy flight, circling, landing, vocalizations) of Marbled Murrelets indicative of nesting in the forest stand where those behaviors occur?"

ODF RESPONSE: *["What is the evidence and how strong is that evidence"] are implicit in the SR methodology, and should be explained in laying the foundation (i.e., intro to) for the questions; as such, [we] think it is better to not include it in the question; but it's good to have a question that examines the range of responses, conditions, etc., knowing that SR methodology focuses on evidence.*

From Kim Nelson, Oregon State University (May 15, 2014):

"This is going to take analyzing the databases of survey data in each state. While there are data from nests in papers and reports, some of these data are in the databases."

ABR RESPONSE: *In the protocol, we emphasize that the purpose of the review is not going to conduct analysis or review of raw data, although we may be able to list sources of these data to note that they exist and may be available for future analyses/metaanalyses.*

ODF RESPONSE: *Agreed; this needs to be clarified in laying the foundation for the questions.*

From Jake Verschuyl, National Council for Air and Stream Improvement (May 16, 2014):

"It will be important to make the distinction between behavioral indicators (e.g. vocalizations) that constitute occupancy, and are indicative only of some element of habitat use, and those which are deterministic of active nesting (e.g. landing). Also, the question should clearly identify whether the scope includes associating behaviors solely with active nesting or whether historical nesting sites were considered.

The wording 'To what extent…' in questions #1 and #2 should be avoided due to the lack of context or direction for quantification of biological response. A clear presentation might include: 'What is the strength of evidence for or against ….'"

ABR response: *We intend to focus on active nesting here as ultimately that is what occupancy is intended to represent.*

ODF response: *["What is the strength of evidence for or against"] are implicit in the SR methodology and should be explained in laying the foundation (i.e., intro to) for the questions; as such, [we] think it is better to not include it in the question; not stuck on "to what extent…", but [we] think it's good to have a question that examines the range of responses, conditions, etc., knowing that SR methodology focuses on evidence; also "…evidence for or against…" focuses on "either-or" rather than a continuum.*

QUESTION 2

Question 2a. To what extent do Marbled Murrelets exhibit nest site fidelity[1] at an identifiable spatial scale (i.e., at the scale of a watershed, forest stand, tree, branch, and platform), and how does the extent of continuous habitat affect nest site fidelity?

Question 2b. How does the extent of continuous habitat relate to the co-occurrence (i.e., nesting by multiple pairs) of murrelets in a forest stand and other scales?

Context for question 2: These subquestions address current information used to inform "site classification". Appendix A of the protocol presents results of analyses to recommend the number of survey site visits in order to achieve a 95% confidence level of correctly classifying occupancy of a survey site by Marbled Murrelets (see also pages 13-15 in the protocol). Although the analysis was done at the survey site level, "site classification" is extended beyond the survey site to the entire survey area, based on explanations regarding the importance of "continuous habitat" (pages 6 and 23) of the protocol. The overall question of the importance of continuous habitat is broad, for example: "How does the amount and extent of continuous habitat relate to the nesting, occupancy, abundance, and persistence at a site?" In this review ODF initially focuses on two sub-questions that are suggested by the language in the protocol explaining the importance of continuous habitat. In addition, other aspects of the hypothesized role of "continuous habitat" also are covered in Question 3 below. As resources allow, other aspects of this broader question may be addressed.

From Chris Jarmer, Oregon Forest Industries Council (May 6, 2014):

"... in "context" for question 2: both 2a and 2b are written very specifically, which is good I believe. But in the context it is offered that "As resources allow, other aspects of this broader question may be addressed." I think it will be highly desirable to address the multitudes of questions that arise in the protocol around site classification. How will you make the call whether "resources allow" a deeper foray into those other issues surrounding site classification?

ABR response: *We have removed the ambiguous sentence. For this project, we are focusing on the hypothesis posed in the protocol regarding the importance of "continuous habitat" and specifically on the observations relating to co-occurrence and nest site fidelity that are cited as evidence supporting this hypothesis (see page 6 of the protocol). This continuous habitat hypothesis is used as the basis for extending the site classification from the survey site to the entire survey area (pg 23 of the protocol). We have added that we will discuss the implications of answers to these two questions (renumbered as 2 and 3) for both the extent of habitat used by nesting murrelets and the classification of sites based on protocol survey results.*

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1 Note in subquestion 2a, that site fidelity refers to fidelity of individual birds and of multi-year persistence of murrelets (with individual identity unknown) at multiple scales.

From Gary Falxa, U.S. Fish and Wildlife Service (May 7, 2014, with input from Deanna Lynch and Lynn Roberts):

"'Context' paragraph: Needs clarification and simplification. The 'context' section talks about 'site classification' and continuous habitat, but how Questions 2a and 2b relate to this context is unclear. What is the question that ODF wants answered? Is it how to manage forests around occupied/nest stands, including, for example, what size of buffers to provide? If so, we suggest the context statement be simplified and focused on that. Also, we note that the classification (occupied, etc.) is applied to the survey area, because that is what is being surveyed. The survey 'site' serves as a method to break the survey 'area' into manageable portions to survey."

ABR response: *We have revised the context to better explain the rationale for addressing these two questions and the implications that will be addressed in discussing the results. See previous comments.*

"Q2a: Comment: As for question 4, if this is intended to inform forest management decisions, I recommend that this question also consider how reductions in the extent of continuous habitat affect both nest site fidelity and likelihood of stand use by nesting Marbled Murrelets.

Suggested rewording: 'What is the evidence, and how strong is that evidence, for Marbled Murrelet nest site fidelity at an identifiable spatial scale (i.e., at the scale of a watershed, forest stand, tree, branch, and platform). Does the extent of continuous habitat, and reductions in that extent, affect nest site fidelity (including the likelihood of murrelets continuing to nest in that 'site')?'"

ABR response: *We believe that effects of reduced extent of habitat, if such information exists, will be addressed within studies considered for the original question and will be considered in the synthesis. Note that this would apply toQ2b and Q4 as well. See previous comments on wording, although we believe the current wording appropriately addresses the scope of the question.*

ODF response: *Addressed via Q2a.*

"Q2b: Suggested rewording: 'What is the evidence for, and how does the extent of continuous habitat relate to the co-occurrence (i.e., nesting by multiple pairs) of murrelets in a forest stand and other scales?'"

ABR response: *We revised the question slightly for clarification but believe that the suggested modification is not needed because of the evidence-focused methodology implicit in SRs.*

From Jake Verschuyl, National Council for Air and Stream Improvement (May 16, 2014):

"It would be good offer separate consideration of the two types of site fidelity mentioned in the footnote, as one is simply continued use of suitable habitat, not really fidelity in a traditional sense."

ABR response: *We will distinguish between types of re-use in the synthesis. Reviewers will note whether individual identities were known or not when extracting data, to facilitate differentiation of studies on this basis.*

"In question #2b, specifying a certain breeding density may be a better descriptor than simply co-occurrence. There would likely be a natural habitat-area effect with more individuals in more total area, irrespective of habitat continuity. It will be important to offer separate consideration of studies that found effects of total habitat area on the probability of finding multiple nests versus those that actually tested nest density metrics against different levels of habitat continuity."

ABR response: *In order to be inclusive of all studies that are pertinent to the broader concept of co-occurrence, in the inclusion criteria and data extraction we specify dependent variables that include density measures or numbers of nests or occurrence of multiple nests. Furthermore, differences between these types of studies presumably also will be reflected in the confidence scoring because of ranking criteria that consider study design and analyses. Based on the studies found, we will determine how best to assess results for the synthesis.*

Question 3. How is the occurrence of Marbled Murrelet nest sites related to the number and size of potential nest platforms and platform tree density within a stand?

Context for question 3: This question is associated with the suitable habitat definitions (p. 2, 2003 protocol) that can be used to inform decisions on what stands to survey. There is currently a brief description in the protocol of murrelet habitat, including a noted platform size (10cm/4inches). ODF would like to better understand the information base to inform decisions on where/what to survey.

From Jake Verschuyl, National Council for Air and Stream Improvement (May 16, 2014):

"It would be useful to define what constitutes a nest site. The relationship between size of platforms or platform tree density and Marbled Murrelet occurrence might differ depending on the scale of the "nest site" (i.e. does this question refer to tree scale or patch scale nest sites? And if the scale is a patch, what are the bounds on patch size?). In addition, it would be good to add more context around the term habitat quality and configuration to understand the effect of:

1. Forest fragmentation
2. Slope
3. Scale of habitat selection—are murrelets nesting in unique trees in a landscape or given current data, is there a linear relationship between habitat and nesting birds?

The wording, "How is…," in questions #3 and #4 should be avoided, again due to the lack of context or direction for quantification of biological response. Statements such as: 'What is the strength of evidence for or against…' will help to reiterate the context that the SR process is based on."

ABR response: *Good point regarding the term "nest sites." This should be changed to "nests within a stand." (Note: we neglected to make this change in the recently distributed draft study protocol but will revise for the final version. JHP).*

We assume that the suggestion for "more context around the term habitat quality and configuration" is in reference to question 4. Question 3 focuses just upon platforms and platform trees in relation to probability of nesting. Question 4 has been broadened to include most scales of habitat associations with nesting success. We do not have the resources at this time to review all studies that pertain to all habitat associations with nesting probability.

Regarding wording of the question, see ODF response above regarding question 1.

From John Chatel, U.S. Forest Service (May 17, 2014):

"The Forest Service within Region 6 appreciates the opportunity to provide input into the ODF systematic review. Based on comments received from Marbled Murrelet Forests and my review we feel the majority of the posed questions are of an appropriate scope and are clearly stated to meet your objectives. We have one question. Your question #3 states, "How is the occurrence of Marbled Murrelet nest sites related to the number and size of potential nest platforms and platform tree density within a stand?" While this question is broad enough to include the array of forest age classes used by Marbled Murrelets, we wonder if it should be restated according to specific age classifications (old-growth, mature, and young stands)? Specifically, "How is the occurrence of Marbled Murrelet nest sites related to the number and size of potential nest platforms and platform tree density within young, mature, and old-growth stands?" We are particularly interested in what platform density in younger forests (60-80 years) constitutes suitable habitat. Although not part of your question, some of our Forests are also interested in what other habitat components associated with appropriate platform densities should indicate surveys are appropriate?"

ABR response: *We have added stand age-class as a factor.*

ODF response: *Agreed, we would like to see it included in the question.*

Question 4. How is Marbled Murrelet nesting success affected by habitat characteristics?

Context for question 4: In this question, habitat characteristics are assumed to include habitat quality, continuity, stand size, and configuration. This question is not centered on the survey protocol. Rather, it focuses on understanding the information available to inform protection measures for nesting sites, including whether certain landscape configurations effect nesting success. In other words, once a nesting site is identified, what measures can maintain the site and increase the likelihood of nesting success?

From Chris Jarmer, Oregon Forest Industries Council (May 6, 2014):

"I am confused by the wording in "context" on question 4, specifically what is meant by "habitat characteristics." It says that it is assumed to include four attributes (habitat quality, continuity, stand size, and configuration), but it does not say if it is limited to those four. And I would add that of the four, only stand size will have consistency of understanding. The other three are much more vague and will generate more uncertainty, not less. I am fine with this if the four are given only as examples and that ALL habitat characteristics (presence of ridges, rivers, stand age, species composition, etc.) are open for examination."

ABR response: *We have expanded the range of habitat characteristics to be more inclusive of sub-stand-level habitat features.*

From Gary Falxa, U.S. Fish and Wildlife Service (May 7, 2014, with input from Deanna Lynch and Lynn Roberts):

"Comment: Suggest rewording this question to be more inclusive: 'How is nesting success, and the likelihood of future occupancy/nesting use, affected by habitat characteristics and changes in those characteristics?'

—the context information for this question suggests ODF may be interested in murrelet conservation measures such as how much of a buffer to leave around a nest/occupied site. If so, I'd think that the question should not be limited to only nesting success.
—the context information for this question also suggests ODF may be interested in how habitat characteristics could be changed to improve conditions (i.e. increase the likelihood of nesting success)."

ABR response: *We are only able to focus on habitat relationships with nest success at this time and are not able to address the broader issue of probability of nesting within the scope of this project; however, we have expanded the range of habitat characteristics to be more inclusive of sub-stand-level habitat features.*

ODF response: *We feel like [the additional consideration of "the likelihood of future occupancy/nesting use"] is captured in nest site fidelity [Q2a]. We are really only interested in nest success for this question. We are already asking questions about site fidelity (future occupancy), co-occurrence and asynchrony (future occupancy), and nest sites and the relative influence of various habitat components at various scales on those aspects of MAMU ecology. We hope to use knowledge gained from all four questions to inform any subsequent proposed conservation measures. [We] think we have the scales right for the specific questions and have left adequate flexibility to address gaps as we discover them.*

From Jake Verschuyl, National Council for Air and Stream Improvement (May 16, 2014):

"In question #4 it is unclear if this includes review of existing analyses of habitat characteristics that are of proven importance to murrelets or simply of all habitat characteristics that one could measure? It seems important to consider which habitat characteristics, reportedly related to murrelet nest success indices, have reliable mechanistic causes associated with them. It also will be important to specify the scales of interest for question #4, as well as specific habitat characteristics being considered."

ABR response: *See responses above regarding scope of habitat characteristics. Given the paucity of experimental data, it seems premature to exclude variables based on a lack of hypothesized or demonstrated mechanisms for their effects. We* have *purposefully avoided specifying habitat characteristics and scales in order to be inclusive for this question.*

From Joan Hagar, US Geological Survey, Forest & Rangeland Ecosystem Science Center (May 19, 2014):

"Should question explicitly include the multiple spatial scales implied in the context?"

ABR RESPONSE: *We will continue to present the context in conjunction with the questions; so the scale information will remain accessible to the reader.*

Appendix 3.2. External comments and responses to these comments on draft Marbled Murrelet review protocol

This section documents comments from external reviewers (i.e., stakeholders and others with interest in Marbled Murrelet policy), whose input on the draft review protocol was solicited and received during the period, June 20 – July 19, 2014. Original document text is in Times New Roman font; reviewers' comments are provided in Arial font, with general comments followed by those pertaining to specific questions. Reviewers' comments are followed (in italics) by responses provided by ODF and the ABR review team. Unless indicated below, typographic/grammatical errors and unclear wording that were indicated by reviewers are not addressed here but were corrected as suggested.

From Kim Nelson, Oregon State University (July 19, 2014):

Background

Line 15

This survey protocol provides standardized techniques for detecting murrelets in forests while accounting for imperfect detection.

"This is not completely true. The probability of detection was developed based on presence detections not occupied, so it does not account for any variation in detecting occupied behaviors. It also does not take into account the difference in detectability between small and larger groups of birds in an area. If there are only 1-3 or so birds in a stand they rarely vocalize and thus are not easy to detect. We hope to resolve these issues in the next version of the protocol."

ABR RESPONSE: *Modified text: "…while partially accounting for …".*

Line 19

Survey data are used to classify forest stands as having "probable absence" of murrelets, "presence" of murrelets flying over the area, or "occupancy" by nesting birds (based on circling behavior or birds flying through the canopy; p. 22 of PSG protocol).

"FYI, ODF and private companies in Oregon have not used circling to indicate occupancy; all other states/agencies have. In addition, ODF management went to all sites where occupied behavior was seen by certified surveyors. If it was not seen again then the site was not necessarily designated as occupied. So you will need to address discrepancies between states and agencies and how everyone was not using/following the protocol in the same manner."

ABR RESPONSE: *Modified text: "…or "occupancy" by nesting birds, based on observed flight behaviors (p. 22 of PSG protocol)."We made this statement more general here, although it is not within the scope of this review to assess how the protocol is being or should be implemented.*

Review Questions

Line 91

Question 1. How are individual behaviors (subcanopy flight, circling, landing, vocalizations) of Marbled Murrelets indicative of nesting in the forest stand where those behaviors occur?

This needs to include breeding and use of a forest stand. Birds do not need to be nesting currently for these behaviors to be important for the life history of murrelets. Please rewrite to include all activities that are important to murrelet breeding including nesting (laying eggs, incubating, feeding/raising young), searching for nest sites, finding mates, exploring their home range, and roosting (this may be related to searching for nests, but birds have been seen hanging out in trees that did not have nests in the same year or subsequent years).

ABR response: *Added text: "We acknowledge that forest habitats also have value for murrelets beyond a direct association with nesting (e.g., prospecting for nest sites, pair-bonding, roosting), but for this question we focused only upon the measureable indicators of nesting." Other "uses" of inland sites are not readily identifiable or quantifiable, and any associations with breeding and breeding success are unknown. We don't dispute that assumptions about the value of any identified "use" of a stand for murrelet life history warrant consideration, but without clear evidence of contributions to breeding success, they are policy decisions that falls outside the scope of this review.*

Line 96

Question 2. To what extent do Marbled Murrelets exhibit nest-site fidelity at various spatial scales (i.e., at the scale of a watershed, forest stand, tree, branch, and platform), and how does the areal extent of continuous habitat affect nest-site fidelity?

Define this ["areal extent"]. Do you mean size? One definition of areal is extent, so this says "extent extent". Rewrite to make clear.

ABR response: *Reworded.*

Line 99

Question 3. How does the areal extent of continuous habitat relate to the co-occurrence (i.e., nesting by multiple pairs) of murrelets in a forest stand and at other spatial scales?

Define continuous too. Contiguous, large blocks, etc.

ABR response: *Definition provided in glossary. Note that "contiguous" means "adjacent" or "adjoining" and refers to a series of discrete unit, whereas "continuous" refers to a single unit that is not divisible. Thus, there may be contiguous stands within a forest but not a contiguous forest, although the term is commonly used.*

Line 119

Question 4. How is the occurrence of Marbled Murrelet nest sites related to the number and size of potential nest platforms and platform tree density within stands of different age-classes (young, mature, and old growth)?

This will take compiling all field information. Many of the nest site data are not published.

ABR response: *Agreed, but beyond the scope of the review. Will be addressed as a need in the synthesis.*

Search Terms and Exclusions

Line 237

For example, tree-nesting murrelets in forested areas obviously have very different breeding habitats than cliff- and burrow-nesting alcids that are generally in coastal or oceanic ecosystems.

But cliff nesting murrelets in forested areas have similar habitats.

ABR response: *Inland forested cliff habitat is potentially quite different from marine cliff habitat, however, we made some adjustments this text.*

Line 240

Further, there probably are differences between murrelets and related species in nest-site fidelity because murrelets tend not to reuse nests regularly (Nelson 1997, Burger et al. 2009), whereas that is the norm for many other species of alcids (e.g., Schreiber and Burger 2002).

This is not true! Birds do reuse trees and nests, and they certainly nest in the same stands year after year. Your information is outdated.

ABR RESPONSE: *We removed this statement.*

Line 243

Lastly, one would expect to see differences in flight behaviors near nests between Marbled Murrelets and other alcids because Marbled Murrelets nest solitarily (vs. dense colonies), generally in trees (vs. treeless areas), and in inland areas (vs. marine islands and cliffs).

Not true. Yes there are fewer murrelets in a stand than alcids at a dense colony, but murrelets circle, call, chase, play just like other alcids do at their colonies.

ABR RESPONSE: *Sentence modified and elaborated.*

Line 246

Thus, for the purpose of this review, we limit searches to studies pertaining to Marbled Murrelets.

This is fine, but please don't use the excuses stated above as they are not accurate.

ABR RESPONSE: *We modified this paragraph extensively and acknowledge a role for considering characteristics of other related species but defend our decision to focus only on Marbled Murrelets for this review of evidence. We contend that it is problematic to use data from other species as evidence for Marbled Murrelets as such an approach could, for example, suggest a conclusion that Marbled Murrelets don't nest in trees or fly inland to nests, among other differences we know to be true.*

Study Inclusion Criteria

Line 289

We will not include undocumented data (e.g., personal communications), sources of raw data, or documents with insufficient information on methodology to allow assessment of the quality or relevance of the study (e.g., presentation abstracts, newsletters).

Then you will have lots of statements saying you do not have enough information to address the questions listed above. Much data is still unpublished or in reports (not necessarily government).

ABR RESPONSE: *Agreed and will be clearly stated in the synthesis. We are including unpublished reports, however.*

Glossary

Line 529

Occupied behavior: a term used in the inland survey protocol (Evans Mack et al. 2003) to describe the following behaviors believed to indicate that the site either has or may have some importance for breeding: subcanopy flights and dives, low circling or arcing, landings, subcanopy wing-beat sounds, stationary calling, and the "jet sounds" associated with diving birds.

Don't forget behaviors associated with breeding like nest searching, searching for mates, etc. Although these behaviors may fit into the categories listed you can't forget that birds use the forest for things other than nesting.

ABR RESPONSE: *We feel that this is a separate question. As stated above, we are focusing here on measureable evidence of breeding, namely nests. It is certainly valid to consider and address the value of habitat for other aspects of breeding behavior, but here we are examining a direct association between behavior and breeding.*

Appendix 3.3. External comments and responses to these comments on draft report of Marbled Murrelet review

This section documents comments from external reviewers (i.e., stakeholders and others with interest in Marbled Murrelet policy), whose input on the draft report of the Marbled Murrelet review was solicited and received during the period, April 16 – June 11, 2015. Reviewers requested and were notified and granted two extensions from the original May 15 due date for receipt of comments.

From Kim Nelson, Oregon State University, Received June 11, 2015:

NOTE: *We address here the general comments made by the reviewer. Unless indicated below, specific comments that were provided in the draft report text were corrected or modified as suggested. Original document text is in regular serif font; reviewer's comments are provided in sans serif font, with general comments followed by those pertaining to specific sections. Reviewer's comments are followed (in italics) by responses provided by the ABR review team.*

Overview

I did not have near enough time to review this huge document. The time allotted for review was totally inadequate. This concerns me greatly given all the errors and misinterpretations I found in the parts that I did have time to review. Every author should have the opportunity to provide corrections to the information you summarized....otherwise the systematic review is not a valid document.

We provided stakeholders with 8 weeks (including extensions) for review of the report. We regret that this was considered insufficient and recognize (and appreciate) the efforts and temporal limitations of voluntary reviewers. Requesting interpretive input from authors on studies included in the review would appear to invite bias in and limit repeatability of the review process; however, it is a suggestion that warrants further consideration, particularly for future metaanalyses of results.

I was surprised by the bias in some of the summaries. For example, in the best written part, the general review is excellent but then the conclusions are totally biased and do not represent what was stated earlier in text. I was also surprised by the errors in interpretations of my research. For example, the supposed "non-nest sites" were actually occupied and nesting sites with birds circling over habitat and non-habitat.

We have attempted to identify sections of the draft report that contained language construed by reviewers (or ourselves) as biased and to delete or revise accordingly. We agree that, on further consideration of all papers included for Question 1, two papers that were initially considered to include information on flight behaviors at non-nest sites did not meet our criteria for excluding the possibility of nesting at the site, and were therefore omitted from our review.

Two things would have greatly improved this report. One would have been to contact the authors to make sure you were interpreting results accurately. The other would have been to analyze existing data on all of these questions that may not be in reports/papers. There are extensive databases in each state that would have given you tons of data on behaviors in occupied sites, co-occurrence, and habitat characteristics associated with nests and nest sites.

See comment above regarding author interpretations. We agree that there exist substantial unpublished data that warrant further analysis to better address the questions included in this review, and we have attempted to address this issue in our sections on data gaps and/or conclusions; however, such novel analyses are beyond the scope of the review process.

All that being said, you and others at ABR have done an amazing amount of work. Impressive! But the many errors need to be corrected and the biases removed. In addition, remove all the biased qualifiers like "coarse", "crude", "just", etc. These are not needed to make your points and really detract from the professionalism of the document.

We appreciate the comments and suggestions.

Methods

Inclusion of the alcid literature would have been the right thing to do.

What about other Brachyramphus murrelets, KIMU and LBMU? They behave similarly to MAMU. Please revise to be accurate. MAMU are not unique among alcids….there are three species that act similarly, although habitat use of these three species differs in some areas.

We have previously addressed our decision to exclude data on other alcids in this review. We contend that the unique breeding habits of marbled (and long-billed) murrelets warrant separate consideration, although we acknowledge that, in the absence of species-specific information, that of other alcid species (and Kittlitz's murrelets in particular) represent the best available data. We support this decision with the simplistic analogy that, in the absence of known nesting habits, inference from other alcid species would indicate that Marbled Murrelets do not nest in trees.

Confidence Rating Factors:

- Study methods: Were the study methods (e.g., audiovisual, radar, telemetry) appropriate for the question of interest? (Scoring: 0 = no; 1 = unknown; 4 = yes).

This needs to be made objective not subjective.

We agree that this is a somewhat subjective, but necessary factor. We modified from an earlier version ("Were the BEST study methods used?") to attempt to reduce subjectivity. We would have welcomed earlier suggestions for alternative versions.

Results and Discussion

<u>Question 1</u>

Use of Nelson data for this (behaviors at non-nest sites) was totally inappropriate given they were one year studies, only a few trees were climbed, and subsequent to the studies cited, these sites were found to be occupied (with more in-depth research and more than one year of work).

See notes above. We omitted these studies after further review of application of our inclusion criteria.

<u>Question 2</u>

Site Fidelity

This section is extremely confusing. You only talk about 2 birds with fidelity to the watershed and stand scales and yet there are tons of data showing fidelity to stands and watersheds year after year. Perhaps you meant to have a NEST section and a DETECTION section…..this would make this discussion much more clear.

All of our results pertain only to nests. This section is an introduction to the subsequent sections in which fidelity is considered at different spatial scales: watersheds containing nests, stands containing nests, etc…

Barbaree et al. had a bird return to the same cup on the same cliff.

We have a picture of the cliff where the bird nested in 2 different years….same cliff, same cup. This statement is only true with the tree nests that we could not hike in to.

We have modified some references to this study accordingly but note that the authors specifically state "Renesting attempts occurred in the same location and nest site type as the first nesting attempts; however, reuse of the same nest bowl, limb, or tree could not be determined because the nest sites were inaccessible." There is no information on birds returning to cliff nests included in the paper we reviewed. As a result, we do not include it in our analysis.

<u>Question 3</u>

… indirect evidence of nesting (e.g., radar surveys, audio-visual detections of "occupied" behaviors) was not included for this critical review , …

This indicated co-occurrence and should have been evaluated in detail.

We have stressed throughout our review our rationale for focusing solely on known nesting to address these questions; while acknowledging that occupancy may indicate more than just active nesting at sites. This broader perspective is worth further consideration but falls outside the scope of this review.

Spatial scales (i.e., watershed, forest stand) often were not explicitly stated in studies; therefore, when appropriate, we conservatively inferred them from mapped locations.

So you looked at data for this question but not elsewhere?

We based our identification of scales of co-occurrence on mapped locations provided in study figures. In one instance, Kuletz et al. 1995, we looked at GoogleEarth to verify inter-nest distances and in doing so noticed that three nests within 1 km of each other fell in what was clearly an unfragmented block of habitat. However, use of GoogleEarth or other outside sources falls outside the scope of this review and was therefore was not repeated for all studies.

Furthermore, nests located could not always be differentiated into those that were active concurrently (evidence of co-occurrence) and those that were active during different years or periods within a year (evidence of re-nesting or re-use).

Why would this matter? This is still co-occurrence of birds in a stand or area. This makes no sense biologically to put this under a different definition. The question is spatial not temporal. The definition says active in the same breeding season, not at the exact same time.

We disagree and believe there are strong biological and management bases for distinguishing temporal and spatial aspects of multiple nesting within an area. Co-occurrence addresses population-level issues and the need for land managers to assess the probability of undetected additional nests to exist within a given spatial scale. Reuse provides information on how the spatial distribution of nests within an area can shift over time. We agree that operationally defining co-occurrence by the presence of active nests within the same season rather than strictly concurrent lends to the possibility of overestimating the number of pairs present by including renesting individuals. Where there was a clear likelihood (as determined by the authors) that multiple nests represented renesting, we excluded these from consideration as co-occurrence but have also acknowledged in this paragraph that frequencies of co-occurrence reported here may be inflated by inclusion of renesting.

Question 4

Platform Density

Two studies (Manley 2003, Silvergieter and Lank 2011a) included data on the same nest trees, following different methods for counting platforms (tree-climbing and ground-based counts, respectively); while one study (Burger et al. 2000) reported comparative results using each of the two methods.

Nelson and Wilson and Hamer and Meekins did this too.

Nelson and Wilson (2002) and Meekins and Hamer (1999) included/compared platform counts from climbing and ground-based observations for platform trees within plots containing murrelet nest trees, not just for the nest trees themselves, as was the case for the studies mentioned here.

Data Gaps

Furthermore, while there has been increasing standardization of terminology associated with nesting platforms, historical differences and some continuing variability create limitations to useful meta-analyses across and within regions.

How do you know? You did not even try to do this. If you had looked at the available databases you could have done some nice analyses.

We agree that further analyses of existing data are possible and would be useful; however novel analyses of raw data lie beyond the scope of a review. It is strictly a meta-analysis of the results of other studies that we address here.

Question 5

Conclusions and Data Gaps

Raphael (2002) and Zharikov et al. (2007) found little evidence for increased nest predation rates at real or artificial Marbled Murrelet associated with the overall degree of landscape fragmentation, although some individual habitat features associated with fragmentation were shown to correlate with predator abundance and predation.

This is just not true. They did find edge and fragmentation effects related to distance to edge, distance to human habitation, distance to berry bushes, etc.

Quote from Zharikov et al: "Marbled Murrelets nested more successfully in landscapes with lower edge contrast and a lower proportion of landscape under young forest…"

Quote from Raphael et al: "Marbled Murrelet nests appear particularly vulnerable to human-induced edges."

We reworded this sentence but also note the first sentence of the Results section in Raphael et al. 2002: "From our experiments, rates of predation in continuous stands did not differ from rates in fragmented stands." And from Zharikov et al. 2007, "Our results suggest that habitat fragmentation per se need not have a negative effect on the birds beyond that as a result of habitat loss, unless associated with an increased abundance of predators." Our emphasis here is to reflect the conclusions of the authors that even without clear associations between general fragmentation measures and nest success, there are specific characteristics of fragmented habitat that have been demonstrated to be negatively correlated with nest success.

Tables

General comment on tables containing evaluation scores:

Reviewer suggested addition of the following text to all table headers:

"Lower scores indicated descriptive studies, small sample sizes, etc."

We feel it is unnecessary to explain the rationale for lower scores within each table as we have addressed the range and average value of scores and any patterns for these scores within each associated section of the text.

Table 4 & Table A6.2.20

Regarding Nelson & Wilson (2002): Footnote in Table 28 states that 2 old nests (nest-sites) were found in the same tree during climber training. This is the only clear reference to reuse of nest-trees anywhere in this report.

Not so. We found trees with multiple nests indicating reuse.

We re-examined the paper and again failed to find any reference to additional trees with multiple nests. As a result, we can only state that one or more trees contained evidence of fidelity.

From Steven P. Courtney and Leigh Anne Starcevich, Western Ecosystems Technology (Support provided by the American Forest Resource Council and the Oregon Forest Industries Council), Received June 11, 2015:

Review of:

Systematic review of Marbled Murrelet research related to nesting habitat use and nest success

by

Plissner JH, Cooper BA, Day RH, Sanzenbacher PM, Burger AE, and Raphael MG

Prepared by

Steven P. Courtney PhD and Leigh Anne Starcevich PhD,

Western Ecosystems Technology

Contents: 2

Introduction

The following is our review of the analytical methodology, and the resulting analysis of the Draft Report Systematic Review of Marbled Murrelet Research Related to Nesting Habitat Use and Nest Success (the draft "SER").

The first section of our review highlights the challenges of using a systematic evidence review in data-poor environments such as the science surrounding the biology of the marbled murrelet.

Next we show that the questions are framed in a manner that fails to address in a meaningful way the policy decisions underpinning the Marbled Murrelet Inland Survey Protocol (the "ISP"). This may have been difficult to foresee when originally crafting the questions. While the answers may still be useful, we would strongly caution against using the SER as direct evidence supporting any particular component of the ISP. Rather, the SER answers very narrow questions and deliberately excludes certain information that may be meaningful to regulators.

The next section provides feedback on each individual question in the SER, with a focus on how the answers could be improved to inform the applicability and policy rationale for the ISP (or lack thereof).

Finally, we provide a critical review of the ISP itself and lay out the policy calls inherent in the survey methodology. We understand that these issues are currently under consideration by the Pacific Seabird Group ("PSG") Marbled Murrelet Technical Committee ("MMTC"), but we intend to highlight these issues in this document for further work by the Oregon Department of Forestry and ABR.

It is worth noting that your email dated April 15, 2015, solicited comments in these terms: "*We do not consider these questions to be exhaustive and do not suggest specific implications of the review for related issues with the ISP or management practices. Our goal was to assess objectively the current state of knowledge for specific topics that can help inform decisions.*" While we appreciate the intended limited scope of your work, in developing our review we struggled to divorce our critique of your analysis from our commentary on the analytical methodology and its utility in informing policy. We considered drafting two separate documents, one focused on the specific answers developed by this SER, and another highlighting the narrow scope of this work and its limited utility in the policy arena. However, ODF has represented that it intends to use this work to inform its continued use of the ISP. In that light, we believe now is the appropriate time to address not only the SER questions, but also the underlying reasons that they are being asked

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Systematic Evidence Reviews

A Systematic Evidence Review (SER) is a widespread and popular technique used in evidence-based approaches in several fields, particularly health care. Table 1 sets out the steps used in SERs. At its best, an SER provides managers and decision-makers with a dispassionate and rigorous analysis of the quality of available data, and the strength of conclusions that can be drawn from them. The technique works best when the literature to be reviewed is large, and data rich, when the quality of data and experimental design are fundamental to evaluating available evidence. Evidence-based approaches using SERs are increasingly used in a wider scope, with applications in economics, overseas development etc. The approach has been less widely adopted in the larger scientific community, with relatively few applications in ecology and resource management. The British-based Center for Evidence-Based Conservation has advocated the technique and has set out a few examples. Broadly speaking, the technique again works best when there is substantive quantitative information applied to broad questions. However the approach is still largely untested in narrow, data-poor situations.

Discussions of evidence-based approaches in environmental issues are provided by Pettorelli (2014) and references therein. SERs are advocated by the Center for Evidence-Based Conservation (website at http://www.cebc.bangor.ac.uk/index.php.en?menu=0&catid=0). Achterman (2011) has advocated for their use in Oregon forests (http://www.environmentalevaluators.net/wp-content/uploads/2011/01/Applying-Systematic-Evidence-Reviews-in-Ecology-Challenges-and-Opportunities.pdf), and succinctly summarized the challenges to using them, and also provided suggested guidelines. Significantly, the SER carried out by Plissner et al steps outside some of these guidelines.

Process and analysis of Plissner et al.

Plissner at al. have generally followed the steps laid out for a data-rich field. Table 1 (an expanded and more explanatory version of the information shown in Table 1 of Plissner et al) shows the steps used in medical applications of SERs. To a large extent Plissner et al. follow these prescriptions. They in particular have applied rigorous criteria for inclusion (or rather exclusion) of the literature to be reviewed. As discussed below (section on Marbled Murrelet data) this is (at first blush) an entirely reasonable approach. By eliminating from discussion many papers that are data poor and essentially natural historical, Plissner et al. have attempted to move the discussion of murrelet conservation away from speculation and advocacy toward a stronger quantitative base. Plissner et al have clearly absorbed the lessons learned in other evidence-based efforts. They have strict protocols for how to 'score' papers, and how to use such scores to weigh evidence. They have also emphasized transparency and a clear record of how evaluations were made and conclusions reached. All these steps follow established procedure for data-rich, broad analyses.

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Marbled Murrelets and data quality

Marbled Murrelets are notoriously difficult to study. The first nest was discovered only in the early 1970s (the last species to be found in North America). The birds primarily use marine habitats, and visit their breeding habitats (mostly forests in the southern part of the range) only to find and use nesting locations. They are cryptically colored, quiet, and fly at high speed at times when they are difficult to see or otherwise detect. As a consequence of all these natural historical quirks, studies on murrelets have for many years been data-poor and exploratory. Nevertheless decision-makers are required to select among management actions. This has resulted in frequent challenges to those choices, and a clear and ongoing need by managers to discriminate between science and advocacy.

Scientists studying murrelets have responded in various ways. Impartially and transparently collected and analyzed data are the strongest basis on which to make conservation decisions, but there are relatively few situations where this is the case for murrelets. While the situation has improved in recent years, it is still the case that many management prescriptions are based upon much earlier work. In such publications, the authors often extrapolated from limited data to provide discussions of (for instance) forest habitat quality. This commentary is not meant as adverse criticism: the standard under law of "best available science" requires that decision-makers use whatever is available, even if that is nothing more than a "scientific opinion" or even the "opinion of a scientist" (Courtney et al 2004). Data poor situations demand that managers use whatever information is available, from whatever source. Likewise, scientists are permitted, ***in their publications***, to speculate and discuss the application of, and limits to, their data. For Marbled Murrelets, the data may be few, but the management needs are large, so the ratio of 'discussion' and natural historical description to data has also been large.

Most notably the Inland Survey Protocol (ISP) has been the subject of extensive discussion for many years. It aims to provide a standardized and replicable approach to delineating forest habitat. Since it was developed by seabird biologists (from the Marbled Murrelet Technical Committee of the Pacific Seabird Group) it has been variously portrayed as based on scientific consensus and the product of seabird conservation advocates. Whatever the truth of such assertions, it remains the working document that guides real-world conservation decision-making. However the ISP has not been subject to formal analysis and adoption by federal regulators. This lack of formal evaluation and adoption is unfortunate in that the ambiguities in the protocol have not been addressed by regulators; the reliance of the ISP upon supposed assertions and arguably weak data is also unresolved. This is all the more problematic in that the ISP has embedded within it policy decisions that are presented instead as science (see final section).

The ODF is to be commended for taking the lead in attempting to resolve ambiguities and uncertainties in the ISP, and to find a rational, science-based way forward to making conservation decisions. The non-confrontational approach of an SER is an attractive option for dealing with situations of arguable bias and uncertain evidence. Unfortunately the particular approach adopted by Plissner et al has resulted in a document that effectively reduces few of the uncertainties regarding the ISP, and instead perpetuates confusion. Some of these problems arise from uncritically applying a technique best suited to data-rich situations to a body of information where there are few hard data. While there are also short-comings in the actual analysis (see below sections; mostly concerning inconsistent and slanted applications of the SER methods to include some and exclude other information) the major source of the confusion is traceable instead to the ISP itself, and to the inherent difficulties of making evidence-based statements about Marbled Murrelets. In such a situation, even a well-executed design for an SER would fail. The overtly quantitative approaches of Plissner et al are inappropriate to data-poor situations.

This is, of course, precisely the approach espoused by the PSG MMTC, where the various technical and policy issues have been debated and laid out in some detail. Unfortunately the work of the MMTC is not formally dissected and analyzed at any point in the SER of Plissner et al. Neither is the extensive analysis of survey results carried out by federal scientists and others in support of the MMTC. While this may seem appropriate under the rubric of a publication-based quantitative-skewed SER, it means that there is little context to understand and then criticize the existing ITP. It may also have been the intent with this SER to avoid confrontation with past authors and established opinion. If so, this has robbed the SER of appropriate context and much valuable information.

Natural history and logic have some roles in conservation, and need to be acknowledged, particularly when data are sparse. Even single observations can be important. The ISP (and the SER) for instance reference two situations where Marbled Murrelets were seen to fly below canopy, but where the animals were reasonably judged to be breeding elsewhere. These simple observations establish beyond any further need of analysis, that not all 'below canopy' behaviors indicate nesting in the immediate vicinity.

Similarly logic must be applied to data. For instance Marbled Murrelets are known to breed in some areas at least of the Tillamook State Forest, despite the catastrophic fires that burned there. Given such an observation to hold either: 1. Marbled Murrelets have persisted for decades in small remnant stands, or 2. They have re-colonized the area as forests have matured and recovered. It is not logical then to assert at one and the same time that murrelets show high site-fidelity (and therefore do not colonize new areas) but also depend critically on large extent stands. These observations are not incorporated into the SER because they are simple and deductive rather than quantitative. This is unfortunate - Logic too has a role.

Disputation and argument may have a role in an effective evaluation of information, but they are probably of limited use in an SER. Unfortunately Plissner et al are inconsistent, and argue for some points of view but not others. For instance at 934 (page 33 of current draft) they state *"Data from Oregon and Washington, where logging is generally extensive and continuity (and perhaps habitat availability is low) also might be expected to have strong fidelity "*. Whether or not we agree with this statement, it is an argument of the authors, not a fact-based, quantitatively justified statement from the literature. It cannot be said to follow the SER protocol as stated.

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Commentary may be appropriate in a fair *evaluation*, but should fall outside the strict guidelines for an SER. At 1822 page 63, the SER states *"Zharikov et al (2006, Study Evaluation Scores:33) found greater nest success in this situation [habitat edges]; however this interpretation of their results has been challenged by Burger and Page (2007).".* In this case the SER authors are using published commentary from one of themselves to argue against acceptance of the quantitative results from one of the most highly ranked studies in the objective evaluation process. This is illogical only if other commentary is excluded (as in fact it is throughout the SER - and indeed on the specific case cited where the original authors' rebuttal is not included). To be consistent with the rest of the document, the commentary by Burger and Page should be removed from the SER, and this whole section revised to reflect the high quality of the Zharikov paper.(Note also that he Burger and Page paper citation is not provided in the references: it is at Landscape Ecology November 2007, Volume 22, Issue 9, pp 1273-1281).

Following these points, the illogic of the application of the SER approach to a data-poor situation is laid bare. The SER should be revised to be rid of all assertions not directly supported by quantitative analysis, unequivocal natural history, math, or logic. In particular the abundant discussions of the MMTC (and its supporting quantitative analysis) could be explicitly incorporated and evaluated.

Critique of the Plissner team approach to SER

Having considered overall scope issues, and the state of Marbled Murrelet science (and hence the approach that is appropriate in an SER), we now consider the actual work carried out by ODF in framing the SER tasks, and by Plissner et al. in responding to these tasks. In this section we focus more on particular technical or administrative issues (albeit still at the level of the entire SER). Our intent is not to be dismissive of the efforts of the SER team. It is rather our goal to help the SER authors improve their responses to the tasks set by ODF. We acknowledge the clear intent of both ODF and the SER team to move to impartial and transparent analysis. In later sections we address smaller-scale critiques of treatment of particular papers or data, and the conclusions Plissner et al. draw from such studies.

Framing of questions

ODF's stated purpose for the SER is "to assess the amount, strength, and relevance of the science related to several central elements of the PSG protocol…" (ln 26-27).

Unfortunately the questions as presented in the SER are somewhat ambiguous in focus. This has led directly to the SER focusing its attention away from the key issues in the PSG protocol, and instead to putting most of the effort into largely unimportant, and in some cases trivial issues. For instance Question 1:

How are individual behaviors (subcanopy flight, circling, landing, vocalizations) of marbled murrelets indicative of nesting in the forest stand where those behaviors occur?

The central element of the PSG protocol to which this question appears to relate is the PSG protocol's specification that a single observation of certain behaviors of a marbled murrelet is sufficiently strong

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evidence for determining that the survey site is being used for nesting by the bird that was observed. Yet, this issue is not directly addressed in the SER.

Next, Question 2 asks:

To what extent do marbled murrelets exhibit nest-site fidelity at various spatial scales (i.e. at the scale of a watershed, forest stand, tree branch, and platform), and how does spatial extent of continuous potential habitat effect nest-site fidelity?

The central element of the PSG protocol to which this question appears to relate is the PSG protocol's specification that a survey site deemed "occupied" under Question 1 be deemed occupied indefinitely due, in large part, to the hypothesis that marbled murrelets exhibit site fidelity. Again, this issue is not directly addressed in the SER.

Finally, Question 3 asks:

How does the spatial extent of continuous potential habitat relate to the co-occurrence (i.e. nesting by multiple pairs) of murrelets in a forest stand and at other spatial scales?

The central element of the PSG protocol to which this question appears to relate is the PSG protocol's specification that the site classification for the survey site be applied, also indefinitely, to the entire survey area containing contiguous suitable nesting habitat. This issue also is not directly addressed in the SER.

To put this in context, with respect to Question 1, what precisely is meant by the term "*indicative*"? In the 11 pages of the SER that deal with this question, nearly the entire analysis and discussion focus on whether the identified behaviors occur at nesting sites (i.e. *indicative* is taken to mean 'provide some evidence for'). Some of this focus borders on the trivial – *do murrelets fly under the canopy and land in trees in nesting habitat*? – particularly when almost no attention is paid to the analysis of the key issue regarding the ISP: do these same behaviors occur at sites not used for nesting? In this alternate case *indicative* could instead be appropriately interpreted instead as "provide unambiguous evidence for." In the context of the discussion below, it is critical whether we interpret *indicative* as pertaining to the obtaining of a true positive, or mostly of avoiding a false positive. This is not a pedantic issue—it leads directly to the allocation of effort within the SER.

Two paragraphs (at pages 18-19, and page 26) comprise almost the entire discussion of the issue of false positives within the SER's consideration of the ISP. While we accept that this small level of analysis may in part reflect the disinterest of murrelet researchers in addressing this issue, it nevertheless is the single most important issue that should be the subject of the SER. Yet almost no attention is paid to it, as a result of the language in the framing questions, and the interpretations put on this language.

Similar ambiguities occur in subsequent questions in the analysis (e.g. how does the spatial extent of continuous potential habitat 'relate to' the co-occurrence . . . of murrelets). In every single case this ambiguity has led to a focus in the SER on an affirmative approach ("provides some evidence for") as opposed to a carefully balanced critical approach ("is the evidence unequivocal?").

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The central element of the PSG protocol to which this question appears to relate is the PSG protocol's specification that the site classification for the survey site be applied, also indefinitely, to the entire survey area containing contiguous suitable nesting habitat. This issue also is not directly addressed in the SER.

To put this in context, with respect to Question 1, what precisely is meant by the term "*indicative*"? In the 11 pages of the SER that deal with this question, nearly the entire analysis and discussion focus on whether the identified behaviors occur at nesting sites (i.e. *indicative* is taken to mean 'provide some evidence for'). Some of this focus borders on the trivial – *do murrelets fly under the canopy and land in trees in nesting habitat*? – particularly when almost no attention is paid to the analysis of the key issue regarding the ISP: do these same behaviors occur at sites not used for nesting? In this alternate case *indicative* could instead be appropriately interpreted instead as "provide unambiguous evidence for." In the context of the discussion below, it is critical whether we interpret *indicative* as pertaining to the obtaining of a true positive, or mostly of avoiding a false positive. This is not a pedantic issue—it leads directly to the allocation of effort within the SER.

Two paragraphs (at pages 18-19, and page 26) comprise almost the entire discussion of the issue of false positives within the SER's consideration of the ISP. While we accept that this small level of analysis may in part reflect the disinterest of murrelet researchers in addressing this issue, it nevertheless is the single most important issue that should be the subject of the SER. Yet almost no attention is paid to it, as a result of the language in the framing questions, and the interpretations put on this language.

Similar ambiguities occur in subsequent questions in the analysis (e.g. how does the spatial extent of continuous potential habitat 'relate to' the co-occurrence . . . of murrelets). In every single case this ambiguity has led to a focus in the SER on an affirmative approach ("provides some evidence for") as opposed to a carefully balanced critical approach ("is the evidence unequivocal?").

8

Going forward, we recommend that the SER team explain how this approach came to dominate the review effort. The SER may have expended effort on, and focused on, unimportant issues to the detriment of the key areas. Should additional effort and renewed analysis be sought by ODF, the final section of our critique provides some input on undertaking a systematic review of the actual central elements of the PSG protocol.

Guidelines for SER

Achterman (2011) provided a strong presentation on the use of SER approaches in environmental evaluations, with particular reference to Oregon forests. She suggested that three approaches were viable:

1. In-house assessments (with a protocol) that carefully documents how a review is conducted, and assessments were reached

2. Commission an SER by an external, independent academic entity, which incorporates all relevant evidence.

3. Participate in an Inter-Agency SER which uses technical experts from many agencies.

Crucial to each of these options is a focus on providing an assessment that is transparent, rigorous and seen to be impartial. This is particularly important for policy relevant questions, or contentious issues, where Achterman argues for selecting option 2.

Essentially the same position is advanced by federal agencies and Congress, who recognize the importance of independent scientific analysis for environmental controversies. The Water Resources Development Act, for instance, mandates that the US Army Corps of Engineers seek independent review from entities that are either "academic, or non-profit scientific institutions."

By contrast, the SER was carried out by consultants with direct murrelet experience and clear conflicts of interest. Large portions of the SER are evaluations by the authors of their own work. By any standard for conflicts of interest (as for instance the process guidance documents for reviews drafted by the National Academies), this results in an SER that is open to accusations of partiality. Note that we are not accusing the SER team of systemic bias. Moreover we believe and acknowledge that any team selected under the RFP process (including ourselves) would have had the same conflicts. Nevertheless it does result in an SER that cannot be described as truly independent, and for which any challenge to the results (as being drafted under conflicts of interest) might reasonably be expected to succeed.

Under these difficult circumstances, how should the SER team proceed? We believe that potential conflicts of interest must be explicitly addressed at each and every instance throughout the document. A simple blanket statement of good intent will not suffice. We also suggest that the SER team seek a further round of review that considers just this concern alone, including subtle and passive impacts (by for instance omitting some papers, downplaying or emphasizing the results of others). Only external review (which addresses such impacts) can help (to an extent) insulate the authors. In particular the SER

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Use of Information

Natural History

Use of unequivocal natural historical observations could be appropriate when the pool of information is as data-poor as is that for Marbled Murrelets.. For instance, even a single observation of multiple active nests in one tree is sufficient to establish that murrelets can breed in very close proximity to each other. Similarly a single observation of birds flying through a canopy but then continuing on elsewhere establishes unequivocally that not all "occupied behaviors" are *sufficient* to establish nesting on-site (c.f. the distinction between *sufficient* and *necessary*). However incorporation of anecdote into an SER is generally problematical – and SER is specifically intended to be used in data-rich situations which will allow for impartial assessments that avoid argumentation and anecdote. If natural history is to be included in the SER it should be non-controversial and unequivocal

Where the SER systematically fails is in deciding which natural history to include. Broadly speaking, only anecdotes and arguments that are part of papers that pass the screen set by the SER are included. Observations and commentaries that are found in less highly scored papers (or those adjudged "tangential") are excluded. Yet those pieces of information are no less reliable than commentary, observations or assertions that happen to be attached to data-rich studies on other things. The screening process used by the SER team is inherently variable, and exclusive of the full range of opinion.

Use of statistical approaches and language

The SER does not clearly summarize how the paucity of statistically-rigorous research on MAMU population characteristics relates to the PSG MAMU protocol. Much of the MAMU research reported in the SER is qualitative or based on anecdotal observations. The reviewers note that descriptive studies were included to "help quantify the relevance/confidence of those types of studies," but extrapolating quantitative inference from qualitative research is tenuous at best. The original RFP charged the reviewers to "assess the amount, strength, and relevance of the science related to several central elements of the PSG protocol," but this link is not explicitly made.

A particular concern is the assumption by the reviewers that hypothesis test power is adequate if significant p-values are reported. This assumption confuses statistical significance with statistical power. A hypothesis test can indicate statistical significance due to overestimation of the test statistic and/or underestimation of its standard error. These biases unduly inflate statistical power due to larger-than-nominal test size, falsely indicating a significant effect. In short, this is a poor assumption.

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Lack of conclusions and synthesis

Perhaps the greatest disappointment we find with the SER is that there is no overall assessment of the strength of the scientific evidence on which the ISP is based. While there is extensive discussion of the merits of individual studies, and some evaluation of the overall "state of play" on a particular issue (and quite extensive discussion of the need for more research) there is no overall assessment of the strength of support for the PSG protocol.

We believe that this is a crucial omission that should be addressed. This will require that the authors of the SER confront a difficult situation head-on: most of the underpinnings of the ISP were not well-supported by evidence at the time the protocol was first designed. Despite ongoing efforts to address some of these concerns at MMTC meetings, the scientific support is still largely weak. To take just one (perhaps the most crucial) example, there has been no systematic attempt to determine whether Marbled Murrelets show "occupied behaviors" over potential but unoccupied habitat. That this issue has not been addressed after more than 30 years of use of the protocol is scarcely credible. The SER authors should not skirt this issue, but should clearly state that the PSG protocol is based on science that is at best incomplete. We believe that the SER must also address the conflation of science with policy-making that is found throughout the PSG protocol. Failure to address this issue means that the SER has not addressed the core issues implicit in the questions posed by ODF.

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<u>Commentary on questions and the SER treatment of them</u>

We now focus our attention on the individual questions analyzed by the SER team. Again our intent is to help subsequent drafts of this review effort to be as effective as possible.

Question 1. How are individual behaviors (subcanopy flight, circling, landing, vocalizations) of marbled murrelets indicative of nesting in the forest stand where those behaviors occur?

As we have discussed above, this is a key question, whose primary focus should be on the effectiveness of the PSG protocol at accurately identifying habitat.

At 465: "A site was considered to have a likely absence of nests if all potential nest trees were searched and no nests were found in the site, or if the habitat was deemed unsuitable for nesting and not closely adjacent to potential nesting habitat". This statement needs clarifying – should it include the word "only'" (as in "A site was only considered . . .")? If so, what is the effect of this step – how many studies were excluded or were moved from one column of the analysis to another by virtue of this decision?

At 469: "Studies in which nesting suitability of habitat where behaviors were detected was unclear were omitted". This is potentially a major concern. Who made the evaluation of whether the habitat suitability was unclear – the original authors, or the SER team? On what basis is the issue deemed unclear? How many such studies are there? If they were to be included and assigned to the category of 'no evidence for nesting', would this show that there are many such cases where there is no supportive evidence justifying occupied status? Intentional or unintentional, filters as these can have the effect of skewing analyses in one direction. If the real intent of the SER question 1 is to assess the potential for false positives in the protocol (as we believe was intended by ODF) then this paragraph suggests that there are relevant studies being excluded and that the overall analysis is under-emphasizing the lack of support for the PSG protocol.

At 513 et seq. This paragraph addresses the single main focus of the SER. Unfortunately it is opaque at several points, and conflates different points in the discussion. It also fails to address some biases in studies- such biases are entirely appropriate subjects for assessment in an SER. This whole paragraph should be revised to be clear and to present information in language that is not loaded.

The analysis discusses two studies where behavior was observed at locations unsuitable for nesting (e.g. talus slopes, clear-cuts) and one study where behavior was observed at an unoccupied forest stand. It is entirely inappropriate to conflate these two sorts of studies. Again, we refer to the importance of focusing on the false positive issue, and the PSG protocol. If we fail to observe murrelet 'occupied' behavior over parking lots what does this prove? Essentially this provides no information, other than that 'occupied' behaviors does not occur in unambiguously unsuitable areas. However if we do observe such behaviors in potentially suitable habitat which are shown to be unoccupied, this is unambiguous and clear evidence for false positives. The relevant data set here are all observations that can be reasonably assessed to fit in this category. Many anecdotal observations (including some in the PSG protocol itself) are relevant and should be collated here. We emphasize that the relevant issue is not whether occupied behaviors occur in non-habitat; it is whether occupied behaviors that are observed in potential forest areas (those that are subject to survey under the PSG protocol) have substantiated associative evidence for nesting.

Conflating studies of different composition (non-habitat conflated unoccupied habitat) also has the effect of inappropriate analyses. The absence of jet-dives and vocalizations in assuredly unsuitable habitat is meaningless. A similar absence from unoccupied but apparently suitable habitat has value. However the SER, by conflating the two sorts of area overstates the evidence associating jet-dives and vocalizations with nesting. In this case, n=1, not 3, as implied by this paragraph.

This section also fails to address a systemic bias in the data that have been collected. This stems from the entirely reasonable approach of murrelet researchers in focusing their attention on areas with murrelets. It is probable moreover that such researchers focus their work in areas with lots of murrelets who are then especially interactive (e.g. become vocal and territorial). This bias will result in both an under-representation of areas with no murrelets, and an over-estimate of the prevalence of occupied behaviors at occupied sites across the landscape.

At 516, the SER states 'climbers were unable to locate evidence of nesting'. The clear intent here is to imply that the site may in fact have been used by murrelets for nesting, but the authors were simply unable to find the nests. This would then 'explain away' the fact that occupied behaviors were observed. This language should be replaced with more accurate and unloaded language – the discussion in Table 2 is accurate "subcanopy flights and > 4 landings observed in area where no nests were found".

This section should also address scale and proximity issues. The studies reported in Table 2 show a pattern of occupied behaviors at and near nest-sites. This is unsurprising and hardly controversial. The SER does not however report on whether the study authors reported occupied behaviors only at or in the immediate proximity of known nests, or whether they occur in a wider area around nests. Such information is highly relevant to issues of contiguity, as well as whether all occupied behaviors indicate nesting at the exact location where they are observed.

A major problem with this entire section is the absence of any formal discussion of known behavior patterns that could reasonably be expected to result in "occupied behaviors" in the absence of actual nesting. Chief among such behavior patterns is prospecting. This behavior occurs in all alcids. In Marbled Murrelets, birds are frequently seen in forest stands outside the nesting season. Naslund (1993) has studied this phenomenon, and provides discussion of examples throughout the range of the species (these are personal communications, but again: these natural historical observations are clear and valuable, and should not be excluded just because they are anecdotal).

By definition, prospecting is thought to include cases where a bird might examine, at close range, potential nest-sites. This then could easily lead to individuals landing in trees which are then rejected as unsuitable. Is such a location nesting habitat? Clearly not, but it could be classified that way, absent tree-climbing efforts. These issues are not even considered in the SER. It may be that there is very little evidence regarding prospecting. If so, that should be stated; in which case, prospecting should remain as a viable explanation for any "occupied behavior" observation.

The SER must include a full discussion of all behavior patterns that might cause individual behaviors (circling, vocalization etc.) classified as 'occupied behaviors'. The lack of such a discussion is a major omission from the SER, and biases it in favor of associating occupied behavior with actual nesting.

At 716, p25. How precisely would anyone conclusively associate a relationship with future nesting? Or rule out nesting at a location in the future? This and other references to the future should be removed. Other speculative statements e.g. at 739-741 about unknowable past or future conditions should be removed.

Question 2. **To what extent do marbled murrelets exhibit nest-site fidelity at various spatial scales (i.e. at the scale of a watershed, forest stand, tree branch, and platform), and how does spatial extent of continuous potential habitat effect nest-site fidelity?**

This section is based on a wider and ill-defined or justified use of the term 'fidelity' than is typical in the literature. We recommend re-writing to clarify just where it implies individual behavior.

In intent, this section of the SER (as also question 3) is intended to address the issue of contiguity. This is one of the most difficult aspects of the PSG ISP to apply, in that it is unclear why occupancy in one area should also apply to increasingly distant areas. This is in effect an extension of survey results in one location to other locations. Clearly data that are collected can only be held to provide direct evidence to the exact areas they were collected. It may or may not be justified to extrapolate results to similar results elsewhere, from a management or conservation point of view – however that is a policy call, which should be made with a full understanding of what evidence is available that supports such an extrapolation. Unfortunately the SER does not provide a direct answer to this question. Moreover, it is likely that the evidence for or against spatial extrapolation will vary with circumstance (habitat breaks, topography, being just two simple and uncontested examples). This section of the SER needs to provide an impartial and unambiguous review of this evidence.

At 928, p33. "The large number of trees climbed (1,628) and the large number of nest-trees found (143) provide strong support for this hypothesis of the effect of habitat continuity on fidelity". This statement (regarding a paper by one of the SER's own authors) is extremely misleading. It implies that the sample size for testing the hypothesis is large (presumably 143, or 1628). However the sample size for the study is 1 (one study site) and it does not in any way test the hypothesis. It is in effect an anecdotal observation that in one site, there were many nests. It does not in any way address differences in habitat continuity on fidelity.

At 934. p33. This sentence is entirely speculative and does not concern any data at all. Why is it included in a literature review? It appears to have been inserted in the hope of influencing forest management in Oregon.

At 949. p.34. Again, in the interests of including all relevant studies, why was there no attempt to document (through an email or letter) what was known about each site?

At 987, p 35. 'Several of the authors…admitted'. This language implies an interaction or discussion with the authors of the SER. Is this the case? If not, use more neutral language (e.g. the authors stated).

At 1025, p 36. We argue above that clear evidence from the Tillamook shows either persistence in small fragments of residual trees, or low fidelity. This observation is known to ODF, and should be referenced here. The SER's statement at 1025 is correct only if there is complete destruction of all nesting habitat. It may be that murrelets are able to survive over a period of decades in remnant trees.

At 887, p 31. The SER unashamedly quotes from one of the authors' own papers, reference to an unpublished study. This violates all the selection criteria used elsewhere in the SER. We actually believe that this sort of use of information is allowable in any review that aims to be comprehensive, complete and rational. However the authors of the SER should be willing to use other such quotes, not just their own.

At 906, p 32. Discussion of Hebert et al. One bird was 'suspected' of nesting. How does this study merit inclusion in the SER, given the lack of any information at all, when other more concrete anecdotal observations are excluded?

Question 3 **How does the spatial extent of continuous potential habitat relate to the co-occurrence (i.e. nesting by multiple pairs) of murrelets in a forest stand and at other spatial scales?**

The key issues for question 2, on contiguity, also apply here.

At 1361, p 48. The clustering of nests in the study by Waterhouse et al is strong evidence for micro-habitat factors at play (unless there is a level of sociality not previously thought likely). The SER authors contrast this with the Desolation Sound study, and imply that this somehow negates the result of the other study. It does not. The comparison is between apples and oranges. The Desolation Sound area is surrounded by abundant habitat (including talus slopes in this area) but marine feeding areas are clustered. The central coast study provides evidence of an effect (microhabitat); the Desolation Sound study shows no evidence for an absence of effect – the conclusions are not symmetrical and opposite.

At 1453. The SER claims 'strong' evidence that nests co-occur (in fact one example would suffice to make that statement), but no evidence on the 'likelihood of co-occurrence'. Given this statement, what is the actual published support for the PSG ISP extrapolation of survey results from one area to another? If there is no published paper on this subject, then the SER authors need to state so unequivocally, and they should attempt to avoid making bold but unsupported assessments on such a policy-relevant issue.

Question 4. How is the occurrence of Marbled murrelet nest sites related to the number and size of potential nest platforms and platform-tree density within stands of different age classes (young, mature and old growth)?

In that the SER authors essentially find that there is too much variation between sites and geographic areas to draw wide-ranging conclusions, we agree with the SER and have no substantive critiques of the document at this point.

Question 5. How is Marbled Murrelet nesting success affected by habitat characteristics?

This section needs to more fully explain the difference between studies of murrelet nests and artificial nests, and the strengths and weaknesses of each approach (e.g. statistical design is possible for artificial nests, but they are not protected by incubating or feeding adults, so actual rates cannot be presented as realistic).

At 1822, p. 63. See above comments on the inappropriate insertion of personal opinion

At 1912 et seq, p67. "the type of edge bordering the nest stand appears to be important". This is a clear over-statement regarding an issue where we have extremely few data. It is a reasonable hypothesis, with some evidence (from artificial nests) in support – nothing more.

Additional comments on methods

At 291, p.11. The SER excludes undocumented data, personal communications, raw data, and documents with poor documentation of methodology. While this is perhaps appropriate in a SER where there is an abundance of quantitative peer-reviewed literature, , in this case it may have removed some useful information from consideration. As stated above, even single observations can be valuable if they show that murrelets exhibit "occupied behavior" away from nest-sites. The excluded data, pers.obs., etc., should be collated and set out so that an independent person can determine whether the SER team has excluded important observations.

At 324, p.326. The SER excluded studies where nesting was known to occur, if the data on nesting and behavior were not published in the exact same papers. Given the overall paucity of information on murrelets, it seems extraordinary to exclude any paper at all that has relevant information, not least for such an arbitrary reason. Indeed, if the goal of the SER was to be comprehensive, there should be a concerted effort to include as many papers as possible; clarifying emails to authors for instance would have been a perfectly transparent way to obtain and document missing pieces of information, so that more data were included.

At 339, p.12. Have the authors of the SER calculated statistical power of the papers reviewed? If not, remove this language which implies that they have used more sophisticated assessments than is the case.

At 372, 375, p.14. Again, have the authors carried out any formal analysis of the statistics used? If not, all this language should be revised to reflect a qualitative assessment of the paper's quantitative merits. It is highly recommended that this section be reviewed again (following any revision) by someone with a statistical background.

At 556, p.20. "while there also is evidence that these behaviors can occur at sites with a likely absence of nests, the evidence is insufficient..." These studies need to be cited. Are they the same ones cited elsewhere in the document? Or are they additional data that have been excluded. If so, then they need to be fully explained and considered as to why they do not provide "adequate data".

At 707, p.25. Again the use of anecdotal data by the authors appears inconsistent.

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<ins>Critically Reviewing the Central Elements of the Pacific Seabird Group Inland Survey Protocol</ins>

As explained above, the SER does not explicitly evaluate the ISP using the criteria set out in the SER, nor explicitly evaluate the studies and analyses on which the protocol is based. Instead, the SER focuses on evaluating published studies (particularly recent work) that addresses some of the concepts discussed when applying the protocol. In this section we provide criticism aimed at including a proper review of the central elements of the PSG protocol.

First, we believe that it is critical to present the ISP and discuss its structures and assumptions, as well its implicit usurpation of policy decisions. For instance, with respect to the ISP's occupancy methodology, the Marbled Murrelet ISP follows many other protocols (e.g. that for Spotted Owls) and is based on the following simple equation:

$P = 1- (1-p)^n$

(Equation 1)

where

P is the proportion of occupied habitat that will be correctly identified as being occupied

p is the conditional probability that a single survey will correctly identify the location as occupied (detect a murrelet that is using the site)

and n is the number of visits to the location.

The PSG ITP is based on an approach that solves for n, given particular values of P. That is, it determines how many visits to make to a location in order to successfully detect murrelets that are in fact occupying the site.

It is important to note that the value of P (the proportion of occupied Murrelet habitat that is detected as such) is set to a value desired by the designers but critically: ***it is the proportion of occupied habitat that will be detected and (presumably) protected.***

This is a **<ins>policy</ins>** decision, embedded within what purports to be a science document.

Its effect is to set the maximum protection level that can be achieved. If (as with the ISP) P is set to .95, then one in twenty occupied sites will not be identified as such (*false negatives*) and will be opened for use (e.g. timber harvest). Whether or not we agree with such a 95% goal, this is clearly a policy issue, and should be decided by policy-makers not scientists. It is highly likely that different policy-makers in different situations, and different geographic areas would differ in their desired level of protection for murrelets. (This issue has been discussed at the MMTC, but in a very cursory manner.)

False positives

Equally problematic from a policy and management point of view is the issue of *false positives*. False positives could occur whenever 1. a non-murrelet is identified as a murrelet, or 2. when a murrelet is identified as exhibiting "occupied behaviors" when it is not so doing, or 3. when "occupied behaviors" are not in fact associated with breeding. While we may all disagree over the likelihood of each of these probabilities, none of them have a value of zero. This is also the very crux of the issue addressed by the SER. As above, simple math can help us with understanding the scope of the issue.

$$Q = 1- (1-q)^n$$

(Equation 2)

Where

Q is the proportion of survey stations that will be falsely classified as occupied when they are not in fact occupied.

q is the conditional probability that a survey visit will produce a false positive

and n is the number of surveys set from the murrelet (or other) protocol design.

A reasonable evaluation might suggest that few non-murrelets are identified as murrelets, but that there are some detections that are not truly showing "occupied behaviors" (e.g. when misjudging the height of the canopy) and that some "occupied behaviors" are not indicative of nesting. It would certainly help, when interpreting the results of ISP surveys if we had reasonable estimates for these terms. The SER could have addressed such estimates.

In our opinion, it might be reasonable and realistic to set q to .01 (where one in every hundred observations is a false positive), and to set n to 6. Then Q will be 0.06 (6% of survey programs will result in false positives at a stand, if there is a one in a hundred chance of a false positive on any one day)

The critical importance of false positives cannot be understated. Moreover ignoring them results (again) in a de facto policy decision by the designers of the PSG protocol. The scale of this decision is at the very heart of ODF's intent with the SER – to determine whether false positives are common or not.

These issues have been (albeit cursorily) discussed at PSG MMTC meetings (and should be captured in the minutes). However note again that ignoring false positives is a policy call disguised as science.

Consider a situation where p = .17 (as in the ISP) but q = .01. That is, one in six surveys will detect murrelets which are truly present (conditional true positive), but only one in one-hundred surveys will yield a false positive at a site. What is the proportion of sites that will be wrongly classified as occupied when they are actually unoccupied? This proportion is *not* 1/17 (or 6/95). To determine how prevalent false positives are across the whole landscapes we must multiply terms across all visits, and also provide an estimate of what proportion of habitats are in fact occupied by murrelets.

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Since murrelets are held to be rare (the basis of the ESA listing) and habitat-limited, it is reasonable to assume that most forestlands are unoccupied. If this proportion is set to say 10% of the landscape that is surveyed, then 90% of surveys might occur in unoccupied habitat.

In such a circumstance the ratio of true positives to false positives at the stand level can be calculated thus:

0.1 x 0.95 : 0.9 x 0.06

That is, 0.095 : 0.054

Or: 36% of sites labelled under the protocol as occupied will **not** in fact be being used by murrelets.

From a management point of view (under these hypothetical but reasonable set of values), more than one-in-three stands reserved for murrelets will not in fact be used by them.

In our view, in order to critically and systematically evaluate the PSG's protocol's reliance on the observation of a single behavior to determine "occupancy," one must set out the levels of these concerns, or explicitly address what would be reasonable values, based on the literature, for terms in these equations. These issues (which have been presented and discussed at PSG) are at the crux of evaluating the ISP, and its support from the literature.

Long-term delineation of occupancy

At various points, the MMTC and the ITP have discussed the use of the protocol in determining long-term use of a stand by murrelets. This is the issue addressed obliquely by Question 2 in the SER, regarding nest-site or stand or watershed level fidelity.

Considering the above equations, it is easy to state that the design of the protocol itself has nothing to say about fidelity. It is simply designed to determine (with a certain desired accuracy for true positives) whether murrelets used an area in the particular years of study. Fidelity is certainly an issue that can be addressed by science. However it is not the subject of the core of the protocol design.

Previous discussions at MMTC have included extensive debate on the reasonableness of extrapolation from data showing occupancy in one year to continued use in other years. This is an appropriate subject for further debate – it is clear that there is no consensus on the issue.

Moreover, whether or not to engage in such a debate is not the purview of a technical group. That is, once again, a policy call.

Contiguous habitat issues

Just as the mathematical design of the protocol cannot be extrapolated in time to other years when data have not been collected, there is no basis within the design itself for extrapolation in space (for instance to contiguous or adjacent habitat). The design itself can only be applied to the data that have been collected in their existing locations. It may be adjudged reasonable to make such extrapolations in space, on the basis of available scientific information, but there is nothing in the math itself to support such a decision. This is the appropriate subject for further discussion, as has occurred at the MMTC, and elsewhere, and further discussed by the SER. It is also (once again) a policy call on which desired level of proof or certainty is needed to make such an extrapolation.

In summary we believe that there has been abundant discussion of many of the issues treated by the SER, but that the design of the SER simply ignores much of this work. This is unfortunate in that Marbled Murrelet science is not highly quantitative, and the 'best available science' (the administrative standard) is often natural historical, observational, and data poor. This has opened the door for a blurring of the lines between scientific analysis and opinion, and between science and policy-making. This is typified by the PSG protocol itself, which must be fully presented and impartially analyzed to address the issues which are the charge of the SER authors.

Conclusions of Plissner et al

As stated above, a major omission from the SER is a frank evaluation of the PSG protocol, and whether the statements and assessments in this policy-infused document are unequivocally justified from a strong scientific record. The authors of the SER are themselves clearly aware (as witness statements throughout the individual sections) that the evidence on some issues is equivocal at best. However there are no direct statements in the SER about the overall poor justification for much of the PSG protocol. The SER's unwillingness to confront this fact, or indeed to express any opinion on the overall utility of the ISP is so complete that it must be presumed to be deliberate. This must be remedied (and explained) in the final revision.

There are indeed no overall conclusions in the SER on the state of murrelet science. Again, this cannot be presented as outside of scope, or as unnecessarily confrontational. It is the very context in which an SER is necessary. The final revision must address this issue.

Conclusions of this review

We believe that the SER, as commissioned by ODF, and carried out by Plissner et al., is a well-intentioned approach to deal with a difficult and ongoing situation. The goal of an impartial and entirely scientific review is laudable. If it is achieved, then it would be a substantive contribution to making policy-relevant science accessible and understandable.

However, as it stands, the SER does not meet this goal. There is inconsistent and poorly explained use of information. There is a clear record of conflict of interest that is simply ignored. Statistical issues are misunderstood, and the interweaving of policy into purportedly scientific documents is ignored. All these issues need to be addressed if the final SER is to be useful in resolving uncertainty and moving to a stronger basis for management.

Support for this review was provided by the American Forest Resource Council and the Oregon Forest Industries council

Response to Courtney and Starcevich

Oregon Department of Forestry/State Forests Division response to comments submitted by Western Ecosystem Technology (WEST, Inc.)

We appreciate the thorough review by Drs. Courtney and Starcevich (WEST) of the draft report prepared by ABR. Whereas WEST provides much material rich for thought with direct application to ABR's work, some of their comments are outside the scope of ABR's work and thus the Department thought it appropriate to respond to this latter set of comments.

WEST provides a critical review of the Inland Survey Protocol (ISP) for Marbled Murrelets, and they discuss how "…the answers [from ABR's review] could be improved to inform the applicability and policy rationale for the ISP (or lack thereof)." When considering these comments that are outside of ABR's scope of work, it helps to examine language in the Request for Proposals for this review, beginning with the purpose of the review:

> The State Forests Division intends to sponsor an assessment of the scientific foundation of central elements in the PSG's survey protocol as well as an assessment of the science supporting several Marbled Murrelet related hypotheses to contribute to the evolution of approaches for the survey and management of murrelets on forest lands. [Pg. 3]

The RFP further states:

> The resulting assessment should be a transparent, objective science review. We expect that it will help us to better differentiate questions of science from value and policy questions. The final contract products will not include any policy recommendations. [Pg. 4]

We re-affirm our decision to separate out the science underlying hypotheses inherent in the ISP from policy decisions in this protocol, and not ask an outside entity to make policy recommendations. We wanted an analysis of the amount, strength, and relevance of scientific evidence for these hypotheses. Keeping this analysis separate from policy decisions based on the hypotheses allows clear delineation of what the science says regarding the hypotheses; this distinction is strengthened by a reliance on evidence rather than speculation since the latter sometimes confounds science with policy implications.

We also stand behind the review methods ABR employed (i.e., using most elements of a Systematic Review) since it enables the removal of opinion from analysis of the hypotheses, as well as clearly delineating gaps in our understanding. WEST states that the biology of Marbled Murrelets is a data poor environment and thus not appropriate for examination via systematic review. While the judgment of it being data poor is subjective, this review method allows for carefully characterizing the evidence base from which people can form their respective opinions on the strength of data related to these hypotheses. This foundation of knowledge, based on carefully analyzed and characterized scientific evidence, can then be used to constructively engage with the PSG protocol group, the U.S. Fish and Wildlife Services, and others to discuss the nature of the science, as well as the nature of policy "calls" inherent in a survey protocol.

Finally, WEST states that "…ODF has represented that it intends to use this work to inform its continued use of the ISP." However, this assertion is not supported by the intended uses of the review, as stated in the RFP:

> The Division expects to use the results of the Marbled Murrelet SR in the following ways:
>
> 1. to inform the ongoing development and revisions to murrelet survey protocols;
>
> 2. to inform longer term Division policies, plans and strategies for murrelet protection;
>
> 3. to develop and refine research and monitoring questions;

4. to inform ODF interactions with other agencies, professional organizations, and other interested parties;

5. to further learn about the SR method, and if/how it may be applied to other topics. [Pg. 4]

In summary, WEST's review has some salient points for ABR to address. However, many of their comments lie outside of ABR's scope of work, and do not align with the purpose and intended uses, as stated in the RFP, of this literature review.

ABR, Inc. response to comments submitted by Western Ecosystem Technology (WEST, Inc.)

We appreciate the thoroughness of the comments provided by Drs. Courtney and Starcevich (WEST), as well as the response by the Oregon Department of Forestry (ODF) to those comments (above). Here, we do not reiterate those points in WEST's review that are specifically addressed by ODF regarding the purpose and scope of this review or alternative approaches and questions of interest. We believe that substantial effort was made throughout the development of our review to solicit, encourage, and consider input from interested parties (including one of the authors and representatives of councils supporting WEST's review) on the questions of interest and the process followed by us in conducting this review. Nevertheless, we do wish to address the many salient points raised by WEST that fall within the scope of this report as follows.

Systematic Evidence Reviews (p. 4)

WEST cites a PowerPoint presentation by Achterman (2011) regarding suggested guidelines for application of SER methodology to forestry issues and states that our approach diverges from these guidelines. Achterman notes in her presentation, however, that "Some SER procedures [her emphasis] could be more readily adopted than full SERs," because of the challenges inherent in reviews of environmental studies. We believe that our review supports and addresses most of the assertions identified by Achterman as challenges to an SER approach and follows her basic guidelines for a collaborative approach to developing the review process.

Process and analysis of Plissner et al. (p. 4)

WEST suggests that we excluded many papers that were considered "data poor and essentially natural historical," however this was not the case. We included all papers that contained pertinent information if they provided sufficient detail on methodology (even if noted as anecdotal observations) for us to be able to assign scores for our evaluation factors. There are multiple examples of data based on single nests or observations included in our review.

Marbled Murrelets and data quality (pp. 5–7)

WEST criticizes the SER approach for questions and issues that are inherently or otherwise presently lacking sufficient data. We agree that questions regarding the breeding ecology of Marbled Murrelets are inherently difficult to address in a systematic and statistically quantifiable manner and have attempted to emphasize the challenges in reviewing and summarizing the information available. Indeed the results of our review do not lend themselves to metaanalyses typical of many SERs that address questions more amenable to rigorously controlled study designs. Instead, we tend to highlight the historical variation in studies for the specific topics and identify data gaps and areas where support for a more cohesive regional approach would better inform all stakeholders. We do agree with the reviewers that there were a few examples of inconsistencies in our presentation of conclusions and interpretations that have strayed from our attempts to provide objective, fact-based results; and we have attempted to delete or modify these examples in the final report.

We note the concerns raised regarding our reference to published commentary (i.e., to Burger and Page 2007) challenging the interpretation of results of the Zharikov et al. (2006) study. While we feel that there is room in an SER for consideration of published challenges to included studies, this should be addressed in an objective manner within the evaluation scoring, either through existing factors regarding design and analysis or as a separate factor with reduced scores for studies whose results have been challenged. Since we do not wish to bias our scoring post hoc, we have removed the singular Burger and Page (2007) comment.

The WEST review concludes that "the illogic of the SER approach to a data-poor situation is laid bare." The authors again are biased by their assumptions of the purpose of the SER (see ODF's response above), whereas we posit that the SER approach in fact helps illuminate the degree to which a "situation" is "data-poor" or "data-rich" and identifies specific data needs.

Critique of the Plissner team approach to SER

Framing of questions (pp. 7–9)

This section discusses issues for which input was solicited and addressed prior to the review, when we sent out a request to all stakeholders for feedback on the five review questions (see Appendix 3.1)

Guidelines for SER (pp. 9-10)

WEST again cites Achterman's 2011 PowerPoint presentation for approaches to performing an SER on issues pertaining to Oregon forests and asserts that her preferred approach is to have an "independent academic entity" perform the review. Achterman, however, also offered an alternative approach using technical experts from multiple agencies. WEST offers the criticism that this review, however, was carried out instead by "consultants with direct murrelet experience and clear conflicts of interest." It should be noted, however, that the team authoring the review includes not only private consultants who have worked extensively on murrelet projects supported by private industry, federal and state forestry agencies, and federal and state wildlife agencies; but also an expert with the U.S. Forest Service and an academic faculty member and researcher at the University of Victoria. The reviewers falsely assert that "[l]arge portions of the SER are evaluations by the authors of their own work." As stated in our protocol, which was sent for review by stakeholders and is attached as Appendix 9, "[a]ny studies included in our review that were authored by a member of the review team will be reviewed by a different member of the team." WEST suggests that another round of review should be carried out to address conflict of interest issues; however, we believe that review already has been solicited and conducted by stakeholders (including the councils represented by the WEST review), who responded to our request for review of this report. Further, specific concerns brought up by reviewers are being addressed in our final report, including the deletion or modification of text that is subjective in nature or interpretation.

Use of information (pp. 10-11)

WEST suggests that we were deficient in our inclusion of published anecdotal observations; however, we made every attempt to include such data in our review. We provided stakeholders with an opportunity to review our list of included studies for each question and suggest additional ones to consider. In order to follow a rigid and repeatable protocol, however, it was necessary to cull data that cannot be evaluated using our scoring criteria. We therefore could not include anecdotal information in the form of personal communications. Along with unpublished raw data, we agree that these additional observations could be valuable and useful in subsequent analyses, but such an approach is beyond the scope of our review.

We appreciate the input of the reviewers on the issue of statistical power. In hindsight, the general nature and sample sizes of the vast majority of studies considered likely warrant exclusion of an evaluation factor focusing strictly on power. In general, even when power is presented, it is typically difficult to interpret because assumed effect sizes are rarely presented or justified. Our intention was not to suggest confounding Type I and Type II errors or the association between α and β, but rather to accept that power generally is not presented for test results that are found to be significant (at $\alpha \leq 0.05$). As a general note, scores for the power factor were highly invariable for most questions and did not significantly impact overall ranking of studies.

WEST's disappointment with the lack of conclusions directly addressing the ISP is understandable, given their apparent expectation that this was the focus of our review; however, we believe that our conclusions fall within the stated scope of the review and do inform stakeholders on issues that pertain to sections of the ISP and other policy decisions. In relation to the example mentioned, we conclude that information is largely lacking on murrelet flight behaviors over non-nesting areas and that this information is critical to assessing the significance of "occupied" behaviors.

Commentary on questions and the SER treatment of them

NOTE: For this section, reviewers' comments are provided in Arial font, followed (in italics) by responses provided by the ABR review team.

Question 1 (pp. 12-14)

At 465: "A site was considered to have a likely absence of nests if all potential nest trees were searched and no nests were found in the site, or if the habitat was deemed unsuitable for nesting and not closely adjacent to potential nesting habitat". This statement needs clarifying – should it include the word "only"" (as in "A site was only considered . . .")? If so, what is the effect of this step – how many studies were excluded or were moved from one column of the analysis to another by virtue of this decision?

We reworded this sentence as suggested. An unknown number of studies were excluded if nesting was uncertain but for the purposes of informing the question of interest it was imperative to have reasonable certainty of absence of nests.

At 469: "Studies in which nesting suitability of habitat where behaviors were detected was unclear were omitted". This is potentially a major concern. Who made the evaluation of whether the habitat suitability was unclear – the original authors, or the SER team? On what basis is the issue deemed unclear? How many such studies are there? If they were to be included and assigned to the category of 'no evidence for nesting', would this show that there are many such cases where there is no supportive evidence justifying occupied status? Intentional or unintentional, filters as these can have the effect of skewing analyses in one direction. If the real intent of the SER question 1 is to assess the potential for false positives in the protocol (as we believe was intended by ODF) then this paragraph suggests that there are relevant studies being excluded and that the overall analysis is under-emphasizing the lack of support for the PSG protocol.

The determination of habitat suitability is based on the original author(s)' interpretations and criteria. We did not exclude studies based upon habitat suitability, only upon known presence or absence of nests. As with the example of controversy over the Zharikov paper, from the standpoint of this review, we are largely limited by the details provided by the authors. These concerns (including the issue of post-publication information revising the status of the sites) are well-founded.

At 513 et seq. This paragraph addresses the single main focus of the SER. Unfortunately it is opaque at several points, and conflates different points in the discussion. It also fails to address some biases in studies- such biases are entirely appropriate subjects for assessment in an SER. This whole paragraph should be revised to be clear and to present information in language that is not loaded.

The analysis discusses two studies where behavior was observed at locations unsuitable for nesting (e.g. talus slopes, clear-cuts) and one study where behavior was observed at an unoccupied forest stand. It is entirely inappropriate to conflate these two sorts of studies. Again, we refer to the importance of focusing on the false positive issue, and the PSG protocol. If we fail to observe murrelet 'occupied' behavior over parking lots what does this prove? Essentially this provides no information, other than that 'occupied' behaviors does not occur in unambiguously unsuitable areas. However if we do observe such behaviors in potentially suitable habitat which are shown to be unoccupied, this is unambiguous and clear evidence for false positives. The relevant data set here are all observations that can be reasonably assessed to fit in this category. Many anecdotal observations (including some in the PSG protocol itself) are relevant and should be collated here. We emphasize that the relevant issue is not whether occupied behaviors occur in non-habitat; it is whether occupied behaviors that are observed in potential forest areas (those that are subject to survey under the PSG protocol) have substantiated associative evidence for nesting.

Conflating studies of different composition (non-habitat conflated unoccupied habitat) also has the effect of inappropriate analyses. The absence of jet-dives and vocalizations in assuredly unsuitable habitat is meaningless. A similar absence from unoccupied but apparently suitable habitat has value. However the SER, by conflating the two sorts of area overstates the evidence associating jet-dives and vocalizations with nesting. In this case, *n*=1, not 3, as implied by this paragraph.

This section also fails to address a systemic bias in the data that have been collected. This stems from the entirely reasonable approach of murrelet researchers in focusing their attention on areas with murrelets. It is probable moreover that such researchers focus their work in areas with lots of murrelets who are then especially interactive (e.g. become vocal and territorial). This bias will result in both an under-representation of areas with no murrelets, and an over-estimate of the prevalence of occupied behaviors at occupied sites across the landscape.

We absolutely agree (and stress in our Data Gaps section) that the critical information needed to address this question is the behavior of murrelet in potential but unutilized nesting habitat; however, there are no studies that have addressed this. As a rule, evidence of "occupied" behaviors at non-nesting areas (regardless of habitat suitability) would be sufficient to indicate that occurrence of such behaviors are insufficient determinants of breeding activity at a site; however, we do not suggest, based on information currently available, that the absence of such behaviors is proof that they do not occur at non-nesting sites. Although we have already explained our rational for omitting personal communications cited in studies from our review, we do, in fact indicate ("Comparisons With Other Studies") that such observations are mentioned in the ISP.

Upon further scrutiny of the three examples cited for behaviors at non-nesting sites, we have now eliminated all but the Hamer and Cummins paper from the paragraph, based on the determination that we erroneously included the other two studies, because the author indicated that nest search efforts were not sufficiently thorough to absolutely confirm an absence of nests (and in fact, nests were subsequently located in the vicinity of the sites). We have revised this section to highlight the limited interpretation of these results.

At 516, the SER states "climbers were unable to locate evidence of nesting." The clear intent here is to imply that the site may in fact have been used by murrelets for nesting, but the authors were simply unable to find the nests. This would then 'explain away' the fact that occupied behaviors were observed. This language should be replaced with more accurate and unloaded language—the discussion in Table 2 is accurate "subcanopy flights and >4 landings observed in area where no nests were found."

Note that these studies were removed, for reasons stated above.

This section should also address scale and proximity issues. The studies reported in Table 2 show a pattern of occupied behaviors at and near nest-sites. This is unsurprising and hardly controversial. The SER does not however report on whether the study authors reported occupied behaviors only at or in the immediate proximity of known nests, or whether they occur in a wider area around nests. Such information is highly relevant to issues of contiguity, as well as whether all occupied behaviors indicate nesting at the exact location where they are observed.

Very good point and issue; however, such information was not provided in studies.

A major problem with this entire section is the absence of any formal discussion of known behavior patterns that could reasonably be expected to result in "occupied behaviors" in the absence of actual nesting. Chief among such behavior patterns is prospecting. This behavior occurs in all alcids. In Marbled Murrelets, birds are frequently seen in forest stands outside the nesting season. Naslund (1993) has studied this phenomenon, and provides discussion of examples throughout the range of the species (these are personal communications, but again: these natural historical observations are clear and valuable, and should not be excluded just because they are anecdotal).

By definition, prospecting is thought to include cases where a bird might examine, at close range, potential nest-sites. This then could easily lead to individuals landing in trees which are then rejected as unsuitable. Is such a location nesting habitat? Clearly not, but it could be classified that way, absent tree-climbing efforts. These issues are not even considered in the SER. It may be that there is very little evidence regarding prospecting. If so, that should be stated; in which case, prospecting should remain as a viable explanation for any "occupied behavior" observation.

This is already stated in the last sentence of the first paragraph for this question.

The SER must include a full discussion of all behavior patterns that might cause individual behaviors (circling, vocalization etc.) classified as 'occupied behaviors'. The lack of such a discussion is a major omission from the SER, and biases it in favor of associating occupied behavior with actual nesting.

We acknowledge in various sections that "occupied" behaviors may be associated with more than just active nesting, although that is our focus for this and most questions we have chosen to address, since it is the only activity that is readily identifiable and quantifiable, with measureable value.

At 716, p. 25: How precisely would anyone conclusively associate a relationship with future nesting? Or rule out nesting at a location in the future? This and other references to the future should be removed. Other speculative statements, e.g., at 739–741 about unknowable past or future conditions, should be removed.

We disagree. It is certainly possible (although not easy) to retrospectively identify correlates of behaviors (e.g., prospecting, nest site fidelity) that can be associated with subsequent nesting at a site, even if the direct association is unknown.

Question 2 (pp. 14–15)

This section is based on a wider and ill-defined or justified use of the term 'fidelity' than is typical in the literature. We recommend re-writing to clarify just where it implies individual behavior.

Reuse of a nest area by the same or different individuals is equally important in terms of the question of how current murrelet nesting is related to future murrelet nesting, which justifies our use of a wider definition for fidelity. We agree, however, that it is useful to recognize the occurrences of reuse by individuals whenever possible.

In intent, this section of the SER (as also question 3) is intended to address the issue of contiguity. This is one of the most difficult aspects of the PSG ISP to apply, in that it is unclear why occupancy in one area should also apply to increasingly distant areas. This is in effect an extension of survey results in one location to other locations. Clearly data that are collected can only be held to provide direct evidence to the exact areas they were collected. It may or may not be justified to extrapolate results to similar results elsewhere, from a management or conservation point of view—however that is a policy call, which should be made with a full understanding of what evidence is available that supports such an extrapolation. Unfortunately the SER does not provide a direct answer to this question. Moreover, it is likely that the evidence for or against spatial extrapolation will vary with circumstance (habitat breaks, topography, being just two simple and uncontested examples). This section of the SER needs to provide an impartial and unambiguous review of this evidence.

We have attempted to do just that in light of very limited information available on habitat continuity. As indicated, much of the difficulty in doing so is due to geographic patterns of habitat; however, there also is the issue that sample sizes are skewed toward studies focusing on large areas of continuous habitat. In addition, low detectability of nests hampers the ability to definitively identify definitively all nesting sites within most patches.

At 928, p. 33: "The large number of trees climbed (1,628) and the large number of nest-trees found (143) provide strong support for this hypothesis of the effect of habitat continuity on fidelity". This statement (regarding a paper by one of the SER's own authors) is extremely misleading. It implies that the sample size for testing the hypothesis is large (presumably 143, or 1628). However the sample size for the study is 1 (one study site) and it does not in any way test the hypothesis. It is in effect an anecdotal observation that in one site, there were many nests. It does not in any way address differences in habitat continuity on fidelity.

We revised the text to include that these numbers apply across eight different study areas, which, along with the effort indicated, does provide stronger support for the hypothesis.

At 934. p33: This sentence is entirely speculative and does not concern any data at all. Why is it included in a literature review? It appears to have been inserted in the hope of influencing forest management in Oregon.

We agree that the sentence is speculative and deleted it.

At 949, p. 34: Again, in the interests of including all relevant studies, why was there no attempt to document (through an email or letter) what was known about each site?

We considered this to be outside the scope of the review, similar to our exclusion of raw, unpublished data.

At 987, p. 35: 'Several of the authors…admitted'. This language implies an interaction or discussion with the authors of the SER. Is this the case? If not, use more neutral language (e.g. the authors stated).

We revised the text.

At 1025, p 36: We argue above that clear evidence from the Tillamook shows either persistence in small fragments of residual trees, or low fidelity. This observation is known to ODF, and should be referenced here. The SER's statement at 1025 is correct only if there is complete destruction of all nesting habitat. It may be that murrelets are able to survive over a period of decades in remnant trees.

We did not find this information in any available report, so it was not included in the review.

At 887, p 31: The SER unashamedly quotes from one of the authors' own papers, reference to an unpublished study. This violates all the selection criteria used elsewhere in the SER. We actually believe that this sort of use of information is allowable in any review that aims to be comprehensive, complete and rational. However the authors of the SER should be willing to use other such quotes, not just their own.

This approach does not violate our selection criteria. The author of the paper was not an author of the section and did not provide comments on inclusion of that information. Also, we have included other previously unpublished data referenced (and included) in analyses by other authors (e.g., Hamer and Nelson 1995, reports by Hébert/Golightly, etc.).

At 906, p 32. Discussion of Hebert et al. One bird was 'suspected' of nesting. How does this study merit inclusion in the SER, given the lack of any information at all, when other more concrete anecdotal observations are excluded?

We included this information because we considered that telemetry information indicating a regular visitation pattern of diurnal inland presence of murrelets in suitable habitat to be sufficient evidence of nesting.

Question 3 (p. 15)

The key issues for question 2, on contiguity, also apply here.

At 1361, p. 48: The clustering of nests in the study by Waterhouse et al is strong evidence for micro-habitat factors at play (unless there is a level of sociality not previously thought likely). The SER authors contrast this with the Desolation Sound study, and imply that this somehow negates the result of the other study. It does not. The comparison is between apples and oranges. The Desolation Sound area is surrounded by abundant habitat (including talus slopes in this area) but marine feeding areas are clustered. The central coast study provides evidence of an effect (microhabitat); the Desolation Sound study shows no evidence for an absence of effect—the conclusions are not symmetrical and opposite.

We did not intend to suggest that either study negates the results of the other, merely to indicate (as WEST states) that extent of continuous habitat alone does not necessarily explain the distribution of nesting habitat. We have reworded the section for clarification.

At 1453: The SER claims 'strong' evidence that nests co-occur (in fact one example would suffice to make that statement), but no evidence on the 'likelihood of co-occurrence'. Given this statement, what is the actual published support for the PSG ISP extrapolation of survey results from one area to another? If there is no published paper on this subject, then the SER authors need to state so unequivocally, and they should attempt to avoid making bold but unsupported assessments on such a policy-relevant issue.

Reworded to clarify that data are insufficient to quantify probabilities of co-occurrence.

Question 4 (p. 16)

In that the SER authors essentially find that there is too much variation between sites and geographic areas to draw wide-ranging conclusions, we agree with the SER and have no substantive critiques of the document at this point.

Question 5 (p. 16)

This section needs to more fully explain the difference between studies of murrelet nests and artificial nests, and the strengths and weaknesses of each approach (e.g. statistical design is possible for artificial nests, but they are not protected by incubating or feeding adults, so actual rates cannot be presented as realistic).

We expanded the text to help address this point.

At 1822, p. 63: See above comments on the inappropriate insertion of personal opinion.

Agree; this text was deleted.

At 1912 et seq, p. 67: "the type of edge bordering the nest stand appears to be important." This is a clear over-statement regarding an issue where we have extremely few data. It is a reasonable hypothesis, with some evidence (from artificial nests) in support—nothing more.

Edge type effects were noted in five studies. We revised wording to emphasize suggestive nature of results of these artificial nest studies.

Additional comments on methods

At 291, p.11: The SER excludes undocumented data, personal communications, raw data, and documents with poor documentation of methodology. While this is perhaps appropriate in a SER where there is an abundance of quantitative peer-reviewed literature, , in this case it may have removed some useful information from consideration. As stated above, even single observations can be valuable if they show that murrelets exhibit "occupied behavior" away from nest-sites. The excluded data, pers. obs., etc., should be collated and set out so that an independent person can determine whether the SER team has excluded important observations.

As indicated in the appendices, we will provide interested parties with a file listing all of the studies considered for inclusion along with the determined presence or absence of each of the inclusion criteria for each question. However, it is an unrealistic expectation and beyond the scope of this work provide a comprehensive list of each occurrence of an anecdotal or pers. comm. reference that was not included in our review. Lastly, please note that we provided all stakeholders an earlier opportunity to review and suggest additions to our list of included studies, in case they were concerned that an important document was not included.

At 324, p.326. The SER excluded studies where nesting was known to occur, if the data on nesting and behavior were not published in the exact same papers. Given the overall paucity of information on murrelets, it seems extraordinary to exclude any paper at all that has relevant information, not least for such an arbitrary reason. Indeed, if the goal of the SER was to be comprehensive, there should be a concerted effort to include as many papers as possible; clarifying emails to authors for instance would have been a perfectly transparent way to obtain and document missing pieces of information, so that more data were included.

We did consider and include studies where information on nesting was referenced in other papers; however, we did not pursue identification of unrelated and un-cited studies that may have offered additional information. This would be an issue to consider for future review efforts of individual questions but poses a challenge to the repeatability of the review effort (procedures for attempting to obtain such information and availability of such information likely to vary extensively).

At 339, p.12: Have the authors of the SER calculated statistical power of the papers reviewed? If not, remove this language which implies that they have used more sophisticated assessments than is the case.

We did not imply that more sophisticated assessments were used, so left the text as-is.

At 372, 375, p.14: Again, have the authors carried out any formal analysis of the statistics used? If not, all this language should be revised to reflect a qualitative assessment of the paper's quantitative merits. It is highly recommended that this section be reviewed again (following any revision) by someone with a statistical background.

We reworded this text to clarify our approach. Also, please note that we did have a biostatistician on our support staff available to help address any statistical questions that were beyond the author's abilities, if/when such questions arose.

At 556, p. 20: "while there also is evidence that these behaviors can occur at sites with a likely absence of nests, the evidence is insufficient…" These studies need to be cited. Are they the same ones cited elsewhere in the document? Or are they additional data that have been excluded. If so, then they need to be fully explained and considered as to why they do not provide "adequate data".

This statement was deleted after some studies previously thought to have occurred at sites with likely absence of nests were determined to have occurred at sites where the absence of nests was not determined with certainty.

At 707, p. 25: Again the use of anecdotal data by the authors appears inconsistent.

See previous comments that address this.

Conclusions of Plissner et al (p. 22)

These issues were addressed in ODF's response.

Appendix 4—Glossary

For the purposes of this review, the following definitions apply:

Circling: any curving flights observed at any height above the canopy.

Continuous potential habitat (as defined in the inland survey protocol; Evans Mack et al. 2003): "[habitat] which contains no gaps in suitable forest cover wider than 100 m (328 ft).

Forest age-classes (functional definition for this review, based upon Franklin and Spies [1991] classification for Douglas-fir forests; not general policy definition):

- Young: coniferous forests ~35–80 years old that have platforms in young trees or in residual older trees.
- Mature: coniferous forests ~80–200 yr old with or without an old-growth component.
- Old-growth: coniferous forest stands >~200 yr old.

Forest stand: An aggregation of trees of sufficiently uniform species composition, age, and condition to be distinguished from the forest or other growth on adjoining areas and considered a homogeneous unit for many management purposes.

Habitat characteristics: biotic and abiotic factors associated with habitat quality, quantity, continuity, or configuration of forest patches/stands or watersheds.

Jet dives: flight behavior involving sudden descent of birds; includes audio detections of "jet" sounds produced during such flight behavior.

Occupied behavior: a term used in the inland survey protocol (Evans Mack et al. 2003) to describe the following behaviors believed to indicate that the site either has or may have some importance for breeding: subcanopy flights and dives, low circling or arcing, landings, subcanopy wing-beat sounds, stationary calling, and the "jet sounds" associated with diving birds.

Patch: An area of forest consisting of a contiguous expanse of similar habitat without gaps in that habitat type.

Platform: a relatively flat surface >10 cm (≥4 in) in diameter and >10 m (≥33 ft) high in the live crown of a coniferous tree (Evans Mack et al. 2003).

Site fidelity: Refers to within-year and between-year returns of birds and re-use of nesting locations (i.e., at the nest cup, limb, tree, patch, site, stand, or watershed scale) by the same or different individuals.

Stationary calling: three or more adult calls heard from a single location within 100 m of observer.

Subcanopy flights: any flights below, through, into, or out of the forest canopy within or adjacent to the potential nesting habitat or anywhere in non-nesting habitat. Also includes flights detected by wing beat sounds heard below canopy.

Survey area: the entire area (often a timber sale and surrounding forest) that is under observation during inland surveys for murrelets, as described in Evans Mack et al. (2003). This may be an entire stand or a portion of a stand of potential habitat and includes, at a minimum, the potential habitat within a proposed project area and contiguous potential habitat within one-quarter mile of the project area boundary.

Survey site: the designated survey unit for the murrelet survey protocol, as described in Evans Mack et al. (2003).

Appendix 5—Studies Identified from Literature Searches

(Excel file to be provided upon request.)

Appendix 6—Study Inclusion Table

Study citation:

Initial source of study:			**Question**		
Inclusion criteria	**1**	**2**	**3**	**4**	**5**
Does the study specifically address Marbled Murrelets?	■	■	■	■	■
Does the study include information on one or more of the following behaviors: circling/arcing flight, flight altitude relative to tree height, wing-whirring, jet sounds, wing-beats, stationary calling?	■				
Does the study include information on known nesting or non-nesting habitat when behaviors were observed?	■				
Does the study include information on either or both of the following: (1) within- or between-year re-use of nesting cup, limb, tree, patch, site, stand, or watershed; or (2) distance between subsequent nests of a bird or pair?		■			
Does the study include information on the known number (1 or >1) or density of nesting pairs within one or more of the following: tree, patch, survey site, stand, watershed?			■		
Does the study include information on one or more of the following: (1) nest-platform diameters; (2) nest-platform density (including definition of minimal platform size); (3) platform-tree density (including definition of minimal platform size)?				■	
Does the study include information on nest success or nest failure?					■
Does the study include information on nest-site habitat characteristics?					■
Does the paper contain sufficient information on methodology and results to assess study quality?	■	■	■	■	■
Will study be included in review?	■	■	■	■	■

Appendix 7—Data-Extraction Tables

Appendix 7.1. Data extraction tables for Question 1:

"How are individual behaviors (subcanopy flight, circling, landing, vocalizations) of Marbled Murrelets indicative of nesting in the forest stand where those behaviors occur?"

Table A7.1.1

Study Citation	Dechesne and Smith 1997
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Naden watershed, Queen Charlotte Island, BC
Study area habitat	A mix of clearcuts, second-growth, and old-growth coniferous forests dominated by Western Hemlock, Western Red Cedar, Sitka Spruce, Mountain Hemlock and Yellow Cedar.
Study design[1]	Both
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, Climbing
Years of study	1995–1996
Within-year study period[4]	5 Jun–25 Aug 1995, 24 Ap–6 Aug 1996
Sample sizes[5]	Occupied behaviors observed in both 1995 (n = 84 occupied detections) and 1996 (n = 8 occupied detections) at the 3PCT station, which had at least 1 active nest nearby in 1995 and at least 1 inactive nest nearby in 1996.
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
How was nesting determined?[6]	Nest-cup, Fecal ring
Behaviors recorded[7]	Sub-canopy flight; Circling above canopy
Was "circling" defined?	No
Nesting/non-nesting habitat?[8]	Nesting habitat
Distances from nests?	No
Distances from nesting habitat?	No
Pertinent results, including statistical significance values and measures of variation[9]	(p. 13, Table 4) 51 subcanopy detections and 33 detections of birds circling above the canopy were observed at the NADE 3PTC survey station in 1995; there was at least 1 active nest located near 3PTC in that year. (p. 14, Table 5) 8 subcanopy detections and 0 detections of birds circling above the canopy were observed at the NADE 3PTC survey station in 1996; there was at least 1 inactive nest located near 3PTC in that year. (p. 13, Table 4), (p. 14, Table 5), (p. 24, Figure 8) Survey stations were located in forested (n =16) and clearcut (n = 13) locations. Occupied behaviors were observed at most stations (including many in clearcut stations), but it was unclear whether or not those behaviors were associated with clearcut habitat or with nearby forest (i.e., potential nesting) habitat. Thus, there was too much uncertainty associated with those data to use them as evidence of occupied behaviors over nonhabitat.

Study Citation	Dechesne and Smith 1997
Potential sources of bias or error	
Effects modifiers[10]	
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Evidence for nesting.
7 Types and definitions of vocalizations and/or flight characteristics recorded.
8 Were behaviors observed in areas with known nesting habitat or known non-nesting habitat?
9 List specific results that are most pertinent to answering the question; include P-values, confidence limits, range of values, standard deviations, or other measures of variation.
10 Potential factors that may have affected results and comparability relative to other studies.

Table A7.1.2

Study Citation	Hamer and Cummins 1990
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	South Fork of Stillaguamish River Basin, WA
Study area habitat	4 habitat types studied: 1) rock/talus, 2) clearcut/meadow/ sapling (i.e., <20 cm dbh),3) small saw/pole forest (20–50 cm dbh), and 4) old growth (>76 cm dbh)/mature forest (50–80 cm dbh)
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, Searched for nests by searching under trees for eggshell fragments.
Years of study	1990
Within-year study period[4]	16 May–15 Aug 1990
Sample sizes[5]	Occupied behaviors observed in both 1995 (n = 84 occupied detections) and 1996 (n = 8 occupied detections) at the 3PCT station, which had at least 1 active nest nearby in 1995 and at least 1 inactive nest nearby in 1996.
Statistical analysis of results	0 occupied behaviors near 31 sites in non-nesting habitat (22 of those 31 sites had presence of murrelets, however). 246 AV surveys conducted at 41 stations in 4 habitat types (3 of which were non-nesting habitat) during a single nesting season.
Statistical power	None—n.a.
Document type	Not applicable
How was nesting determined?[6]	Agency technical report paper
Behaviors recorded[7]	Eggshell fragments
Was "circling" defined?	No
Nesting/non-nesting habitat?[8]	Both
Distances from nests?	No
Distances from nesting habitat?	Yes
Pertinent results, including statistical significance values and measures of variation[9]	(p. 13, Table 4) 51 subcanopy detections and 33 detections of Below-canopy flights were never observed in non-habitat sites (i.e., in rock/talus, clearcut/meadow/sapling [i.e., <20 cm dbh], or small saw/pole forests [20–50 cm dbh]). Murrelets only were observed to fly through the canopy at old growth/ mature sites (n = 37 subcanopy flights, but although it was potential habitat, it was unknown if any birds actually nested in those sites). Thus, subcanopy flights was the only flight behavior that appeared to be associated only with old growth/ mature habitat (i.e., with potential nesting habitat). Subcanopy flights comprised 5% of the 765 total detections (p. 24). (Table 9) 0 occupied behaviors near 31 sites in non-nesting habitat (22 of those 31 sites had presence of murrelets, however).

Study Citation	Hamer and Cummins 1990
Potential sources of bias or error	None apparent
Effects modifiers[10]	None apparent
Additional notes	The 2 known nests that were found were not linked to any particular flight behaviors. Information on which of the stations in old growth/mature habitat actually contained nesting birds were not available. We assume that the other three habitat types (i.e., rock/talus; clearcut/meadow/sapling; and small saw/pole forest) were non-nesting habitats, based on the descriptions provided for those habitats.

1 Brief description of study design (e.g., qualitative, quantitative).

2 Anecdotal, descriptive, or experimental, control groups, replicates.

3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.

4 How often were data collected within a season?

5 Number of birds, nests, sites, replicates, visits.

6 Evidence for nesting.

7 Types and definitions of vocalizations and/or flight characteristics recorded.

8 Were behaviors observed in areas with known nesting habitat or known non-nesting habitat?

9 List specific results that are most pertinent to answering the question; include P-values, confidence limits, range of values, standard deviations, or other measures of variation.

10 Potential factors that may have affected results and comparability relative to other studies.

Table A7.1.3

Study Citation	Jones 2001
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Spipiyus Park, Caren Range, coastal BC
Study area habitat	Old growth coniferous forest (Western and Mountain Hemlock, Amabilis Fir, and Yellow Cedar), surrounded by some recently logged areas
Study design[1]	Qualitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Cameras
Years of study	1991–1994 and 1996–1997
Within-year study period[4]	Variable among years, but always within the May–early August period
Sample sizes[5]	2 active nests were found. Adults observed flying into nests 104 times (48 times in 1993, 16 in 1994, and 40 in 1997. n = 73.5 h, 36.5 h, and 101.5 h observing the nest in 1993, 1994, and 1997, respectively. n = 18 stationary calls from a nest.
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Book/book chapter
How was nesting determined?[6]	Nestling
Behaviors recorded[7]	Landing/take-off, Sub-canopy flight, Circling above canopy, Wing-whirring, Stationary calls
Was "circling" defined?	No
Nesting/non-nesting habitat?[8]	Both
Distances from nests?	No
Distances from nesting habitat?	No
Pertinent results, including statistical significance values and measures of variation[9]	2 active nests were found and observed. 1 of the nests was active in both 1993 and in 1994 and the other nest was active in 1997. (p. 95–96) Adults observed flying into nests (i.e., subcanopy flights and landings) a total of 104 times during this study (48 times in 1993, 16 in 1994, and 40 in 1997). (p. 96) Adults made calls stationary calls at the nest during 18 of 40 chick-feeding trips in 1997. (p. 97) Wing whirring sounds made frequently by 1 of the nesting pair when flying into the nest in 1997. On 6 occasions, an adult passed by the nest, circled back over an adjacent clearcut and returned to the nest. Wing sounds also were observed on several occasions at the 1993 and 1994 nest sites.

Study Citation	Jones 2001
Pertinent results, including statistical significance values and measures of variation (cont.)[9]	(p. 36) A bird carrying a fish was observed circling a nearby lake at 0.5 canopy heights, then flew through the trees to the active nest. (p. 62) A silent bird carrying a fish was observed circling over the vicinity of an active nest at twice the canopy height, then dove into the canopy at a location approximately 200 m from the active nest.
Potential sources of bias or error	None apparent
Effects modifiers[10]	Habitat effects unlikely but possible.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Evidence for nesting.
7 Types and definitions of vocalizations and/or flight characteristics recorded.
8 Were behaviors observed in areas with known nesting habitat or known non-nesting habitat?
9 List specific results that are most pertinent to answering the question; include P-values, confidence limits, range of values, standard deviations, or other measures of variation.
10 Potential factors that may have affected results and comparability relative to other studies.

Table A7.1.4

Study Citation	Lougheed et al. 1998
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Bunster Range mountains on the mainland coast of BC, near Desolation Sound
Study area habitat	Old growth coniferous forest, with fragmentation due to logging in some areas
Study design[1]	Qualitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing, Telemetry, Mist nets and dip-netting used to capture and tag birds that were then followed to find their nests.
Years of study	1997
Within-year study period[4]	13 May–9 Aug 1997
Sample sizes[5]	Approximately four 2-h-long dawn AV surveys were conducted at each of 27 known nest trees (only 3 of the 27 were active in 1997). In addition, 2 of the nest trees were used as monitoring sites and surveyed on a weekly basis (14 surveys at each site).
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Agency technical report paper
How was nesting determined?[6]	Nestling, Egg, Nest-cup, Eggshell fragments, Fecal ring, Fledgling
Behaviors recorded[7]	Landing/take-off, Sub-canopy flight, Circling above canopy
Was "circling" defined?	No
Nesting/non-nesting habitat?[8]	Nesting habitat
Distances from nests?	No
Distances from nesting habitat?	No
Pertinent results, including statistical significance values and measures of variation[9]	2 active nests were found and observed. 1 of the nests was All 27 nests found in 1995 and 1996 telemetry/climbing studies (plus 3 new nests found in 1997) had AV detections of murrelets in the vicinity of the nest during 1997. Note that of the 30 nests, only 3 were active in 1997. Of those 30 nests where AV surveys were conducted, 18 (including the 3 active nests) had observations of subcanopy flights (direct flights and circling). Six of those 18 nests also had landings in the nest tree. Another 6 of the 29 nests did not have subcanopy flights, but did have observations of murrelets circling above the canopy. The remaining 6 of the 27 nests had murrelet detections, but no occupied behaviors (i.e., subcanopy flights or circling above canopy) were observed.

Study Citation	Lougheed et al. 1998
Potential sources of bias or error	None apparent
Effects modifiers[10]	Habitat effects unlikely but possible.
Additional notes	Note that numbers of nests on p. 14 of Results do not match nest numbers given in parentheses.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Evidence for nesting.
7 Types and definitions of vocalizations and/or flight characteristics recorded.
8 Were behaviors observed in areas with known nesting habitat or known non-nesting habitat?
9 List specific results that are most pertinent to answering the question; include P-values, confidence limits, range of values, standard deviations, or other measures of variation.
10 Potential factors that may have affected results and comparability relative to other studies.

Table A7.1.5

Study Citation	Manley and Kelson 1995
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Carmanah and Walbran valleys, Vancouver Island, BC
Study area habitat	Coastal old-growth coniferous forest
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, Climbing
Years of study	1990 and 1991
Within-year study period[4]	Tree climbing and visual observations were conducted for an unknown number of days during 3 Jun–5 Aug 1990 and 13 Apr–13 Aug 1991
Sample sizes[5]	2 nests were found based upon locations of subcanopy behaviors ($n > 7$ subcanopy behaviors) observed during two years of AV surveys
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Peer-reviewed publication
How was nesting determined?[6]	Nest-cup, Eggshell fragments, Fecal ring, Feathers
Behaviors recorded[7]	Landing/take-off, Sub-canopy flight, Wing-whirring, Stationary calls
Was "circling" defined?	No
Nesting/non-nesting habitat?[8]	Nesting habitat
Distances from nests?	Yes
Distances from nesting habitat?	No
Pertinent results, including statistical significance values and measures of variation[9]	(p. 27) "The first nest was found on 3 Aug 1990, 2 days after we observed a murrelet land in the tree. Surveys the following 2 mornings, before JOK climbed the tree, revealed no further activity. In 1991, the forest in the vicinity of the 1990 nest was surveyed for murrelet activity from 13 Apr to 13 Aug. Murrelets were landing in 6 trees within 100 m of the 1990 nest on 3 and 4 Jun, and 12 and 18 Jul. All landings occurred in 172–261-cm dbh Sitka spruce 28–2 min before sunrise. Other behaviors in this area included below-canopy flights by single and pairs of birds, buzzing (low flights with audible wingbeats), and calling from stationary points. We climbed 6 landing and 10 other potential nest trees (large-diameter trees with large mossy branches) in the area beginning 15 Aug, 17 days after dawn activity had ceased. On 24 Aug 1991, an unoccupied nest site was found 168 m from the 1990 nest at a bearing of 70°." (p. 28) "Flying into the nest from below appeared to be the clearest path into both nests. We observed a murrelet approach the 1990 nest by flying low along a logging road then rising steeply into the tree crown."

Study Citation	Manley and Kelson 1995
Potential sources of bias or error	None apparent
Effects modifiers[10]	Habitat effects unlikely but possible.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Evidence for nesting.
7 Types and definitions of vocalizations and/or flight characteristics recorded.
8 Were behaviors observed in areas with known nesting habitat or known non-nesting habitat?
9 List specific results that are most pertinent to answering the question; include P-values, confidence limits, range of values, standard deviations, or other measures of variation.
10 Potential factors that may have affected results and comparability relative to other studies.

Table A7.1.6

Study Citation	Manley 1999
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Southern mainland coast of BC, in the Bunster Range
Study area habitat	Primarily late-successional coniferous forests, with Douglas Fir, Western Hemlock, Mountain Hemlock, Western Redcedar and Yellow Cedar
Study design[1]	Both
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing
Years of study	1996
Within-year study period[4]	Behavioral at monitoring sites during 20 May–14 Aug 1996; observations at known nest sites during 1–31 Jul 1995, 13 May–15 Aug 1996, and May–Aug 1997.
Sample sizes[5]	Behavioral observations near 13 of 52 nests (7 of which were active; 6 were inactive at time of observation). *n* >200 occupied behaviors near known active or inactive nests.
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Thesis/dissertation
How was nesting determined?[6]	Nestling, Incubating adult, Nest-cup
Behaviors recorded[7]	Landing/take-off, Sub-canopy flight, Circling above canopy, Wing-whirring, Stationary calls
Was "circling" defined?	No
Nesting/non-nesting habitat?[8]	Nesting habitat
Distances from nests?	No
Distances from nesting habitat?	No
Pertinent results, including statistical significance values and measures of variation[9]	(p. 16 and 19, Figure 5) AV surveys were conducted in 1996 at Monitoring Site (MS1), which had 1 inactive nest, and at MS2, which had 2 active nests. At MS1, they observed 34 subcanopy flights, 9 circling above canopy, 74 straight flights above canopy height, and 58 heard-only detections. At MS2, they observed 39 subcanopy flights, 57 circling above canopy, 97 straight flights above canopy height, and 162 heard-only detections. (p. 20–30) Watched 7 active nests during 1994–1997 and observed incubation exchanges (n = 4), wingbeat sounds at nest sites (n > 2), chick-feeding (during n = 18 surveys), and stationary calling from nest (n = 4 calls; including 1 soft "eh-eh" call, 1 soft "Q" call, 1 "alternate" call, and 1 keer call). (p. 30–31) "Adult birds at Nest 1 always entered and exited the nest from the south. They approached the nest flying low (1–3 m above the ground) down a logging road located 30 m from the nest. Surveys along the approach route to the nest revealed that the birds were flying along a creek to its junction with the

Study Citation	Manley 1999
Pertinent results, including statistical significance values and measures of variation (cont.)[9]	road 150 m south of the nest. Birds were heard made 'swooshing' or quiet wing-beat sounds during all landings and departures from Nest 1. Murrelets approached Nest 3 by flying through a bog clearing, then along a 5-m wide path in the forest uphill for about 40 m to the nest tree. Nest 3 was located on the north edge of the path. The path remained from mining exploration approximately 15 to 25 years ago and is covered in Vaccinium q. and conifer saplings. Birds flew as low as 7–10 m above the ground when approaching and leaving the nest tree. Wingbeats were heard on one half of flights to and from Nest 3." (p. 31–33) A total of 26 landings in 6 trees with inactive nests were observed in 1996, with landings occurring on 16 of the 37 dawn surveys. Inactive nests had subcanopy flights (i.e., either "fly-bys" near nest, or subcanopy circling/straight flights near the inactive nest tree) during 94% of dawn surveys. (p. 38, Table 10) Occupied flight behavior (i.e., subcanopy flights or above-canopy circling) was observed near 19 (57%) of the active and inactive nest trees monitored during 1995–1997. (p. 46) Author suggests that occupied behaviors may indicate not only nesting, but past nesting or future nesting, based on their observations of occupied behaviors at both active and inactive nest sites.
Potential sources of bias or error	None apparent
Effects modifiers[10]	Habitat effects unlikely but possible
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Evidence for nesting.
7 Types and definitions of vocalizations and/or flight characteristics recorded.
8 Were behaviors observed in areas with known nesting habitat or known non-nesting habitat?
9 List specific results that are most pertinent to answering the question; include P-values, confidence limits, range of values, standard deviations, or other measures of variation.
10 Potential factors that may have affected results and comparability relative to other studies.

Table A7.1.7

Study Citation	Naslund 1993
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Big Basin Redwoods State Park, Santa Cruz County, CA
Study area habitat	Large stand of old-growth redwood-Douglas fir forest in the Santa Cruz Mountains, CA
Study design[1]	Quantitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing
Years of study	1989–1990
Within-year study period[4]	Nest observations during 10 June–31 July
Sample sizes[5]	Occupied behaviors observed at 2 nests over 2 breeding seasons. [Note that we do not include data already extracted for Singer et al. (1991) who studied the same nest sites in 1989. Both nests were active in 1989 and inactive in 1990].
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Thesis/dissertation
How was nesting determined?[6]	Nestling
Behaviors recorded[7]	Sub-canopy flight, Circling above canopy
Was "circling" defined?	No
Nesting/non-nesting habitat?[8]	Nesting habitat
Distances from nests?	No
Distances from nesting habitat?	No
Pertinent results, including statistical significance values and measures of variation[9]	Occupied behaviors observed at 2 nests over 2 breeding seasons [Note that we do not include data already extracted for Singer et al. (1991) who studied the same nest sites in 1989. Both nests were active in 1989 and inactive in 1990]. (p. 47) Occupied behaviors (subcanopy flights or circling above canopy) were observed in the vicinity of the Waddell Creek nest on 93% (n = 14) and 67% (n = 18) of intensive AV surveys in the summers of 1989 (when nest was active) and 1990 (when nest was inactive), respectively. (p. 47–48, Table 1.5) Occupied behaviors (subcanopy flights or circling above canopy) were observed in the vicinity of the Opal Creek nest during 83% of the intensive surveys in both summer 1989 (n = 6 surveys; nest active) and summer 1990 (n = 12 surveys; nest inactive). (p. 55) "Murrelets did not reuse the Opal Creek nest following-nesting failure in 1989. No nesting attempts were made ateither nest in 1990. However, murrelets did engage in stationary calls or flight behaviors associated with nesting (e.g. below canopy flights including fly-bys, flying-in tandem, tail-chasing,

Study Citation	Naslund 1993
Pertinent results, including statistical significance values and measures of variation (cont.)[9]	stall-flights, landings, or departures) in the vicinity of both nests during the summer of 1990. Murrelets flew below canopy on 13 of 19 surveys conducted at Waddell Creek during summer 1990 and 14 of 18 surveys at Opal Creek."
Potential sources of bias or error	None apparent
Effects modifiers[10]	Nest was in a different (redwood-dominated) habitat type than found in most of Oregon, but unknown if that would lead to a modifying effect.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).

2 Anecdotal, descriptive, or experimental, control groups, replicates.

3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.

4 How often were data collected within a season?

5 Number of birds, nests, sites, replicates, visits.

6 Evidence for nesting.

7 Types and definitions of vocalizations and/or flight characteristics recorded.

8 Were behaviors observed in areas with known nesting habitat or known non-nesting habitat?

9 List specific results that are most pertinent to answering the question; include P-values, confidence limits, range of values, standard deviations, or other measures of variation.

10 Potential factors that may have affected results and comparability relative to other studies.

Table A7.1.8

Study Citation	Nelson and Hardin 1993
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Central Oregon Coast, same locations as Nelson and Peck (1995).
Study area habitat	Mature/old-growth coniferous forest
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, Climbing
Years of study	1992
Within-year study period[4]	25 May–15 Aug
Sample sizes[5]	The only relevant information in this report not already found in Nelson and Peck (1995), was the observation of occupied flight behavior at an inactive nest.
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
How was nesting determined?[6]	Nest-cup
Behaviors recorded[7]	Landing/take-off, Sub-canopy flight, Circling above canopy
Was "circling" defined?	No
Nesting/non-nesting habitat?[8]	Both
Distances from nests?	No
Distances from nesting habitat?	No
Pertinent results, including statistical significance values and measures of variation[9]	(p. 19) At an inactive nest site at Siuslaw 1, "a single bird was observed for 5 minutes circling around the nest tree on 5 Aug. The bird circled 7 times and landed momentarily on the nest limb between 4 of the circles. No activity was recorded on subsequent surveys."
Potential sources of bias or error	None apparent
Effects modifiers[10]	None apparent
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Evidence for nesting.
7 Types and definitions of vocalizations and/or flight characteristics recorded.
8 Were behaviors observed in areas with known nesting habitat or known non-nesting habitat?
9 List specific results that are most pertinent to answering the question; include P-values, confidence limits, range of values, standard deviations, or other measures of variation.
10 Potential factors that may have affected results and comparability relative to other studies.

Table A7.1.9

Study Citation	Nelson and Peck 1995
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Central Oregon Coast Range.
Study area habitat	Mature/old-growth coniferous forests
Study design[1]	Qualitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing, Cameras, Sound recording near nests.
Years of study	1990–1992
Within-year study period[4]	All observations fell between 14 May and 2 Sep
Sample sizes[5]	Behavior of adults observed at 9 active nests. Adult vocalizations observed at all 9 nests. $n = 42$ incubation exchanges and n = 62 chick feedings (i.e., subcanopy flights and landings). $n > 2$ circling above nest canopy. $n = 3$ jet sounds near nests.
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
How was nesting determined?[6]	Nestling, Egg, Incubating adult
Behaviors recorded[7]	Landing/take-off, Sub-canopy flight, Circling above canopy, Dives, Wing-whirring, Jet sounds, Stationary calls
Was "circling" defined?	No
Nesting/non-nesting habitat?[8]	Nesting habitat
Distances from nests?	Yes
Distances from nesting habitat?	No
Pertinent results, including statistical significance values and measures of variation[9]	Subcanopy flights observed at all nests during incubation exchanges (n = 42) and chick feedings (n = 62).
	(p. 48) On two occasions, adults simultaneously arrived at the nest for a feeding visit. On both occasions, one of the adult then left the nest and circled above the nest stand, only to return to the nest after the other adult departed.
	(p. 49) Murrelets used consistent flight paths when entering and exiting nests through the forests. Murrelets generally approached the nests at heights lower than the nest (sometimes as low as 5 m above ground level), rising to "stall" just prior to reaching the landing pad. Landings could sometimes be heard from the ground. Outgoing birds dropped 5–30 m before ascending above the canopy. After ascending through the canopy, these birds either flew directly away from nest, or circled away from nest.
	(p. 49) "Flight patterns observed in association with nests and nest stands included flights through, into and out of the forest canopy, landing in trees, calling from stationary locations, circling through or above the forest canopy, and flying straight

Study Citation	Nelson and Peck 1995
Pertinent results, including statistical significance values and measures of variation (cont.)[9]	above or below the canopy. Landings and departures in trees near known nests were often seen throughout the breeding season, although most of this activity occurred in July. In addition, birds were observed landing on nest limbs or other limbs in known nest trees in years subsequent to discovery. For example, a bird was observed landing on the Valley of the Giants 1990 nest limb in 1992 and 1993, but birds did not nest there in those years. Murrelets sometimes also created sounds with their wings during landings and take-offs from trees, and while flying through and over the canopy. In addition, on 3 occasions, a rapid, dive combined with a loud sound, similar to a jet engine of an airplane, was heard adjacent to nests." (p. 50) Soft (i.e., groan and whistle) vocalizations from adults were heard at all nine nests, but loud adult calls (groan and keer calls) were uncommon and only heard at four of the nests.
Potential sources of bias or error	None apparent
Effects modifiers[10]	None apparent
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Evidence for nesting.
7 Types and definitions of vocalizations and/or flight characteristics recorded.
8 Were behaviors observed in areas with known nesting habitat or known non-nesting habitat?
9 List specific results that are most pertinent to answering the question; include P-values, confidence limits, range of values, standard deviations, or other measures of variation.
10 Potential factors that may have affected results and comparability relative to other studies.

Table A7.1.10

Study Citation	Nelson and Wilson 2002
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Clatsop, Tillamook, and Elliott State Forests, OR
Study area habitat	A mosaic of mature and old-growth coniferous forest stands, in the Sitka Spruce and Western Hemlock zones of the Oregon Coast Range
Study design[1]	Both
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing
Years of study	1995–1999
Within-year study period[4]	May–Aug
Sample sizes[5]	None—n.a.
Statistical analysis of results	Not applicable
Statistical power	Unpublished report
Document type	Nestling, Egg, Incubating adult, Nest-cup
How was nesting determined?[6]	Landing/take-off, Sub-canopy flight, Circling above canopy, Stationary calls
Behaviors recorded[7]	No
Was "circling" defined?	Nesting habitat
Nesting/non-nesting habitat?[8]	Yes
Distances from nests?	No
Distances from nesting habitat?	No
Pertinent results, including statistical significance values and measures of variation[9]	(Table 2, p. 21) Nests found by climbers following observations of birds landing. (p. 93–95, Table 35, in combination with p. 21–22, Table 2) Circling was observed a total of 33 times, at 5 of the 7 survey sites containing active nests in that year and for a total of 84 times at 10 of the 41 survey sites containing inactive nests but no known active nests in that year. Below-canopy flights were observed a total of 785 times, at 7 of the 7 survey sites containing active nests in that year and for a total of 846 times at 19 of the 41 sites containing inactive nests but no known active nests in that year. (p. 109) "We also think it important to note some of the interesting behaviors we observed at nests prior to egg laying. At 3 nests in Oregon, including the 1997 Little Rackheap and the 1998 North Rector nests, landings were observed in the nest tree prior to actual egg laying. At these nests, 2 adults generally arrived together and spent <1 to 33 min together on the nest limb copulating or preparing the nest for egg laying. The adults could often be heard softly vocalizing during these nests visits, and they sometimes gave one to 2 loud "keer" calls as they left the nest limb."

Study Citation	Nelson and Wilson 2002
Potential sources of bias or error	None apparent
Effects modifiers[10]	Habitat effects (e.g., old-growth vs. mature stands) unlikely but possible.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Evidence for nesting.
7 Types and definitions of vocalizations and/or flight characteristics recorded.
8 Were behaviors observed in areas with known nesting habitat or known non-nesting habitat?
9 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
10 Potential factors that may have affected results and comparability relative to other studies.

Table A7.1.11

Study Citation	Nelson et al. 1994
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Central Oregon Coastal Range, in the Valley and the Giants and at another area near Coos Bay
Study area habitat	Old-growth/mature coniferous forests with known concentrations of murrelet detections.
Study design[1]	Both
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing, Cameras, Eggshell searches near the bases of potential nest trees.
Years of study	1993
Within-year study period[4]	Audio-visual observations during May–Aug and tree-climbing from 24 Aug–2 Nov
Sample sizes[5]	Made audio-visual observations of murrelets near 1 active and 11 inactive nests. Observed >34 subcanopy flights, 5 landings, 4 vocalizations from nest, and 54 instances of circling.
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
How was nesting determined?[6]	Nest-cup, Eggshell fragments
Behaviors recorded[7]	Landing/take-off, Sub-canopy flight, Circling above canopy, Stationary calls
Was "circling" defined?	No
Nesting/non-nesting habitat?[8]	Nesting habitat
Distances from nests?	No
Distances from nesting habitat?	No
Pertinent results, including statistical significance values and measures of variation[9]	(p. 29, Table 4) At the 1 active nest site in the Lower Valley site, murrelets were observed flying through the canopy and landing during 2 days of observations. (p. 29, Table 4) There were 6 inactive nests in the Upper Plateau site in the Valley of the Giants (a ~500 m by ~800 m plot). In 25 survey days at that plot, there were 54 observations of birds circling above canopy, 5 observations of below-canopy circling, 27 subcanopy (direct) flights, 1 landing, and 4 stationary calls. (p. 9) Murrelets were observed landing in 3 adjacent trees at the School Marm site and subsequently, 2 inactive nests were found when those 3 trees were climbed. Similarly, an inactive nest was found in a tree where a murrelet landed in the Five Mile Flume site. The authors stated that it was not clear if nesting was initiated at any of those landing sites, however, and that it was possible that the landings were related only to pre-nesting or non-nesting behaviors.

Study Citation	Nelson et al. 1994
Potential sources of bias or error	None apparent
Effects modifiers[10]	None apparent
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).

2 Anecdotal, descriptive, or experimental, control groups, replicates.

3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.

4 How often were data collected within a season?

5 Number of birds, nests, sites, replicates, visits.

6 Evidence for nesting.

7 Types and definitions of vocalizations and/or flight characteristics recorded.

8 Were behaviors observed in areas with known nesting habitat or known non-nesting habitat?

9 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.

10 Potential factors that may have affected results and comparability relative to other studies.

Table A7.1.12

Study Citation	Singer et al. 1991
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Big Basin Redwoods State Park, Santa Cruz County, CA
Study area habitat	large stand of old-growth redwood-Douglas-fir forest in the Santa Cruz Mountains, CA
Study design[1]	Both
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing, Ground-searching for eggshells
Years of study	1989
Within-year study period[4]	Nest observations during 10 Jun–31 Jul
Sample sizes[5]	Made behavioral observations in the vicinity of 2 active nests. n = 51 nest exchanges or chick-feedings (i.e., subcanopy flights). Also observed "tail-chasing" (n = 6); "buzzing" (n > 1); "stall-flight" (n > 1); and "fly-bys" (n > 1). n = 1 stationary call at an active nest.
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
How was nesting determined?[6]	Nestling, Nest-cup
Behaviors recorded[7]	Landing/take-off, Sub-canopy flight, Stationary calls
Was "circling" defined?	No
Nesting/non-nesting habitat?[8]	Nesting habitat
Distances from nests?	No
Distances from nesting habitat?	No
Pertinent results, including statistical significance values and measures of variation[9]	(p. 331) A few seconds of soft vocalizations was heard coming from an active nest site
	(p. 335) Several distinctive subcanopy behaviors were observed near the active nest sites, including "tail-chasing" where one bird flies closely behind another (*n* = 6); "buzzing" where a single bird flies at 10–30 m above ground level making a continuous low-pitched buzzing wing sound (*n* >1); "stall-flight" where a low-flying bird hovers over a branch, or lands momentarily, before flying on (*n* >1); and "fly-bys" where a single bird flies silently past the nest at approximately the same height as the nest (*n* >1, but stated that this was "observed frequently").
	(p. 337) " Most birds arrived (at the nest) from the west and departed to the west, flying over the tops of some younger redwoods on the edge of the clearing."
	(p. 337) Nest exchanges or chick-feeding (i.e., subcanopy flights) observed on 51 occasions.

Study Citation	Singer et al. 1991
Potential sources of bias or error	None apparent
Effects modifiers[10]	Nest was in a different (redwood-dominated) habitat type than found in most of Oregon, but unknown if that would lead to a modifying effect.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Evidence for nesting.
7 Types and definitions of vocalizations and/or flight characteristics recorded.
8 Were behaviors observed in areas with known nesting habitat or known non-nesting habitat?
9 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
10 Potential factors that may have affected results and comparability relative to other studies.

Table A7.1.13

Study Citation	Singer et al. 1995
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Big Basin Redwoods State Park, Santa Cruz County, CA
Study area habitat	Largest remaining stand (~1,700 ha) of old-growth redwood-Douglas-fir forest in Santa Cruz Mountains
Study design[1]	Both
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing
Years of study	1991–1994
Within-year study period[4]	5 May–3 Jul 1991, 24 May–7 Jun 1992, 3 Apr–1 Aug 1993, 2 Apr–31 Jul 1994
Sample sizes[5]	Observed flight behavior for 3 years near an active nest and 1 year at a nest that likely failed early in incubation. $n = 17$ nest exchanges (i.e., subcanopy flights), 26 feeding visits (i.e., subcanopy flights), >25 subcanopy "flybys," and 2 stationary vocalizations.
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
How was nesting determined?[6]	Nestling, Nest-cup, Eggshell fragments, Fecal ring
Behaviors recorded[7]	Landing/take-off, Sub-canopy flight, Wing-whirring, Stationary calls
Was "circling" defined?	No
Nesting/non-nesting habitat?[8]	Nesting habitat
Distances from nests?	Yes
Distances from nesting habitat?	No
Pertinent results, including statistical significance values and measures of variation[9]	(p. 54) Nests were found in same redwood tree in 1991, 1992 (different branch in same tree), and 1994 (same nest-cup as that was used in 1991). Eggshell fragments were found below tree in 1993 (early May), suggesting to authors that the nest suffered predation in that year. (p. 54) "Below-canopy flights were common within the nesting stand, but were concentrated along repeatedly used flight routes. Adults accessed nest sites by flying for at least 100 m through the canopy along these routes." Authors speculated (p. 61) that the below-canopy flight routes may help reduce predation at nests and reduce predation of adults flying to and from the nest. (p. 57–59) Total numbers of behavioral observations near active nests in 1991, 1992 and 1994 included 17 nest exchanges (i.e., subcanopy flights), 26 feeding visits (i.e., subcanopy flights), subcanopy "flybys" of adult birds flying past the nest at nest height on 25 of 27 mornings in 1991 and "several" times in both 1992

Study Citation	Singer et al. 1995
Pertinent results, including statistical significance values and measures of variation (cont.)[9]	and 1994, and 2 stationary calls from the nest (4 soft "grunt" calls on 1 occasion and some "faint lisping whistles" and "3 loud nasal" calls on the second occasion). (p. 58–59) One subcanopy flight path extended a total of 182 m from the nest location to a stream corridor and another subcanopy flight path extended 109 m from the nest tree to a stream corridor. (p. 59) Adults flying to and from the nest usually were silent, except for occasional audible wingbeats (and the two instances of stationary calling mentioned above).
Potential sources of bias or error	None apparent
Effects modifiers[10]	Nest was in a different (redwood-dominated) habitat type than found in most of Oregon, but unknown if that would lead to a modifying effect.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Evidence for nesting.
7 Types and definitions of vocalizations and/or flight characteristics recorded.
8 Were behaviors observed in areas with known nesting habitat or known non-nesting habitat?
9 List specific results that are most pertinent to answering the question; include P-values, confidence limits, range of values, standard deviations, or other measures of variation.
10 Potential factors that may have affected results and comparability relative to other studies.

Table A7.1.14

Study Citation	Suddjian 2003
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	South Fork of Butano Creek watershed (study area) and Pescadero watershed (control area), San Mateo County, CA
Study area habitat	Remnant stand of old-growth redwood/Douglas-fir forest (in control areas and in southern portion of study area) and younger stands of same habitat type (with scattered residual old-growth trees) in northern portion of study area
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual
Years of study	1992–2001
Within-year study period[4]	28 Apr–29 Jul
Sample sizes[5]	*n* = 4 study sites with known nests (i.e., Unit A [1994 and 2000], Unit B 1996, 2000), Dearborn Control site (1997), and Hidden Gulch Control site (1995). Numerous detections of occupied behaviors were observed in all year's at all 4 sites.
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
How was nesting determined?[6]	Nestling, Egg, Eggshell fragments
Behaviors recorded[7]	Sub-canopy flight
Was "circling" defined?	No
Nesting/non-nesting habitat?[8]	Nesting habitat
Distances from nests?	No
Distances from nesting habitat?	No
Pertinent results, including statistical significance values and measures of variation[9]	(p. 12) A total of 23,083 detections were observed over the course of the study, including 3,101 occupied detections. (p. 13, Figures 20–22) Below-canopy flights, landings, and stationary calling were commonly recorded at all stations over the years in Unit A. (p. 14, Figures 20–22) Subcanopy flights and landings were commonly observed in Unit B. (p. 15–19; Figure 25) Evidence of nesting was found at the Dearborn Control site (eggshells under tree in 1997), Hidden Gulch control site (raven egg predation event observed in 1995), Unit A (eggshells found under two trees in 1994, a grounded fledgling observed in 2000), and Unit B (grounded fledgling found in 1996, predated nest found in 2000). No direct evidence of nesting was observed in Units C or D.

Study Citation	Suddjian 2003
Pertinent results, including statistical significance values and measures of variation (cont.)[9]	(Table 8) Multiple observations of occupied behavior (subcanopy behaviors) were observed in both the Big Creek Timber company (i.e., with residual old-growth) and Butano State Park (i.e., old-growth) portions of Units A&B in all years of study during 1992–2001. Occupied detections also were observed most years at Units C&D (i.e., the 2 sites without definitive presence of nests), but in lower numbers than at Units A&B. (Figures 21 and 22) Occupied detections (subcanopy behaviors) were observed on >40% of surveys during all years at Unit A and on >40% of surveys during 7 of 10 years at Unit B. (Table 10) Multiple observations of occupied behavior (subcanopy behaviors) were observed in the Hidden Gulch and Dearborn control sites in all years of study (1993–2001).
Potential sources of bias or error	None apparent
Effects modifiers[10]	Different (redwood-dominated) habitat type than found in most of Oregon, but unknown if that would lead to a modifying effect in behavior.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Evidence for nesting.
7 Types and definitions of vocalizations and/or flight characteristics recorded.
8 Were behaviors observed in areas with known nesting habitat or known non-nesting habitat?
9 List specific results that are most pertinent to answering the question; include P-values, confidence limits, range of values, standard deviations, or other measures of variation.
10 Potential factors that may have affected results and comparability relative to other studies.

Table A7.1.15

Study Citation	Varoujean et al. 1989
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Near the Brandy bar on the Umqua River, ~22 km from the coast, Douglas County, OR
Study area habitat	Mature coniferous forest, with patches of older Douglas-fir
Study design[1]	Both
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, Climbing, Telemetry
Years of study	1988
Within-year study period[4]	Telemetry observations 14–23 Jun 1988, AV surveys during 15 Jun–19 Aug 1988
Sample sizes[5]	Flight behavior observed near 1 presumed nest site (based on telemetry-derived attendance pattern). *n* = 3 circling events by telemetered bird and *n* = 20 circling pairs seen by AV observers
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Agency technical report paper
How was nesting determined?[6]	A telemetered bird exhibited a 24-h attendance pattern at the site
Behaviors recorded[7]	Landing/take-off, Circling above canopy
Was "circling" defined?	No
Nesting/non-nesting habitat?[8]	Nesting habitat
Distances from nests?	No
Distances from nesting habitat?	No
Pertinent results, including statistical significance values and measures of variation[9]	(p. 18–20, Table 5) A telemetered bird circled for 5–9 minutes before landing at its presumed nest site on 3 of 4 visits. On the way back to sea, however, the telemetered bird was never observed circling after takeoff; it always made a direct flight away from the nest (*n* = 5 mornings). (p. 21–22, Table 6) Circling pairs of birds over the basin containing the presumed nest site were observed by AV observers a total of 20 times, after the telemetry device apparently failed. "Location of the primary observation station (Figure 2) allowed us to follow the course of circling murrelets until they descended into the forest at the north end of the basin, where they were lost from sight. In general, circling pairs of murrelets flew an oval course that followed the east and west ridge lines of the basin, and it took 11–27 seconds to complete 1 full turn around the oval. Up to 6 pairs of circling Marbled Murrelets were observed on 1 day, and 1 of these pairs circled over the basin 7 times before descending below the forest canopy."

Study Citation	Varoujean et al. 1989
Potential sources of bias or error	No nest found when the 3 trees at telemetry location were climbed, but bird assumed to be incubating because of its 24-hour attendance pattern. Thus it is possible (but believed by authors to be unlikely) that the bird did not actually nest there.
Effects modifiers[10]	
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).

2 Anecdotal, descriptive, or experimental, control groups, replicates.

3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.

4 How often were data collected within a season?

5 Number of birds, nests, sites, replicates, visits.

6 Evidence for nesting.

7 Types and definitions of vocalizations and/or flight characteristics recorded.

8 Were behaviors observed in areas with known nesting habitat or known non-nesting habitat?

9 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.

10 Potential factors that may have affected results and comparability relative to other studies.

Table A7.1.15

Study Citation	Witt 1998
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Radar Creek drainage of the Coast Range, 34 km NW of Roseburg, Douglas County, OR
Study area habitat	Old-growth Douglas-fir forest.
Study design[1]	Both
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing, Cameras
Years of study	1994
Within-year study period[4]	19 Jul–29 Aug 1994
Sample sizes[5]	Subcanopy and circling behaviors observed during 25 of 28 morning surveys and 3 of 5 evening surveys at the active nest site.
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
How was nesting determined?[6]	Nestling
Behaviors recorded[7]	Landing/take-off, Sub-canopy flight, Circling above canopy, Wing-whirring, Jet sounds
Was "circling" defined?	No
Nesting/non-nesting habitat?[8]	Nesting habitat
Distances from nests?	No
Distances from nesting habitat?	No
Pertinent results, including statistical significance values and measures of variation[9]	An active nest was found at the inland edge of the species' range. The authors state it is likely that all of the flight behaviors that they observed at this stand were of a single pair of nesting birds. (p. 28, text and Table 1) Subcanopy and circling behaviors observed near the active nest site during 25 of 28 morning surveys and on 3 of 5 evening surveys. Further, landing or taking off from the nest tree was observed on at least 20 of 32 surveys, direct flights below canopy were observed on at least 5 of 32 surveys, circling (height relative to canopy unknown) was observed during at least 1 survey, and direct flights over the canopy were observed on at least 3 of 32 surveys. In addition, 82% of all visual detections were below-canopy detections and 5% of visual detections were >1.75 X canopy height. (p. 29) Wing sounds, including wingbeats and the "jet sounds" were heard on 7 occasions, always just prior to an adult entering the nest tree.

Study Citation	Witt 1998
Potential sources of bias or error	None apparent
Effects modifiers[10]	Seasonal effects possible because only studied the chick-rearing period), but it is unknown what those effects might have been.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Evidence for nesting.
7 Types and definitions of vocalizations and/or flight characteristics recorded.
8 Were behaviors observed in areas with known nesting habitat or known non-nesting habitat?
9 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
10 Potential factors that may have affected results and comparability relative to other studies.

Appendix 7.2. Data extraction tables for Question 2:

"To what extent do Marbled Murrelets exhibit nest-site fidelity at various spatial scales (i.e., at the scale of a watershed, forest stand, tree, branch, and platform), and how does the spatial extent of continuous potential habitat affect nest-site fidelity?"

Table A7.2.1

Study Citation	Barbaree et al. 2014
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Port Snettisham (SE of Juneau), Southeastern Alaska
Study area habitat	Small- or medium-productivity old-growth forest (Western Hemlock, Mountain Hemlock, Sitka Spruce) at lower elevations, rocky and alpine habitats above 600 m elevation
Study design[1]	Qualitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Climbing, Telemetry, Aerial surveys; some ground-based visits to nests, but were unable to climb trees to look for nest-platforms
Years of study	2007–2008
Within-year study period[4]	15 May–16 (?) Sep 2007, 26 May–16 (?) Sep 2008 [exact dates not presented--these are extremes mentioned]
Sample sizes[5]	35 active nests (but only 33 able to be found)
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Watershed
How was nesting determined?[7]	Telemetry
Multiple nesting for known individuals?[8]	Yes
Extent of habitat (area)[9]	Port Snettisham = 2 main watersheds (Speel River, Whiting River) is old-growth forest except for powerline cut along N side Speel Arm (width unknown); other nests found in nearby Tracy Arm (wilderness area) and Admiralty Island (wilderness area)
Nests within or between years?	Within year
Pertinent results, including statistical significance values and measures of variation[10]	(p. 177) Located with aerial surveys and described 33 active nest sites, plus had 2 other nests that they never could locate; nest locations verified by ≥2 detections of radio-tagged murrelet at same location during aerial surveys. Visited 7 of these nest-sites on the ground. (p. 177, Fig. 3) Nest-sites located in Port Snettisham watershed (n = 28, with 17 in Speel Arm, 8 in Whiting River, and 3 in unstated locations), on Snettisham Peninsula (n = 3), in Tracy Arm (n = 1), or on Admiralty Island (n = 2). Not stated explicitly that multiple nests occurred in a specific area in the same year or multiple years, but the essentially-identical nest-initiation rates between years imply multiple nests in most areas in both years. (p. 177–178) Found nest-sites in forests (n = 15) and on ground (n = 16); also had 4 nests where forested and unforested areas both occurred, so habitat could not be determined with certainty. Tree nests included Western Hemlock (n = 4), Mountain Hemlock (n = 1), Sitka Spruce (n = 1), and unidentified tree

Study Citation	Barbaree et al. 2014
Pertinent results, including statistical significance values and measures of variation[10]	(n = 1). Ground nests included rocky cliff-faces (n = 10), often in areas with trees, and alpine scree or rocky slopes near or above tree-line (n = 6). (p. 179) 4 (16%) of 25 murrelets that failed in first nest renested, all after 21 Jun, whereas 0 (0%) of 8 murrelets renested if nest failed during nestling period; hence, 4 (24%) of 17 nests that failed during incubation renested. Renesting occurred in same location and nest-site type as first nesting attempts, but reuse of exactly same nest-cups could not be determined because nests were unable to be visited. (p. 179) Renesting murrelets laid second egg 11–20 days after failure of first nest.
Potential sources of bias or error	Appears to be good random sample of birds on the water early in summer, some of which nested later. In addition, not all nested within a particular area, instead nesting over a broad area in the surrounding vicinity, so appeared to provide a good random sample of birds, nesting, and nesting attempts in this area.
Effects modifiers[11]	Data are from AK, so comparability to OR may be questionable. However, doubtful that tree type has significant effect on reuse, so this behavior probably transcends forest type and instead depends more on issues such as overall habitat availability.
Additional notes	Unfortunately, because of small sample sizes, breakdowns of numbers of males and females tagged by year and numbers of nests in each habitat type/area by year are not detailed.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Evidence for nesting.
8 Was multiple nesting documented for known individuals?
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include P-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.2.2

Study Citation	Bloxton and Raphael 2009
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Olympic Peninsula, WA (primary study area), Cascade Mountains, WA, and southern Vancouver Island, BC
Study area habitat	Not described; however, appeared to be mostly forested area with one nest found on cliff
Study design[1]	Qualitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing, Telemetry
Years of study	2004–2008
Within-year study period[4]	27 Apr–1 Aug 2004, 28 Apr–4 Sep 2005, 27 Apr–24 Jul 2006, 3 May–10 Aug 2007, 9 May–7 Aug 2008
Sample sizes[5]	14 nests on Olympic Peninsula, 1 in Cascade Mountains, and 5 on SW Vancouver Island; however, not all nest locations found; only 1 nest rechecked in subsequent year
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Watershed, larger area (Olympic Peninsula, SW Vancouver Island)
How was nesting determined?[7]	Nestling, egg, incubating adult, nest-cup, eggshell fragments, fecal ring, feathers, adult landing/taking-off, telemetry, cameras
Multiple nesting for known individuals?[8]	No
Extent of habitat (area)[9]	Not specified; however, nests found from Olympic Peninsula to Vancouver Island
Nests within or between years?	Both
Pertinent results, including statistical significance values and measures of variation[10]	(p. 5–6) 3 active nests found in 2004, 7 found in 2005, 2 found in 2006, 5 found in 2007, and 2 found in 2008. (p. 11) In addition, found one active nest without telemetry in 2006. This nest, in Olympic National Park, appeared to be successful in 2006 (it had a large, prominent fecal ring) was checked again in 2007 and there was a nest in the same spot, indicating fidelity and reuse of nest-cups. (p. 8) Table of characteristics of 18 nest-sites found presented in Table 2. One nest actually was on a cliff. (p. 11) The authors did not appear to revisit nest-sites from one year to next to determine whether those sites were reused in any subsequent years. Only exception was a nest-site that was found independently, which they did recheck and that was reused in following year—but they did not recheck it again in the final year of the study. (Appendices) Multiple nests found within watershed for North Fork Soleduck River, but in different years.

Study Citation	Bloxton and Raphael 2009
Potential sources of bias or error	Seems to be thorough study in which aerial telemetry was used to locate nest areas, then ground-based telemetry was used to locate nest-sites. Appears to be good random sample of birds at sea, as indicated by the extensive area over which these birds nested.
Effects modifiers[11]	Most nests in Douglas Fir, Western Hemlock, and Western Redcedar, so comparability to OR probably pretty good. One nest on a cliff, so comparability to OR unclear.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Evidence for nesting.
8 Was multiple nesting documented for individual birds?
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.2.3

Study Citation	Burger 1994
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Carmanah-Walbran watersheds, southwestern Vancouver Island, BC
Study area habitat	Valley-bottom old-growth coastal forest; dominant tree species included Western Hemlock, Sitka Spruce, Western Redcedar, and Amabilis Fir; many trees 200–600 yr old, and some >1,000 yr old
Study design[1]	Qualitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing
Years of study	1990–1993
Within-year study period[4]	Mid-May–early Aug 1990, late Apr–early Aug 1991–1993
Sample sizes[5]	6 nests found (1 in 1990, 1 in 1991, 3 in 1992, and 1 in 1993)
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Watershed
How was nesting determined?[7]	Nest-cup, Eggshell fragments, Fecal ring, Feathers
Multiple nesting for known individuals?[8]	No
Extent of habitat (area)[9]	Carmanah Valley is 22-km-long unlogged watershed; Walbran Valley is not described
Nests within or between years?	Both
Pertinent results, including statistical significance values and measures of variation[10]	Details of nest-sites published in Manley and Kelson (1995)—also reviewed for this project.
	(p. 21) Six nests found, 5 in Sitka Spruce and 1 in Western Hemlock.
	(p. 22) All nests found in 1992 checked by climbers in each year following discovery, but no evidence that nest-sites or nest-trees were used again in subsequent years—no renesting within 3 yr (*n* = 1), 2 years (*n* = 2), or 1 yr (*n* = 5).
	(p. 22–23) Obvious nest depressions were evident 1 yr after use in some cases, but nests were barely visible as brown patches in moss 2 yr after use. 2 of nests found in 1992 were old and appeared to have been used in previous year, as indicated by growth of epiphytes in and near the nest-cup.
Potential sources of bias or error	Authors indicated that valley-bottoms were sampled well but valley-sides were not. Sampling appeared to have been well designed and conducted.

Study Citation	Burger 1994
Effects modifiers[11]	Data are from BC, so comparability to OR may be questionable. However, doubtful that tree type has significant effect on reuse, so this behavior probably transcends forest type and instead depends more on issues such as overall habitat availability.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Evidence for nesting.
8 Was multiple nesting documented for individual birds?
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include P-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.2.4

Study Citation	Burger et al. 2000
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Southeastern Vancouver Island, BC
Study area habitat	Old-growth dry coastal Douglas Fir and Western Hemlock forest
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, Climbing
Years of study	1998–1999
Within-year study period[4]	Not specified in 1998; 13 May–16 Jul in 1999
Sample sizes[5]	3 nests
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Watershed, Stand, Tree
How was nesting determined?[7]	Nest-cup, Eggshell fragments
Multiple nesting for known individuals?[8]	No
Extent of habitat (area)[9]	67 stands, of which 49 were sampled, were determined to have suitable nesting habitat, which was described as being old-growth forest with mixed canopy height, some old trees, and an area >1 ha
Nests within or between years?	Both
Pertinent results, including statistical significance values and measures of variation[10]	(p. 23–24, Table 12) Two nests found in one tree, one nest found in a tree in another stand. The two nests in one tree were estimated at 1–2 and 2–3 years old, and nest in other tree was estimated at 1 year old; large eggshell fragments found in nest, suggesting that nest was not successful. (p. 24) Additional audiovisual detections indicate that multiple nests were being used in Sooke Hills Park and the Greater Victoria Water Supply Area, plus on Weyerhaeuser lands. These are the largest and least-fragmented remnants of old-growth and mature forests on SE Vancouver Island.
Potential sources of bias or error	Appears to be carefully developed sampling design for looking at patches of old-growth forest near Victoria by first screening for suitability for nesting, then surveyed the area intensively and climbed trees after 1999 breeding season.

Study Citation	Burger et al. 2000
Effects modifiers[11]	Data are from BC, so comparability to OR may be questionable. However, doubtful that tree type has significant effect on reuse, so this behavior probably transcends forest type and instead depends more on issues such as overall habitat availability.
Additional notes	On p. 11–12, description of dates on which stands were visited is somewhat confusing (13 May–10 Jun for first visit, 3 Jun–6 Jul for second visit).

1 Brief description of study design (e.g., qualitative, quantitative).

2 Anecdotal, descriptive, or experimental, control groups, replicates.

3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.

4 How often were data collected within a season?

5 Number of birds, nests, sites, replicates, visits.

6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.

7 Evidence for nesting.

8 Was multiple nesting documented for individual birds?

9 Acreage of habitat, continuous or not, and how defined.

10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.

11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.2.5

Study Citation	Burger et al. 2009
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Southern Mainland Coast, Eastern Vancouver Island, and Western Vancouver Island murrelet conservation regions, BC
Study area habitat	Not described, although presumably in coastal old-growth coniferous forest
Study design[1]	Qualitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing, Telemetry
Years of study	On or before 1991 to 2008 or 2009
Within-year study period[4]	Not specified
Sample sizes[5]	Variable, depending on attribute
Statistical analysis of results	Descriptive statistics only: Chi-square test
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Watershed, Tree, Branch, Platform
How was nesting determined?[7]	Nestling, Egg, Incubating adult, Nest-cup, Eggshell fragments, Fecal ring, Telemetry
Multiple nesting for known individuals?[8]	No
Extent of habitat (area)[9]	Not clearly specified, but covers large areas, most of which have experienced some clearcutting
Nests within or between years?	Both
Pertinent results, including statistical significance values and measures of variation[10]	Data from variety of sources summarized in Table 1 (p. 220) (p. 219) During radio-tracking study at Desolation Sound, 1 bird tracked in both 1999 and 2001; separate nests found in trees within 200 m of each other. In same study, 1 radio-tagged male used same forest stand to renest in same year after failed first attempt, but unable to confirm whether same tree was used. (p. 219) In Bunster Range, interannual reuse of nest-trees occurred at 1 (12%) of 8 nest trees in 1996 and at 3 (11%) of 27 nest-trees in 1997. Of the 4 nest-trees that were reused, the same limb and nest-cup were reused in 2 (50%) of the trees and different limbs were reused in 2 (50%) of the trees. In Caren Range, 1 nest-cup was used in 2 successive years. At 1 of 2 nest-sites on southwestern Vancouver Island, 1 of 2 nest-cups was used in successive years. (p. 219–220) Of 1628 trees climbed in BC over numerous years and locations, 143 (9%) were found to be nest-trees. Of these 143 nest-trees, 26 (18%) showed evidence of multiple nesting (multiple nest-sites within the tree or other evidence that the tree was used >1 time). However, there was geographic variation in these patterns: 23% on Southern Mainland Coast (n = 92 nest-trees), 50% (n = 2 nest-trees) on Eastern Vancouver Island, and

Study Citation	Burger et al. 2009
Pertinent results, including statistical significance values and measures of variation (continued)[10]	8% (n = 49 nest-trees) in Western Vancouver Island. Overall, the reuse of nest-trees in highly disturbed regions (Southern Mainland Coast, Eastern Vancouver Island) was significantly higher (22 of 94 trees) than in less-disturbed region (Western Vancouver Island (4 of 49 trees). (p. 220–221) Detailed description of how many nests were recorded in nest-trees, with up to 3 nests found in a single tree. Some trees actually had 2 nest-cups on the same branch. (p. 221) In Southern Mainland Coast, 7 (23%) of 23 nest-trees checked in subsequent years showed evidence of reuse. However, nest-trees that were reused were not necessarily used in every year; similar studies by Manley found gaps of 1–2 years between reuse of a nest-tree. (p. 221) In Western Vancouver Island, 1 (7%) of 14 nests showed evidence of reuse; actually appeared to be using same nest-cup, although evidence inconclusive. (p. 221) Nests were revisited in Carmanah and Walbron valleys for several years; fishy odor and fecal ring not detectable to human 1 year after nesting; eggshell fragments present in nests for 3 years (1 nest for 4 years). Nest-cup depression and damage to moss visible for 3–4 years after nesting. Most nests evident to human observers =>2 years after nesting, and some for much longer. (p. 221) Clear evidence of reuse of nest-sites in BC, although no proof that reuse was done by same birds and no way to test whether reuse was affected by success or failure of previous years' nesting attempts. (p. 221–222) Clear spatial difference in reuse of nest-sites: (1) on Southern Mainland Coast (70% of suitable trees have been logged), 25% of nest-trees had >1 nest and 23% of nest-trees were reused within 3 yr of first use; (2) on Eastern Vancouver Island (77% of suitable trees have been logged), 50% of nest-trees had 2 nests (but only 2 trees examined); (3) on Western Vancouver Island (up to 47% of suitable trees have been logged in some areas but almost none in others), only 8% of nest-trees had >1 nest. (p. 222) Telemetry data suggest fidelity at larger scales, in that birds may not reuse the same nest-tree in subsequent years (some do), but they may nest in nearby trees in subsequent years. (p. 222) If replacement laying occurs, it may occur in the same forest stand, but relaying in same nest tree has not been documented. (p. 222) In California, where 95% of suitable nest-trees have been logged, reuse of nesting-trees, limbs, and nest-cups is common. (p. 222–223) One nest-tree in Oregon used in 1991 and 1993 but not 1992, and different limb used each year; other evidence for reuse of nest-trees in Washington and Oregon also mentioned but not presented.

Study Citation	Burger et al. 2009
Potential sources of bias or error	Authors admit that sample sizes are small in some regions, but the results still follow the broad-scale pattern of reuse.
Effects modifiers[11]	Data are from BC forests, but authors present data from other regions (including OR) that follow similar pattern.
Additional notes	Impressive job of pulling together scattered data from a variety of sources to make a coherent story. Includes data presented in Burger et al. (2000), Conroy et al. (2002), and Manley (1999), all of which were evaluated for this particular question. Also contains Vancouver Island data presented in Bloxton and Raphael (2009). However, paper includes additional, unpublished data not available in reports. Data presented here in Table 1 (52 trees monitored) also include data presented in Table 10 (36 trees monitored) in Manley (1999); however, this table also includes unpublished data from Manley to reach total of 52 trees monitored for re-use. Hence, this publication supersedes that one.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Evidence for nesting.
8 Was multiple nesting documented for individual birds?
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.2.6

Study Citation	Conroy et al. 2002
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Ursus Valley, Clayoquot Sound, Vancouver Island, BC
Study area habitat	Range of habitat quality for murrelets, from Suboptimal to Excellent (Unsuitable habitat was not evaluated); tree species included Western and Mountain hemlocks, Amabilis and Douglas firs, Western Redcedar, Yellow cedar, and Sitka Spruce
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Climbing
Years of study	1998–2000
Within-year study period[4]	Not defined
Sample sizes[5]	5 nests
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Tree
How was nesting determined?[7]	Nest-cup, Eggshell fragments, Fecal ring, Feathers
Multiple nesting for known individuals?[8]	No
Extent of habitat (area)[9]	Not specified, but appears to be extremely large area
Nests within or between years?	Both
Pertinent results, including statistical significance values and measures of variation[10]	(p. 127) Climbed 7 species of conifers totaling 467 trees. (p. 128) Located 5 nests; 1 was active in year of discovery, and other 4 had been used in previous years. All nests were in habitat rated as Excellent; none were in Good or Suboptimal habitat. (p. 135) 2 nests were in Western Redcedar, 1 was in Amabilis Fir, 1 was in Western Hemlock, and 1 was in Sitka Spruce.
Potential sources of bias or error	Potential platform densities were assessed only by observers on the ground with binoculars. Authors admitted that design for sampling potential nest-trees had weaknesses.
Effects modifiers[11]	Data are from BC, so comparability to OR may be questionable. However, doubtful that tree type has significant effect on reuse, so this behavior probably transcends forest type and instead depends more on issues such as overall habitat availability.

Study Citation	Conroy et al. 2002
Additional notes	No way to tell whether any of the nests that were located were from the same watershed or stand of trees.

1 Brief description of study design (e.g., qualitative, quantitative).

2 Anecdotal, descriptive, or experimental, control groups, replicates.

3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.

4 How often were data collected within a season?

5 Number of birds, nests, sites, replicates, visits.

6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.

7 Evidence for nesting.

8 Was multiple nesting documented for individual birds?

9 Acreage of habitat, continuous or not, and how defined.

10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.

11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.2.7

Study Citation	Divoky and Horton 1995
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Not described; summary of results of literature search across bird family Alcidae
Study area habitat	Not applicable
Study design[1]	Qualitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Variety of methods; presumably mostly banding recoveries
Years of study	Not applicable
Within-year study period[4]	Not applicable
Sample sizes[5]	Not described
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Agency technical report paper
Spatial scale(s)[6]	Not applicable
How was nesting determined?[7]	Not specified
Multiple nesting for known individuals?[8]	No
Extent of habitat (area)[9]	Not clearly specified
Nests within or between years?	Between years
Pertinent results, including statistical significance values and measures of variation[10]	(p. 83) Site-fidelity can reduce potential reproductive effort by (1) increasing chances of breeding with previous year's mate; (2) reducing need to locate suitable nest site every year; and (3) increasing familiarity with marine and terrestrial environment. (p. 83) Rates of nest-site fidelity for alcids generally are high: Razorbills 92%, Common Murres 96%, Black Guillemots 57–95%, Pigeon Guillemots 86%, Ancient Murrelets 78%, Atlantic Puffins 93%. (p. 83) Rate of site-fidelity should be related to rate at which nesting habitat is created and destroyed, mortality rate of breeding birds, reproductive success, and availability of nest-sites. For guillemots at least, nest changes caused by breeding failure usually are on the order of tens of meters (i.e., not far). (p. 84) Murrelets have high fidelity to nesting area: have been recorded in same forest stands in northern CA for ≥20 years, in central CA for ≥18 years, in OR for ≥7 years, and in WA for ≥3 years. (p. 84) One case in which nesting occurred in same nest-tree 4 times. (p. 84) Observed fidelity to same nest-cup in successive years appears to be lower than for other alcids, possibly because of

Study Citation	Divoky and Horton 1995
Pertinent results, including statistical significance values and measures of variation[10]	high rates of predation observed in murrelet nests. Implication of predation is that, because forest stands were not open prior to logging years ago, nest-site fidelity should have been higher than what is recorded now. (p. 86) When nest-sites are limiting, loss of nesting habitat reduces long-term reproductive potential of a population; especially true for murrelets, which require trees =>200 years old. Results in displacement of breeding birds. (p. 86) Fragmentation also may reduce long-term reproductive potential of a population by increasing densities of predator populations, most of which are "edge" species. Results in both displacement of breeding birds and decreased breeding success. (p. 86) High nest-site fidelity makes it difficult for breeding murrelets to move to new areas and breed after habitat loss, whereas low nest-site fidelity may make them more adaptable to habitat loss; however, it also depends on the scale of the fidelity (i.e., whether the fidelity is to a nesting branch, a nest-tree, a forest stand, a watershed, etc.). (p. 87) Relying on occupied behaviors as an indication of nesting has weaknesses: (1) recently mature forests that could support nesting may not be discovered immediately by murrelets, so you could have "false negatives" of no detections; (2) in areas where there is large nonbreeding population that is limited by availability of nest-sites, birds could visit inappropriate habitat, creating "false positives" of detections.
Potential sources of bias or error	No issues with sampling design—study summarized data across alcid family to see what patterns might be seen in murrelets.
Effects modifiers[11]	None of the other alcids for which extensive data were available are cryptic, solitary nesters, so comparability about aspects of life-history may be compromised.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Evidence for nesting.
8 Was multiple nesting documented for individual birds?
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.2.8

Study Citation	Drever et al. 1998
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Desolation Sound and Bunster Range, BC
Study area habitat	Coastal old-growth forest dominated by Western and Mountain hemlocks, Douglas and Amabilis firs, and Yellow Cedar
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, Climbing, Telemetry, egg-shell transects
Years of study	1996
Within-year study period[4]	Mid-May to early Aug
Sample sizes[5]	23 nest-trees and 41 nesting attempts
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Stand
How was nesting determined?[7]	Nest-cup, Eggshell fragments, Fecal ring, Feathers
Multiple nesting for known individuals?[8]	No
Extent of habitat (area)[9]	1700 ha of old-growth forest with mining years ago creating gaps ~15 m wide in part of study area
Nests within or between years?	Both
Pertinent results, including statistical significance values and measures of variation[10]	(p. 15) Climbed 355 trees to search for nests. (p. 15–16) Located 23 nest-cups in 1996 by observing birds land or by climbing trees. Including the 9 nests located in 1994 and 1995, total of 32 nests and 41 nesting attempts (including nests that were reused and trees with multiple nests). (p. 15) 25% of nest-trees contained >1 nest-cup, indicating that they had been used for >1 breeding attempt. (p. 16) Unsuccessful nests (81% of nests) had empty nest-cups or eggshell fragments; successful nests (10% of nests) had fecal ring and chick down. Other 10% of nests may have fledged chicks in previous years; had eggshell fragments and chick down but fecal ring had disappeared. (p. 16) 3 (33.3%) of 9 nests found in previous years were reused or revisited by murrelets in 1996. (p. 16) Murrelets also attempted to renest at 2 sites [= nest-cups? Nest-trees? Not clear] in 1996, but both attempts apparently failed. (p. 17) Although it has been assumed that reuse of nesting sites is done by the same individuals, no conclusive evidence has been obtained. Hence, it also is possible that different individuals may attempt to reuse nest-sites when nesting habitat is limited and competition for nests is high.

Study Citation	Drever et al. 1998
Potential sources of bias or error	Mostly anecdotal information; no apparent bias.
Effects modifiers[11]	Data are from BC, so comparability to OR may be questionable. However, doubtful that tree type has significant effect on reuse, so this behavior probably transcends forest type and instead depends more on issues such as overall habitat availability.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).

2 Anecdotal, descriptive, or experimental, control groups, replicates.

3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.

4 How often were data collected within a season?

5 Number of birds, nests, sites, replicates, visits.

6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.

7 Evidence for nesting.

8 Was multiple nesting documented for individual birds?

9 Acreage of habitat, continuous or not, and how defined.

10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.

11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.2.9

Study Citation	Golightly and Schneider 2011
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Redwood National and State parks, northern CA
Study area habitat	Old-growth Coast Redwoods
Study design[1]	Qualitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Climbing, Cameras
Years of study	2001–2010
Within-year study period[4]	11 May–15 Jul 2009, 3 May–17 Aug 2010
Sample sizes[5]	10 nest-years
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Tree, Branch, Platform
How was nesting determined?[7]	Egg, Incubating adult, Nest-cup
Multiple nesting for known individuals?[8]	Yes
Extent of habitat (area)[9]	Not specified, although Wikipedia indicates that there are 39,000 acres of old-growth forest in the two parks combined
Nests within or between years?	Between years
Pertinent results, including statistical significance values and measures of variation[10]	Same nest as that discussed in Golightly and Schneider (2009). (p. 2) No evidence of nesting at the branch recorded in 2009, although a banded murrelet visited the site on 17 Jun, in early morning, and sat on the nest-cup that had been used for nesting in several previous years. On p. 7, the authors indicate that they could not be certain that the pair did not initiate a nest in 2009, and that the banded female was the one that visited the nest. (p. 3) Nesting occurred, but just not in the nest-cup that had been used in previous years. (Occurred out of the field of vision of the camera and caught on audio feed.) Egg laid on 3 or 4 Jun, hatched 30 Jun. Chick then was killed by predator (Gray Jay) shortly thereafter. Down from a chick found near the nest-cup, which was extremely worn. After predation event, adult murrelets were recorded at the nest on 3 occasions. [NOTE: It appears that they mean Jul, not Jun, in their dates of post-predation visits by adults.] (p. 4) Murrelets laid eggs in 7 of 10 years (all except 2006, 2007, and 2009) but were successful only in 2 years (2001, 2003); nests were lost to predation in other 5 years. (p. 5) Murrelets are adapted to avoiding predation, but logging has opened up so much habitat that populations of corvids and other species have been able to increase and have caused depressed productivity.

Study Citation	Golightly and Schneider 2011
Pertinent results, including statistical significance values and measures of variation[10]	(p. 6–7) Authors suggest that it is possible that murrelets do not "initiate a nest annually." Decreased breeding effort has been recorded in years with low prey availability. (p. 7) Authors suggest that it is possible that this pair of murrelets nested somewhere else in 2006, 2007, and 2009. (p. 7) Authors suggest that their hypothesis that the male had died, causing no nesting in 2006 and 2007, may be wrong and would require a string of improbable events to have occurred. (p. 7) This nest proves that an individual murrelet can exhibit fidelity to both a nest-branch and a nest-site for multiple consecutive years, even when a nest is not initiated at that site annually. (p. 7) The authors go on to state that this is the same pair using the nest-branch in all years, even though they do not prove this statement.
Potential sources of bias or error	Nice small study of one nest over 10 years (adds to timeline for Golightly & Schneider 2009), with banded female detectable over multiple years. Unfortunately, male was not banded, so apparent hiatus in breeding could have been caused by no breeding at all because of lack of food, death of male that required development of new pair bond on part of female, no breeding because some alcids do not breed every year, etc.
Effects modifiers[11]	Data are from CA, so comparability to OR may be questionable. However, doubtful that tree type has significant effect on reuse, so this behavior probably transcends forest type and instead depends more on issues such as overall habitat availability.
Additional notes	Same nest as that discussed in Golightly and Schneider (2009), Hebert and Golightly (2006), and Hebert et al. (2011), so this publication supersedes them. Also same nest as that discussed in Hebert et al. (2011) and Hebert and Golightly (2006).

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Evidence for nesting.
8 Was multiple nesting documented for individual birds?
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.2.10

Study Citation	Hébert and Golightly 2006
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Redwood National and State parks, northern CA
Study area habitat	Coast Redwoods
Study design[1]	Qualitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing, Telemetry, Cameras
Years of study	2001–2003 (but 1 nest to 2005)
Within-year study period[4]	Apr–Jul
Sample sizes[5]	10 nests with multiple years of checks for reuse
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Tree, Branch, Platform
How was nesting determined?[7]	Nestling, Egg, Incubating adult, Nest-cup
Multiple nesting for known individuals?[8]	Yes
Extent of habitat (area)[9]	Not specified, although Wikipedia indicates that there are 39,000 acres of old-growth forest in the two parks combined
Nests within or between years?	Both
Pertinent results, including statistical significance values and measures of variation[10]	(p. 262–263) Nest 1 located in 2001; Nests 2–7 located in 2002; Nests 8–10 located in 2003. (p. 263) Renesting attempted at Nest 5 in 2002. Renesting attempted at Nest 8 in 2003. (p. 263–265) At Nest 1 (found in 2001), birds nested again at nest-site in 2002, but no renesting occurred after egg was lost. Birds nested again (successfully) in 2003; video showed that bird had aluminum band on left leg, suggesting that it was the female who had been banded that way in 2001. Video indicated that birds nested again at this nest-site in both 2004 and 2005, but nests were unsuccessful in both years. (p. 265) At Nest 2 (found in 2002), no evidence that birds returned to nest-site in either 2003 or 2004. (p. 265) At Nest 3 (found in 2002), no evidence that birds returned to nest-site in either 2003 or 2004. (p. 265) At Nest 4 (found in 2002), no evidence that birds returned to nest-site in either 2003 or 2004. (p. 265–266) At Nest 5 (found in 2002), birds recorded nesting (unsuccessfully) at same nest-site in 2003, but no evidence that birds returned to nest-site in 2004.

Study Citation	Hébert and Golightly 2006
Pertinent results, including statistical significance values and measures of variation[10]	(p. 266) At Nest 6 (found in 2002), there was evidence that the nest-platform had been used previously—there were 2 nest-cups; nest failed in 2002. In 2003, two birds recorded landing at same nest-site used in 2002, but they did not appear to nest; no evidence that birds returned to nest-site in 2004. (p. 267) At Nest 7 (found in 2002), no evidence that birds returned to nest-site in either 2003 or 2004. (p. 267) At Nest 8 (found in 2003), no evidence that birds returned to nest-site in 2004. (p. 267) At Nest 9 (found in 2003), no evidence that birds returned to nest-site in 2004. (p. 267) At Nest 10 (found in 2003), no evidence that birds returned to nest-site in 2004. (p. 267) Of the 10 nest-sites examined, 3 (30%) were used in consecutive years, and 1 (10%) was use for 5 consecutive years. (p. 268) Rates of nest-site fidelity are much higher in other alcids than in murrelets. Authors suggest that nest-sites could be limiting for murrelets because most large branches are not usable—access to a branch appears to be a key element in determining suitability of a nesting platform. (p. 269) Nest-site fidelity has several advantages for birds that exhibit it. It takes much time in most alcids but is even more difficult for murrelets, which typically have only a couple of hours of crepuscular light/day to search for nest-sites. (p. 270–271) Because annual survival averages ~85%, 20% [NOTE: Should be 15%.] of nests would suffer the loss of one member of a pair every year. Hence, new pairs must be formed constantly. In addition, fidelity should be strongest in pairs that nest successfully, but (as stated above) it can be overridden by access to nest-site. Storms, falling braches, etc., may affect access to nest-sites and nest-site quality from year to year.
Potential sources of bias or error	Authors admit that some nests may not have been checked often enough in subsequent years to detect eggs that had been laid but lost before next nest-check.
Effects modifiers[11]	Data are from CA, so comparability to OR may be questionable. However, doubtful that tree type has significant effect on reuse, so this behavior probably transcends forest type and instead depends more on issues such as overall habitat availability.
Additional notes	Nest 1 discussed in this report appears to be the same long-term nest studied by Golightly and Schneider (2009, 2011) and Hebert et al. (2011); however, data also are presented on other nests.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Evidence for nesting.
8 Was multiple nesting documented for individual birds?
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.2.11

Study Citation	Hébert et al. 2003
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Redwood National and State parks, northern CA
Study area habitat	Coast Redwoods
Study design[1]	Qualitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Telemetry, Cameras
Years of study	2001–2002
Within-year study period[4]	12 Apr–10 Jul 2001, 13 Apr–2 Sep 2002
Sample sizes[5]	2 telemetered birds that appeared to have renested
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Large stretch of forest in national and state parks
How was nesting determined?[7]	Nestling, Telemetered activity patterns
Multiple nesting for known individuals?[8]	Yes
Extent of habitat (area)[9]	Not specified, although Wikipedia indicates that there are 39,000 acres of old-growth forest in the two parks combined
Nests within or between years?	Within year
Pertinent results, including statistical significance values and measures of variation[10]	Exact dates of surveys each year not specified. (p. 262) Murrelet suspected of renesting in 2001 initially captured on 13 Apr but not recorded in forest until 17 May (recorded only at sea up to that point); alternated daily shifts at sea and (presumably) on nest 17–29 May, after which recorded only at sea, suggesting nesting failure. Visited same nesting area for a few minutes each morning for next 9 days after (presumed) nest failure. Bird again recorded on telemetry in vicinity of first nest-site on 14 Jun, but appeared to have lost that nest too. However, nests never found, so unclear whether same nest-site or nest-tree was reused. (p. 263) Murrelet suspected of renesting in 2002 initially captured on 17 May but not recorded in forest until 13 Jun; alternated daily shifts at sea and (presumably) on nest 13–23 Jun, after which recorded only at sea, suggesting nesting failure. Visited same nesting area for a few minutes each morning on at least 16 days after (presumed) nest failure. Bird again recorded on telemetry in vicinity of first nest-site on 21 Jul (suggesting renesting), but lost telemetry unit on 3 Aug. Nest-tree located on 30 Jul and camera set up; egg hatched 16 to 19 Aug, but chick died 1–2 Sep. First nest-site not found, so unclear whether same nest-site or nest-tree was reused; however, same clump of trees was used for nesting.

Study Citation	Hébert et al. 2003
Pertinent results, including statistical significance values and measures of variation[10]	(p. 263) Murrelets can renest 2–4 weeks after first egg has been lost. Authors suggested that, because of high rates of predation on murrelet nests, renesting may be a common phenomenon in this species. (p. 263–264) The fact that murrelets continue to visit vicinity of nesting tree following failure of first egg is common in other alcids and may be related to retention of nest-sites and/or mates for renesting.
Potential sources of bias or error	Descriptive study of telemetered birds, some of which nested later, so appears to be a good random sample.
Effects modifiers[11]	Data are from CA, so comparability to OR may be questionable. However, doubtful that tree type has significant effect on reuse, so this behavior probably transcends forest type and instead depends more on issues such as overall habitat availability.
Additional notes	Unclear whether one of these nests is the same as the long-term nest studied by Golightly and Schneider (2009, 2001) and Hebert et al. (2011).

1 Brief description of study design (e.g., qualitative, quantitative).

2 Anecdotal, descriptive, or experimental, control groups, replicates.

3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.

4 How often were data collected within a season?

5 Number of birds, nests, sites, replicates, visits.

6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.

7 Evidence for nesting.

8 Was multiple nesting documented for individual birds?

9 Acreage of habitat, continuous or not, and how defined.

10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.

11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.2.12

Study Citation	Hirsch et al. 1981
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Barren Islands, northern Gulf of Alaska, AK
Study area habitat	Heath- and grass-covered slope overlooking the ocean, under rock ledge
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Visiting nest
Years of study	1979 (but compares w/1978 data)
Within-year study period[4]	On or before 6 Jul to 16 Aug (night of fledging)
Sample sizes[5]	1 nest
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Nest-cup
How was nesting determined?[7]	Nestling, Egg, Nest-cup
Multiple nesting for known individuals?[8]	No
Extent of habitat (area)[9]	Not clearly specified
Nests within or between years?	Between years
Pertinent results, including statistical significance values and measures of variation[10]	(p. 264) Nest was located 10 m south of 1978 nest described by Simons (1980), indicating reuse of nesting area by murrelets.
	(p. 264) Nest-cup was located below rock ledge that appeared to provide some protection from elements and that provided more protection than 1978 nest.
	(p. 265) Both adults arrived on night of fledging; chick was gone next morning, indicating nocturnal fledging; 3 days later, adult and juvenile seen in nearby cove, <0.5 km from nest-site.
Potential sources of bias or error	None apparent; simple description of nest and chick.
Effects modifiers[11]	Nest on the ground in area without trees in AK, so comparability to OR questionable.
Additional notes	Adds to data published by Simons (1980) for a nearby nest 1 year earlier; presumably the same pair.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Evidence for nesting.
8 Was multiple nesting documented for individual birds?
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include P-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.2.13

Study Citation	Jones 2001
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Spipiyus Park, Caren Range, coastal BC
Study area habitat	Old growth coniferous forest (Western and Mountain Hemlock, Amabilis Fir, and Yellow Cedar), surrounded by some recently logged areas
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, Cameras
Years of study	1991–1994 and 1996–1997
Within-year study period[4]	Variable among years, but always within the May–early Aug period
Sample sizes[5]	Two nests were found by audiovisual observers. One nest was active in both 1993 and 1994. The other nest was active in 1997
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Book/book chapter
Spatial scale(s)[6]	Watershed, Stand, Study site, Patch, Tree, Branch, Platform
How was nesting determined?[7]	Nestling
Multiple nesting for known individuals?[8]	Yes
Extent of habitat (area)[9]	The Park consists of a mostly contiguous block of old growth approximately 800 ha in size, surrounded by managed forests.
Nests within or between years?	Between years
Pertinent results, including statistical significance values and measures of variation[10]	(p. 52, 77, and 95) Two nests were found. One nest was active in both 1993 and 1994 and although not explicitly stated, it appears that the same nest-cup was used in both years (the nest was in the same location on the same branch in both years). One of the members of those pairs was believed to have been the same individual (i.e., present both years) because it had unique plumage markings. The second nest was active in 1997 and was located in the same large area of old-growth forest that makes up the Park (i.e., within ~3 km of the 1993–1994 nest), but the exact locations of both nests were not provided. Thus, it is not known whether this second nest was in the same forest stand or watershed as the 1993–1994 nest. (p. 78) Consistent movements of adult birds flying in the canopy also were observed near the 1997 nest site during 1996. The author speculated that it may have been the same pair of birds nesting at that site 2 years in a row (i.e., that the same nest may have been used in both 1996 and 1997), but an actual nest site was not located in 1996.

Study Citation	Jones 2001
Potential sources of bias or error	None apparent
Effects modifiers[11]	None apparent
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Evidence for nesting.
8 Was multiple nesting documented for individual birds?
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.2.14

Study Citation	Lougheed et al. 1998
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Desolation Sound, BC
Study area habitat	Old-growth coast forest; primary trees include Western and Mountain hemlocks, Western Redcedar, Yellow Cedar, and Douglas and Silver Firs; most low-elevation sites have been logged
Study design[1]	Qualitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing
Years of study	1997 (forest study began in 1994, overall study began in 1991)
Within-year study period[4]	13 MY–19 AU 1997
Sample sizes[5]	27 nest-trees
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Stand, Tree
How was nesting determined?[7]	Nestling, Nest-cup, Eggshell fragments, Fecal ring, Adult landing
Multiple nesting for known individuals?[8]	No
Extent of habitat (area)[9]	Malaspina landscape unit (~80,000 ha) has 2973 ha of remaining old-growth forest; not clear whether contiguous
Nests within or between years?	Both
Pertinent results, including statistical significance values and measures of variation[10]	(p. 12) Surveyed 27 nest-trees between 14 MY and 6 AU 1997. (p. 14) After breeding season, climbed 18 of the 27 nest-trees, 3 new landing-trees, and 3 other tree-nests near known nests. [NOTE: p. 14 says that 3 new nest-trees were located while surveying known nests; I assume that these are the 3 other trees referred to here.] (p. 14) All 27 nest-trees found during 1995–1996 surveys had murrelet detections in 1997, indicating at least some level of reuse among years. (p. 16) Found 27 nest-trees; speculated that reuse and revisitation is occurring at or near old nest-trees. Occupied circling behavior occurred at 16 (59%) of the nest-trees, occupied behavior occurred at 6 (22%) of nest-trees, and birds actually landed at 3 (11%) of the nest-trees. (p. 18) 3 of the nest-trees were documented as being reused in 1997. (p. 18) One nest-tree had 2 nest-sites, but there is no mention for the other 26 nest-trees. (Results) From comments in Results, it appears that some or most of these trees were logged during the summer of 1997.

Study Citation	Lougheed et al. 1998
Potential sources of bias or error	Difficult to evaluate whether there are biases or errors.
Effects modifiers[11]	Data are from BC, so comparability to OR may be questionable. However, doubtful that tree type has significant effect on reuse, so this behavior probably transcends forest type and instead depends more on issues such as overall habitat availability.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Evidence for nesting.
8 Was multiple nesting documented for individual birds?
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.2.15

Study Citation	Manley 1999
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Sunshine Coast Forest District, BC
Study area habitat	Coastal forest, some of which is old-growth; Western Hemlock, Douglas and Silver firs, Western Redcedar, Yellow Cedar, and Shore Pine
Study design[1]	Qualitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing
Years of study	1995–1997 (later says 1994–1997)
Within-year study period[4]	1 Jun–31 Jul and 3–29 Aug 1995, 13 May–5 Aug 1996, not described in 1997
Sample sizes[5]	52 nest-trees found in 1994–1997
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Thesis/dissertation
Spatial scale(s)[6]	Tree, Branch, Platform
How was nesting determined?[7]	Nestling, Nest-cup, Eggshell fragments, Fecal ring, Feathers, Adult landing, Adult fly in/out of canopy
Multiple nesting for known individuals?[8]	No
Extent of habitat (area)[9]	Not specified
Nests within or between years?	Both
Pertinent results, including statistical significance values and measures of variation[10]	(p. 20) Found 52 nests in 1994–1997. [NOTE: Earlier says that study was done 1995–1997, so sudden switch to 1994 as starting year is confusing.] 41 of these trees were found by tree-climbing after the breeding season. (p.36) In 1996, 12% (1 of 8) of nest-sites were reused; in 1997, 11% (3 of 27) were reused; and, overall, 4 (11%) of 36 nest-sites in 1994–1995 were reused at least 1 year. Reused nests had been successful or failed—there was no pattern to whether a nest-site was reused. Reuse attempts occurred either in the same nest-site or on different limbs in the same tree. (p. 36) 10 (19%) of 52 nest-trees had >1 nest-site within the tree, indicating that these nest-trees had been used >1 year. 9 trees had 2 nest-sites, and 1 tree had 3 nest-sites. (p. 47) Murrelets reused nest-trees within years, between years, and over multiple years. Most reused nest-trees were visited by murrelets prior to the reuse; most reuse occurred after nest failure.

Study Citation	Manley 1999
Pertinent results, including statistical significance values and measures of variation[10]	(p. 48) Reuse of nest-trees and nest-sites indicates that they are important for up to several breeding attempts. However, author admits that, because birds were not marked, it was unclear whether it was the same or other birds who were reusing the nest-trees and nest-sites. (p. 48) It is important to distinguish whether reuse reflects nest-fidelity or habitat limitation because these 2 factors have different implications for habitat management. (p. 48) Suggests that reuse of nests may be lower in murrelets than in other alcids because murrelets may exhibit fidelity at a larger spatial scale than colonial seabirds—e.g., a stand of trees. If they nest in a tree 100 m from known nest-tree, may be difficult to detect. (p. 93–94) 52% of nest-sites in this study were associated with another nest-tree within 100 m; for most of the clusters, there was no evidence that nests were active at the same time, but two pairs of active nests occurred 38 m and 50 m from each other. Author suggests that nest clusters may represent multiple nesting attempts within the same stand by a breeding pair and indicate fidelity to a nest-patch instead of a nest-tree or a nest-platform. Author speculated that high nest density, clustering, and reuse of nest-sites and nest-stands all suggest that habitat and nest-sites are limiting in the Bunster Range.
Potential sources of bias or error	Not clear how good they were at detecting nests that actually were there but were missed—no double-blind trials were conducted. Also, author admits that using the proportion of nest-trees with >1 nest-site as a measure of reuse would not detect reuse of the same nest-site or detect multiple nests used within a single year.
Effects modifiers[11]	Data are from BC, so comparability to OR may be questionable. However, doubtful that tree type has significant effect on reuse, so this behavior probably transcends forest type and instead depends more on issues such as overall habitat availability.
Additional notes	Data presented here in Table 10 (36 trees monitored) are included in Table 1 (52 trees monitored) in Burger et al. (2009); however, that table also includes unpublished data from Manley to reach total of 52 trees monitored for re-use. Hence, that publication supersedes this one.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Evidence for nesting.
8 Was multiple nesting documented for individual birds?
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.2.16

Study Citation	Manley 2003
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Desolation Sound and Clayoquot Sound, BC
Study area habitat	Coastal old-growth and harvested forests; Western and Mountain hemlocks, Western Redcedar, Douglas Fir, and Pacific Silver Fir
Study design[1]	Qualitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Climbing, Telemetry
Years of study	1998–2002
Within-year study period[4]	Not provided
Sample sizes[5]	43 nest-trees (but Table 1 says 44) in Desolation Sound and 27 nest-trees in Clayoquot Sound where data on nest-patches and nest-trees were collected
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Watershed, Stand, Patch, Tree, Platform
How was nesting determined?[7]	Nest-cup
Multiple nesting for known individuals?[8]	No
Extent of habitat (area)[9]	Not clear; lower-elevation forests in Desolation Sound have been logged but higher-elevation ones are mostly intact; several watersheds in Clayoquot Sound are considered pristine
Nests within or between years?	Within year
Pertinent results, including statistical significance values and measures of variation[10]	(p. 5) Five nest-trees contained 2 nest-sites, 1 from the current year and 1 from previous nesting attempt. (Table 1) In Desolation Sound, 44 nest-trees had 48 nest-sites; hence, 4 nest-trees (11%) had >1 nest-site. In Clayoquot Sound, 27 nest-trees had 28 nest-sites; hence, 1 nest-tree (4%) had >1 nest-site. Note that the number/percentage of supernumerary nest-sites is higher in Desolation Sound, which had a much higher rate of logging, than in Clayoquot Sound, which was much less logged.
Potential sources of bias or error	Not clear how good they were at detecting nests that actually were there but were missed—no double-blind trials were conducted. Unable to locate all nests, especially nests on the ground, so frequencies may not be correct.
Effects modifiers[11]	Data are from BC, so comparability to OR may be questionable. However, doubtful that tree type has significant effect on reuse, so this behavior probably transcends forest type and instead depends more on issues such as overall habitat availability.

Study Citation	Manley 2003
Additional notes	Criteria for detecting a nest are not presented. Total nest locations and nest patches were not defined (nest trees and nest sites are self-explanatory). Manley thesis (1999) defines a patch as an area 0.2 ha around a nest-tree. "Nest-locations" is obscure and undefined everywhere. Use in Table 2 of (a) 23 nest-locations, (b) 0 nest-patches, (c) 8 nest-trees, and (d) 8 nest-sites in Desolation Sound in 1998 illustrates only some of the confusion associated with these obscure terms. Some nests were on the ground in rocky cliff habitat; most were not accessible.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Evidence for nesting.
8 Was multiple nesting documented for individual birds?
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.2.17

Study Citation	Meekins and Hamer 1999
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Olympic Peninsula, WA (western lowlands)
Study area habitat	Old-growth coastal forest; Western Hemlock, Western Redcedar, Douglas and Silver firs, Sitka Spruce, Hemlock Dwarf Mistletoe
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Climbing
Years of study	1996 (pilot study) –1998
Within-year study period[4]	Fall of 1996, breeding seasons of 1997–1998
Sample sizes[5]	4 nests in 1996, 13 nests in 1997, and 10 nests in 1998 (i.e., n = 27); however, also found 2 nests during other studies that were included in this study
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Stand, Tree, Platform, Plot
How was nesting determined?[7]	Nest-cup, Eggshell fragments, Fecal ring, Feathers, Landing pads
Multiple nesting for known individuals?[8]	No
Extent of habitat (area)[9]	Not specified
Nests within or between years?	Within year
Pertinent results, including statistical significance values and measures of variation[10]	(p. 8) In 1996, found 4 old nest-sites (1 in Stand 180 and 3 in Stand 215) after climbing 159 trees.
	(p. 8–9) In 1997, found 13 inactive nest-sites (7 more in additional plots in Stand 215 and 6 nests in Stand 005) after climbing 428 trees.
	(p. 9) Also found 2 other nest-sites incidentally.
	(p. 9) In 1998, found 10 nest-sites (8 inactive and 2 active; 6 in Stand 31, 3 in Stand 65, and 1 in Stand 190) after climbing 911 trees. One nest had a fecal ring and one contained eggshell fragments, but the other 8 nests appeared to be active.
	(p. 9) Across all years, climbed 1,498 trees and located 27 nest-sites in 22 nest-trees (1.5% of all trees climbed). [NOTE: This number excludes the 2 trees where nest-sites were found incidentally.]
	(p. 9) Across all years, surveyed 60 nest plots, of which 14 (23%) contained nest-sites; 7 (50%) of those 14 plots with nest-sites contained >1 nest-site, and 3 (21%) contained >2 nest-sites.

Study Citation	Manley 1999
Pertinent results, including statistical significance values and measures of variation[10]	(p. 9) Across all years, of the 22 nest-trees examined, 4 (18%) contained >1 nest-site: 2 trees had 2 nest-sites each, 1 tree had 3 nest-sites, and 1 tree had 4 nest-sites. Although it is not stated explicitly, it appears that these multiple nests in a nest-tree are nests from different years—there are not multiple active nests in a tree in the same year. (p. 24) Authors suggest that, because multiple nest-sites often were found in the same plot or the same tree, it is likely that pairs return to the same patch of forest to renest, probably using different trees and limbs in the same forest patch. [NOTE: Unclear exactly what authors mean by "forest patch."] Also suggest that multiple pairs are creating the multiple nest-sites in the same area, although they present no evidence for such an assertion. "In either case it is apparent that birds are attracted to the same tree and forest patch over time and may have high affinity for these areas."
Potential sources of bias or error	Not clear how good they were at detecting nests that actually were there but were missed—no double-blind trials were conducted.
Effects modifiers[11]	None apparent
Additional notes	Not clear how far away nest-trees within a plot actually are from each other. Unclear why such a high percentage of nests were not active.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Evidence for nesting.
8 Was multiple nesting documented for individual birds?
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.2.18

Study Citation	Naslund et al. 1995
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Naked, Afognak, and Kodiak islands, northern Gulf of Alaska, AK
Study area habitat	Coastal old-growth forest (Western Hemlock, Mountain Hemlock, and Sitka Spruce in PWS; only Sitka Spruce on other 2 islands)
Study design[1]	Qualitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing, viewing nests from nearby trees
Years of study	1991 (Naked Island) –1992 (Naked, Afognak, Kodiak islands)
Within-year study period[4]	"During the breeding season"
Sample sizes[5]	14 nest-trees on the 3 islands (Naked—6 in 1991, 4 in 1992; Afognak—2 in 1992; Kodiak—2 in 1992)
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Watershed, Tree, Platform
How was nesting determined?[7]	Nestling, Egg, Eggshell fragments, Fecal ring, Adult landing, Adult fly in/out of canopy
Multiple nesting for known individuals?[8]	No
Extent of habitat (area)[9]	Acreage of habitat not specified; Naked Island unlogged; Afognak Island heavily logged; Kodiak Island logged in only a few locations
Nests within or between years?	Between years
Pertinent results, including statistical significance values and measures of variation[10]	(p. 15) Located 14 nest-trees over the 2 years (10 on Naked, 2 on Afognak, 2 on Kodiak). (p. 15) The 10 nests on Naked Island located in 5 different forest stands, implying multiple nesting within a forest stand. (p. 15) 2 nest-trees were 10 m apart, and 2 nest-trees were <50 m apart. (p. 15) No indication that 1991 nests were reused in 1992, although authors admit that nest-checks were not done often enough to exclude possibility that murrelets nested and failed between visits. (p. 15) No evidence of renesting at failed 1992 nests. (p. 15) In 1992, no sign of nest-cup, eggshell fragments, or fecal rings at nest that had been active in 1991. (p. 15) At 6 of 7 nests where murrelets were active (landed, displayed, or copulated), nest cups later were recorded.

Study Citation	Naslund et al. 1995
Pertinent results, including statistical significance values and measures of variation[10]	(p. 16) Recorded 21 trees where murrelets landed on branches but no nests were found; however, 15 of these trees were not climbed, so unclear how they confirmed lack of nests. (p. 16) All landing trees on Naked and Kodiak islands were located <200 m from known nest-tree. (p. 16) At least 4 landing platforms used repeatedly and in consecutive years, including 1 used in 1991 that had nest in 1992. One landing platform had slight depression and worn spot in 1992; murrelets were active on this branch in both years, so this actually may have been nesting attempt in 1991 too. (p. 23) On Naked Island, there were only small stands of contiguous forest that were intermixed with patches of open muskeg and low-tree-size and low-volume forests. However, sizes of stands on Naked I. were not described. (p. 24) Their observations of murrelets using same trees for landing or nesting in consecutive years suggests some degree of site- or area-fidelity. (p. 24) Although authors first suggest that proximity of landing and nest-trees supports idea that murrelets may nest in groups within forest stands, they later admit that these records simply may have been renesting attempts by failed breeders. (p. 24) Tree-size alone does not predict suitability of a tree for nesting—other characteristics (e.g., age, size, species, presence of platforms, slope aspect) should be considered too.
Potential sources of bias or error	Authors admit that extremely well concealed nest-sites may have been too hard to find, biasing samples of nest-site characteristics. Also, not clear how good they were at detecting nests that actually were there but were missed--no double-blind trials were conducted.
Effects modifiers[11]	Data are from AK, so comparability to OR may be questionable. However, doubtful that tree type has significant effect on reuse, so this behavior probably transcends forest type and instead depends more on issues such as overall habitat availability.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Evidence for nesting.
8 Was multiple nesting documented for individual birds?
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.2.19

Study Citation	Nelson and Peck 1995
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Coast Ranges and Siskiyou Mountains, western OR
Study area habitat	Mosaic of young trees and mature forests with small, isolated patches of old-growth forests; Douglas Fir is primary canopy-forming tree in the N and variety of conifers in the S
Study design[1]	Qualitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing, Cameras, finding eggshells on ground
Years of study	1990–1992 (checked for reuse in 1993)
Within-year study period[4]	Not specified
Sample sizes[5]	2 active nests in 1990, 5 active nests in 1991, 2 active nests in 1992, plus 2 inactive nests in 1992 and 1993
Statistical analysis of results	Descriptive statistics only
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Tree, Branch, Platform
How was nesting determined?[7]	Nestling, Egg, Nest-cup, Eggshell fragments, Adult fly in/out of canopy
Multiple nesting for known individuals?[8]	No
Extent of habitat (area)[9]	Not specified, but study covered all parts of OR where nests have been found
Nests within or between years?	Between years
Pertinent results, including statistical significance values and measures of variation[10]	(p. 45) 8 of 9 nests found in Douglas Fir, 1 found in Sitka Spruce. (p. 45) Nests active over ~6 months; earliest activity 14 May (but 1 pair seen landing on nest limb 3 times in early May) and latest activity (predation of chick) 2 Sep. (p. 46) None of active nest-platforms were used in subsequent years; however, 2 nest-trees were used in subsequent years. (p. 46) Five Rivers nest active 1991 and possibly 1992, with what appeared to be 1992 nest-platform different from that used in 1991; had at least 2 nest-platforms. (p. 46) Valley of Giants nest active in 1990, 1992, and 1993; had 3 nest-platforms, at least of 2 of which were used. (p. 49) Landings and departures in trees near known nests were seen throughout nesting season but were most common in Jul. (p. 49) Birds were seen landing on nest-limbs or other limbs in known nest trees in years after nest was first discovered.

Study Citation	Nelson and Peck 1995
Pertinent results, including statistical significance values and measures of variation[10]	(p. 51–52) One additional nest found in OR after this study was over was used in subsequent years, although different nest-platform was used; that makes 1 tree in OR with same nest-platform used in subsequent years and 3 trees with different platform used in subsequent years.
Potential sources of bias or error	None apparent
Effects modifiers[11]	Paper describes nests in OR, so highly relevant to study.
Additional notes	Authors indicate that the study was conducted 1990 to 1992, then present some data from 1993, making understanding some of the paper difficult. Data on some nests from Valley of Giants appears to be presented in Nelson et al. (1994), but that latter report includes data from other nests in the same area.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Evidence for nesting.
8 Was multiple nesting documented for individual birds?
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.2.20

Study Citation	Nelson and Wilson 2002
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Clatsop, Tillamook, and Elliott state forests, western OR
Study area habitat	Sitka Spruce, Western Hemlock zones; mosaic of young, mature, and old-growth Douglas Fir, Sitka Spruce, and Western Hemlock stands
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, Climbing, Cameras, binoculars from ground or adjacent tree
Years of study	1995–1999 (Table 2 says 1994)
Within-year study period[4]	22 Jun–19 Aug 1995, 1 Jul–6 Aug 1996, 12 May–31 Aug 1997, 1 May–31 Aug 1998, 6 May–23 Aug 1999
Sample sizes[5]	37 nest-trees
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Stand, Survey site, Tree
How was nesting determined?[7]	Nest-cup, Eggshell fragments, Fecal ring, Feathers, Landing pad
Multiple nesting for known individuals?[8]	No
Extent of habitat (area)[9]	Almost 250,000 ha in 3 forests combined; acreage and continuity of old-growth forest not delineated, but "the distribution and abundance of old-growth trees and stands are limited" because of fires and logging
Nests within or between years?	Both
Pertinent results, including statistical significance values and measures of variation[10]	(p. 20) Located 37 nest-trees during 1994–1999 (3 in Clatsop State Forest [SF], 23 in Tillamook SF, and 11 in Elliott SF). (p. 20, Table 2) 10 of the 37 nests were active, whereas 27 nests were old and from previous years. Unfortunately, the changing nature of the sampling every year makes interpreting how the number of nests in a site can increase or decrease among years very difficult to interpret. (p. 20 onward) Not clear whether they ever revisited old nest-trees to determine whether birds were using the same nest-trees in subsequent years. (p. 70) Footnote in Table 28 states that 2 old nests (nest-sites) were found in the same tree during climber training. This is the only clear reference to reuse of nest-trees anywhere in this report.

Study Citation	Nelson and Wilson 2002
Pertinent results, including statistical significance values and measures of variation[10]	(p. 71) At North Rector sites in Tillamook State Forest, 2 active nest-trees were found in 1994 [i.e., before this study is alleged to have occurred; similar reference to 1994 at top of p. 97] ~30 m from each other, indicating that there may be multiple use of a stand of trees within a year. (p. 88–92) Tables 30–34 list 35, not 37, nests across the 3 SFs: 3 in Clatsop SF, 21 in Tillamook SF, and 11 in Elliott SF. The 2 missing nests in Tillamook SF are unaccounted for. (p. 110–111) Authors admit that tree-climbing may not always be accurate in determining presence or absence of a nest.
Potential sources of bias or error	Authors admit that tree-climbers may not find all nests in a tree.
Effects modifiers[11]	Paper describes nests in OR, so highly relevant to study.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Evidence for nesting.
8 Was multiple nesting documented for individual birds?
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.2.21

Study Citation	Ryder et al. 2012
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Elk Creek, Chiliwack River, BC
Study area habitat	Western Redcedar and Douglas-fir with scattered Bigleaf Maples; sounds as though most is second-growth trees with residual old-growth forest
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Climbing
Years of study	1955
Within-year study period[4]	11–12 Jun
Sample sizes[5]	1 nest, plus 2 eggshell fragments
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Tree
How was nesting determined?[7]	Incubating adult, Eggshell fragments, Fecal ring
Multiple nesting for known individuals?[8]	No
Extent of habitat (area)[9]	Not presented
Nests within or between years?	Between years
Pertinent results, including statistical significance values and measures of variation[10]	(p. 51) Found egg-shell on mossy forest floor in area with large Western Redcedars and Douglas-firs. (p. 51) Climbed large, moss-covered Bigleaf Maple the next day, but not clear why they climbed this tree. (p. 52) Found another eggshell on forest floor the next day, again in area with large Western Redcedars and Douglas-firs. (p. 53) Thick layer of white feces around the nest could not have been produced by a chick of the year; authors suspect that fecal ring had been created by chick of previous year. [NOTE: Other papers consistently indicate that fecal rings are gone by the year after a nestling was in the nest, indicating that this fecal ring had to be from the year when it was discovered.]
Potential sources of bias or error	None apparent.
Effects modifiers[11]	Only nest ever found in maple tree or deciduous tree, for that matter; however, eggshell fragments also were found in Western Redcedar and Douglas-fir forests—but eggshells have been found in those forests before.

Study Citation	Ryder et al. 2012
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Evidence for nesting.
8 Was multiple nesting documented for individual birds?
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.2.22

Study Citation	Singer et al. 1995
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Big Basin Redwoods State Park, CA
Study area habitat	Largest remaining stand (~1700 ha) of old-growth Coast Redwood-Douglas Fir forest in Santa Cruz Mountains
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, Climbing, spotting-scope
Years of study	1991–1994
Within-year study period[4]	5 May–3 Jul 1991, 24 May–7 Jun 1992, 3 Apr–1 Aug 1993, 2 Apr–31 Jul 1994
Sample sizes[5]	4 nest-years
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Tree, Branch, Platform
How was nesting determined?[7]	Nestling, Nest-cup, Eggshell fragments, Fecal ring
Multiple nesting for known individuals?[8]	No
Extent of habitat (area)[9]	~1700 ha of remnant old-growth forest
Nests within or between years?	Between years
Pertinent results, including statistical significance values and measures of variation[10]	(p. 55) Nests found in same Coast Redwood tree in 1991, 1992 (different branch in same tree), and 1994 (same nest-cup as that used in 1991). Eggshell fragments found below tree in 1993 (early May), indicating use of the same nest-tree over 4 consecutive years; however, tree not climbed to find nest, which was suspected to have suffered predation. (p. 56) All evidence of fecal ring at 1991 nest gone when tree climbed again in 1992 (bird nested on different branch in 1992). (p. 61–62) Although same nest-tree was used in 4 consecutive years, no definitive evidence that the same birds nested in that tree every year; nevertheless, the strong pattern of nest-site fidelity in alcids in general suggests that it was the same pair of birds. (p. 62) Although they indicate that this study found birds using the same nest-cup in consecutive years, they earlier (at beginning of Results) explicitly state that different nest-branches were used in consecutive years.
Potential sources of bias or error	None apparent
Effects modifiers[11]	Data are from CA, so comparability to OR may be questionable. However, doubtful that tree type has significant effect on reuse, so this behavior probably transcends forest type and instead depends more on issues such as overall habitat availability.

Study Citation	Singer et al. 1995
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Evidence for nesting.
8 Was multiple nesting documented for individual birds?
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.2.23

Study Citation	Spickler and Sillett 1998
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Prairie Creek Redwoods State Park, northern CA
Study area habitat	Old-growth Coast Redwood forest
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Climbing
Years of study	1998
Within-year study period[4]	24 Oct
Sample sizes[5]	1 nest
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Tree, Platform
How was nesting determined?[7]	Eggshell fragments, Fecal ring, Nasal bones of what was suspected to be juvenile murrelet from previous year
Multiple nesting for known individuals?[8]	No
Extent of habitat (area)[9]	~14,000 acres in park, but continuity not specified; however, it is a state park, so presumably it is an extensive, continuous stand of forest
Nests within or between years?	Between years
Pertinent results, including statistical significance values and measures of variation[10]	(p. 1) Found nest by what appeared to be tree-climbing, although not explicitly stated. (p. 1) Eggshell fragments and shell membrane adjacent to and within nest cup; fecal ring believed to be from chick produced that year. (p. 1) Fragment of what was believed to be nasal bone of murrelet chick from previous year found covered by feces on outer edge of nest. Authors point out that this is only indirect evidence of reuse of nests-cups. (p. 2) Less than 3 months after collecting data on nest, all but a trace of nesting evidence was gone.
Potential sources of bias or error	No obvious bias because $n = 1$ anecdotal study, although paper is not clear why this tree was climbed (if it actually was) and whether other trees were climbed. Authors admit that evidence of reuse of trees for nesting is only indirect.

Study Citation	Spickler and Sillett 1998
Effects modifiers[11]	Data are from CA, so comparability to OR may be questionable. However, doubtful that tree type has significant effect on reuse, so this behavior probably transcends forest type and instead depends more on issues such as overall habitat availability.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Evidence for nesting.
8 Was multiple nesting documented for individual birds?
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Appendix 7.3. Data extraction tables for Question 3:

"How does the spatial extent of continuous potential habitat relate to the co-occurrence (i.e., nesting by multiple pairs) of murrelets in a forest stand and at other spatial scales?"

Table A7.3.1

Study Citation	Bloxton and Raphael 2009
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Olympic National Park, WA and Carmanah and Walbran watersheds (southwestern Vancouver Island)
Study area habitat	Variable including large areas of mature coniferous forest
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Radio-telemetry
Years of study	2004–2008
Within-year study period[4]	April–July
Sample sizes[5]	12 nests
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Agency technical report paper
Spatial scale(s)[6]	Watershed
How was nesting determined?[7]	Telemetry
Dependent variable[8]	Number of nests
Extent of habitat (area)[9]	Not specified
Pertinent results, including statistical significance values and measures of variation[10]	Summarized multiple years of telemetry studies (2004–2008) for birds captured in the Strait of Juan de Fuca. Tracked birds at marine and inland locations and over the duration of study found 12 murrelet nests total. (p. 17–36) Descriptions and maps of each nest site provide information to determine co-occurrence of nests at the watershed scale in both Olympic National Park, WA and Carmanah and Walbran, BC. Maps also allow for approximation of inter-nest distances for 2 different instances of co-occurrence.
Results: Distance(s) between nests and whether in same tree, patch, stand, watershed (if known)	Thus it can be concluded that there was 1 case of co-occurrence of 2 nests and 1 case of co-occurrence of 3 nests at the watershed scale in Olympic National Park, WA. For the Carmanah and Walbran watersheds there were 3 cases of co-occurrence of 2 nests and 1 case of co-occurrence of 3 nests. Inter-nest distances for 2 cases of co-occurrence in BC were 5 km and 7 km. There was no information provided on the amount or extent of continuous habitat.
Potential sources of bias or error	None apparent
Effects modifiers[11]	Radio-telemetry methods eliminated biases (e.g., habitat, topography) often found in other studies of murrelet nesting.

Study Citation	Bloxton and Raphael 2009
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, etc.
7 Evidence for nesting.
8 Presence of multiple nests, total number of nests/pairs, nesting density, etc.
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.3.2

Study Citation	Burger 1994
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Carmanah and Walbran valleys, Vancouver Island, BC
Study area habitat	Old-growth coniferous coastal forest (Sitka Spruce, Western Hemlock, Western Redcedar, Amabilis fir)
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, Climbing
Years of study	1990–1993
Within-year study period[4]	1990 = May–Aug; 1991 = Apr–Jul; 1992–1993 = May–Jul
Sample sizes[5]	6 nests
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Watershed, Stand, Survey site
How was nesting determined?[7]	Eggshell fragments, Fecal ring, Feathers, Adult landing, stationary calling, landing pad
Dependent variable[8]	Number of nests
Extent of habitat (area)[9]	Habitat extent not quantified but qualitative description of watersheds as "unfragmented old-growth forest" suggests continuity.
Pertinent results, including statistical significance values and measures of variation[10]	Over 4 years of study (1990–1993) researchers found 6 murrelet nests resulting from behavioral observations during audiovisual surveys (i.e., murrelets landing in trees) and climbing potential nest trees in areas where nesting was suspected. Three of these nests were active in the same year. (p. 22) "Most tree-climbing was done after the peak of murrelet activity in mid-July. This was done to reduce the possibilities of disturbing active nests. All nests were unoccupied when discovered…." (p. 22) Four nests had fecal rings with sufficient amounts of fresh fecal matter to indicate that these nests had likely been recently occupied by a well-developed chick and might have fledged. Thus, these nests were active in the years found; 1 in each of the 4 years of the study. (p. 23) Two of the nests found in 1992 appeared old and were presumed to have been used in the previous year (1991) but not in the current year (1992).

Study Citation	Bloxton and Raphael 2009
Pertinent results, including statistical significance values and measures of variation (continued)[10]	Based on these observations there were a total of 3 nests that co-occurred in 1991, assuming that the older nests found in 1992 were actually active in 1991. All 3 nests were in the Walbran watershed in close proximity to West Walbran Creek (Figure 3). Two of these nests were within 1 km of each other (West Walbran nest sites) and the third was located approximately 5–6 km downstream. The study did not present detailed (quantitative) information on the extent of continuous habitat in the West Walbran watershed, however, informative statements included: (p. 3) "The Carmanah Valley [adjacent to the West Walbran watershed] provides a 22 km long unlogged watershed…." (p. 14) When describing high densities of murrelets during marine surveys the author states, "Both of these stretches are adjacent to large tracts of unfragmented old-growth forest (the Nitinat Triangle Portion of the PRNP and the Carmanah-Walbran watersheds, respectively)."
Results: Distance(s) between nests and whether in same tree, patch, stand, watershed (if known)	Thus it can be concluded that in 1991 three murrelet nests co-occurred within continuous habitat at the watershed scale (within ~5–6 km of each other) and 2 of those nests also co-occurred in continuous habitat at the forest stand scale (within ~1 km of each other).
Potential sources of bias or error	The assumption of co-occurrence relies on the correct classification of year when older nests active.
Effects modifiers[11]	A strong El Niño event in 1992 and a repeat of these warm water conditions in 1993 likely affected the distribution and densities of murrelets during the study.
Additional notes	Habitat information: The Carmanah Valley is a 22 km long unlogged watershed. There are no roads in most of the Carmanah and Walbran watersheds. In each watershed there were trees 200–600 yrs old and in some cases trees exceeding 1,000 yrs old.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, etc.
7 Evidence for nesting.
8 Presence of multiple nests, total number of nests/pairs, nesting density, etc.
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.3.3

Study Citation	Carter and Sealy 1987
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	BC, WA
Study area habitat	Old-growth forest (tree species not specified)
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Anecdotal observations collected from historical records
Years of study	1919, 1950s, 1967
Within-year study period[4]	Not specified
Sample sizes[5]	6 grounded nestlings
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Watershed, Stand, Survey site, Patch, Tree
How was nesting determined?[7]	Nestling
Dependent variable[8]	Number of birds, number of nests
Extent of habitat (area)[9]	Not provided
Pertinent results, including statistical significance values and measures of variation[10]	The authors compiled inland records of hatching-year birds from various sources including literature, museum specimens and collections, field notes, and personal communications from others seabird researchers working on the west coast. Findings of co-occurrence of nesting murrelets (p. 59, Table 1) Gilltoyees Inlet, BC; August 1919; two downy chicks found on the ground by a marsh. Holber, BC; August 1967; two downy chicks fell from a tree being felled by loggers (Harris 1971). Sultan River Basin, WA; summer 1950s; two downy chicks fell from a tree being felled by loggers. There is no information provided on continuous habitat.
Results: Distance(s) between nests and whether in same tree, patch, stand, watershed (if known)	These records all reported 2 downy checks seen close together. Because murrelets have a single chick per nest and downy chicks are presumably not mobile enough to move far distances from the nest, these observations represent co-occurrence of 2 murrelet nests at the watershed scale (3 cases), forest stand scale (3 cases) and tree scale (1 case).
Potential sources of bias or error	None apparent

Study Citation	Carter and Sealy 1987
Effects modifiers[11]	Results on co-occurrence are based strictly on downed chicks, whereas most other sources involved actual murrelet nest sites.
Additional notes	(p. 61) "... 2 downy young dropped out of a tree (which probably contained nests) being felled by loggers in both record nos. 6 [Holber, BC] and 10 [Sultan River Basin, WA]…" (p. 68) "This dependence [on old-growth, tree-nesting habitat] may lead to solitary nests occurring in close proximity to each other where such habitat is patchily distributed, either naturally or through logging of adjacent areas. The 2 downy young found together in record nos. 5, 6 and 10 further support this suggestion because Marbled Murrelets only lay 1 egg and only single nests have been reported…"

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, etc.
7 Evidence for nesting.
8 Presence of multiple nests, total number of nests/pairs, nesting density, etc.
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.3.4

Study Citation	Hamer and Cummins 1990
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Stillaguamish River Basin, Sloan Creek, Sauk River, northwest WA
Study area habitat	Mostly forested variable age stands (clearcuts, disturbed younger forest, old-growth)
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, climbing, systematic walking surveys to look for eggshells
Years of study	1990
Within-year study period[4]	16 May to 15 Aug
Sample sizes[5]	2 nests
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Watershed, Stand, Survey site, Patch
How was nesting determined?[7]	Nestling, Eggshell fragments
Dependent variable[8]	Number of nests
Extent of habitat (area)[9]	753 square km study area. Continuity not quantified but habitat described as both highly fragmented areas and large contiguous forest stands.
Pertinent results, including statistical significance values and measures of variation[10]	Nest searching: Researchers conducted extensive audiovisual surveys and also dedicated nest searches using fixed-point surveys in high-use stands to track murrelets to trees, as well as systematic walking surveys to look for eggshells. (p. 47) "Two nests were located on U.S.F.S. [US Forest Service] managed lands, one on 13 Jul and another on 6 Aug. The nests were located only 46 m (150 ft) apart and contained 1 chick each." These nests were found based on eggshell fragments beneath trees that were subsequently climbed and searched for nests. The nest trees were both old-growth Western Hemlocks within a larger stand of Western Hemlock, Douglas Fir, and Western Redcedar. The researchers stated that these nests represent some of the first evidence of semicolonial nesting of murrelets. Although not quantified there was continuity of habitat at the forest stand scale (i.e., stand of old-growth). Inter-nest distance was 46 m and nest densities were not provided.

Study Citation	Hamer and Cummins 1990
Results: Distance(s) between nests and whether in same tree, patch, stand, watershed (if known)	These results indicate co-occurrence of 2 Marbled Murrelet nests at the watershed and stand scale, as well as the survey site and patch level.
Potential sources of bias or error	None apparent
Effects modifiers[11]	None apparent
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, etc.
7 Evidence for nesting.
8 Presence of multiple nests, total number of nests/pairs, nesting density, etc.
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.3.5

Study Citation	Hull et al. 2001
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Desolation Sound, BC
Study area habitat	Old-growth forest
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Climbing, Telemetry
Years of study	1998
Within-year study period[4]	4 May to early Jul
Sample sizes[5]	23 nests
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Watershed
How was nesting determined?[7]	Incubating adult, Fecal ring, Feathers, Radio-telemetry
Dependent variable[8]	Number of nests
Extent of habitat (area)[9]	Habitat extent not quantified. Continuity not quantified but qualitative description included highly fragmented areas (lower elevations) and also more intact (continuous) habitat (higher elevations).
Pertinent results, including statistical significance values and measures of variation[10]	Nesting activity: (p. 1,039) "Twenty-three nests were found, with active incubation at 16, and active chick-rearing at 12. A minimum of 3 nests fledged chicks, 9 were failures, and 11 were unknown." A map of telemetry locations and nest sites of murrelets (with no symbology to differentiate the two) provided enough information to infer co-occurrence (>1 murrelet nest) in at least three different watersheds in the greater Desolation Sound study area. Habitat continuity: (p. 1,043) Based on qualitative descriptions most of the low elevation forest around desolation sound was highly fragmented because of logging, whereas less habitat modification had occurred at higher elevations. The elevations of nest sites in the study ranged from 300–1,300 m asl and 14 of 23 nests were at elevations >800 m. Therefore presumably nests found during the study were generally in less fragmented forest habitats but there is not sufficient information provided to make definitive statements on this subject.

Study Citation	Hull et al. 2001
Results: Distance(s) between nests and whether in same tree, patch, stand, watershed (if known)	Co-occurrence in at least 3 watersheds.
Potential sources of bias or error	Nest locations were not provided and watersheds not delineated so the scale of co-occurrence was conservatively inferred.
Effects modifiers[11]	Radio-telemetry methods eliminated biases (e.g., habitat, topography) often found in other studies of murrelet nesting.
Additional notes	Nest locations were not noted on study map and neither watersheds nor forest stands were delineated so we had to make conservative assumptions of the scale of co-occurrence (i.e., at three different watersheds) and intensity of co-occurrence (i.e., >1 nest).

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, etc.
7 Evidence for nesting.
8 Presence of multiple nests, total number of nests/pairs, nesting density, etc.
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.3.6

Study Citation	Kuletz et al. 1995
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Western Prince William Sound (northern Gulf of Alaska), AK
Study area habitat	Coniferous forest with unforested areas (muskeg, lakes, and areas above treeline)
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, Telemetry, Boats
Years of study	1994
Within-year study period[4]	3 Jun to 28 Jul
Sample sizes[5]	6 nests (3 tree-nests; 3 cliff/ground nests)
Statistical analysis of results	Descriptive statistics only
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Watershed, Forest Stand
How was nesting determined?[7]	Nestling, Radio-telemetry locations
Dependent variable[8]	Number of nests
Extent of habitat (area)[9]	Habitat extent not quantified but area described as mostly forested with breaks at muskeg and ponds and above tree-line.
Pertinent results, including statistical significance values and measures of variation[10]	Murrelet nesting: (p. 14-15) "Three of the potential nests were at the head of East Finger Inlet, within 1 km of each other, and appeared to be tree nests. We hiked to 2 of the sites and were probably within 20 m of the nest tree." The researchers speculated that all nest site locations were mapped to within 50 m of the actual nest. "The other 3 nests appeared to be ground-cliff nests, one of which was confirmed when we found the chick in a cliff crevice on the coast of Kings Bay. The second ground-cliff nest was 5.7 km inland near Cotterell Glacier in treeless, rugged and inaccessible terrain. The third ground/tree nest was 2.3 km inland, west of West Finger Inlet." Habitat continuity: No specific information was provided on the extent (acreage or continuity) of habitat for the study area or nest sites, however both main study sites were qualitatively described as forested with the exception of areas above tree line at one site (>300 m elevation) and occasional unforested muskeg or ponds at the other site. Therefore these areas can be generally inferred as contiguous forested habitat below tree line and based on maps the three tree nests all co-occurred within continuous forested habitat.

Study Citation	Kuletz et al. 1995
Results: Distance(s) between nests and whether in same tree, patch, stand, watershed (if known)	The 3 murrelet tree-nests all co-occurred at the watershed and forest stand scale and the distance between nests was ≤1 km. Based on the maps provided it was not possible to discern at what scale the ground-nests occurred but the distance between these nests ranged from 6–12 km.
Potential sources of bias or error	Exact nest locations/trees were not determined (with tree-climbing), however, nesting evidence was convincing and nest locations determined within 50 m.
Effects modifiers[11]	Radio-telemetry methods eliminated biases (e.g., habitat, topography) often found in other studies of murrelet nesting.
Additional notes	Radio-telemetry methods: A total of 47 Marbled Murrelets were radio-tagged at two different capture sites and tracked by air, by boat, and from stationary points on land. Nest locations: After tracking birds to inland sites during aerial surveys observers on the ground attempted to pinpoint signal locations of nesting birds. The researchers thought that nest site locations were mapped to within 50 m at each site.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, etc.
7 Evidence for nesting.
8 Presence of multiple nests, total number of nests/pairs, nesting density, etc.
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.3.7

Study Citation	Manley 1999
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Sunshine Coast (Bunster Range, Theodosia Valley, Britain Valley), southwestern BC
Study area habitat	Mixed coniferous forest (Douglas Fir, Shore Pine, Western Hemlock, Western Redcedar, Pacific Silver Fir, Yellow Cedar, Mountain Hemlock)
Study design[1]	Both
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing, Telemetry
Years of study	1994–1997
Within-year study period[4]	Variable among years. Ranged from 13 May–5 August.
Sample sizes[5]	52 nest trees
Statistical analysis of results	Descriptive statistics only
Statistical power	Not applicable
Document type	Thesis/dissertation
Spatial scale(s)[6]	Watershed, Forest Stand, Survey site, Patch, Sunshine Coast study area
How was nesting determined?[7]	Incubating adult, Nest-cup, Eggshell fragments, Fecal ring, Feathers, Adult landing
Dependent variable[8]	Number of nests, nest density
Extent of habitat (area)[9]	35,404 ha in larger landscape unit (4,874 ha late successional forest). Continuity quantified at stand level but insufficient details on nest locations to match with stand areas.
Pertinent results, including statistical significance values and measures of variation[10]	Marbled Murrelet nests: (p. 20) Researchers found a total of 52 nests trees at multiple study sites at the Sunshine Coast from 1994–1997. (p. 21, Table 3) Results of nest monitoring from 1994–1996 indicated co-occurrence of 2 nests in 1995 and 4 nests in 1996. This was for nests that were active when found versus determination of status from tree-climbing at the end of the season after breeding activities had concluded. (p. 35, Table 8) The table provides the outcome of murrelet nesting attempts on the Sunshine Coast from 1994–1997. Based on the number of known fate nests there were 3 active nests in 1995, 10 active nests in 1996, and 8 active nests in 1997. These data present minimum estimates of co-occurrence each year because there was a larger sample for which nest fate was unknown and therefore the year when nests were last active was presumably unknown. Because these results included data on nests from tree-climbing at the end of the breeding season

Study Citation	Manley 1999
Pertinent results, including statistical significance values and measures of variation (continued)[10]	this data set was more comprehensive than what was reported in Table 3. Regardless, it was not possible to determine the scale of co-occurrence at the watershed or smaller scales from data presented in this table (but see below for more detailed information). (p. 78 and p. 80, Table 28) For areas with clusters of 2 or more nest sites data was presented on the distance between nest trees and nest densities. With the exception of 2 nests in 1996 and 2 nests in 1997, it was not possible to determine if/what nests were active in the same year (i.e., co-occurred). The inter-nest distance between nest trees with nests determined active at the same time (and thus co-occurring) was 38 m for 2 nest trees in 1996 (nests 5 and 11) and 58 m for 2 nest trees in 1997 (nests 47 and 48). The study site where these nests occurred was not specified but was presumably the Bunster Range where the researchers conducted more intensive behavioral observations. Nest densities for 4 different clusters of nests were 1.3 nests/ha, 2.6 nests/ha, 4.2 nests/ha, and 4.2 nests/ha, but it was not stated and therefore is unknown how many of these nests (ranging from 2–9 per cluster) co-occurred (i.e., were active in the same year). In summary, there was co-occurrence of Marbled Murrelet nests in the greater Sunshine Coast study area in 1995 (3 nests), 1996 (10 nests), and 1997 (8 nests). Based on the inter-nest distances of 2 active nests in 1996 (38 m) and 2 active nests in 1997 (58 m) there was also co-occurrence at the watershed and forest stand scale (so also survey site and patch scales) at locations not specified. Continuous habitat The amount of continuous forest area and number of nest trees was provided for 20 different stands with 51 murrelet nests total (p. 79, Table 27). However there was no accompanying information on what years nests were active and if/when there was co-occurrence. Therefore it was not possible to determine if there was continuous habitat for the larger sample of co-occurring nests or the amount of continuous habitat where nests were found to co-occur at the watershed and stand scales.
Results: Distance(s) between nests and whether in same tree, patch, stand, watershed (if known)	2 nests 38 m apart and 2 nests 58 m apart; therefore, co-occurrence in the same patch, stand, and watershed.
Potential sources of bias or error	None Apparent
Effects modifiers[11]	Radio-telemetry methods eliminated biases (e.g., habitat, topography) often found in other studies of murrelet nesting.
Additional notes	For the Bunster Range portion of the greater Sunshine Coast study area the current study (Manley 1999) overlapped with both Drever et al. (1998) and Lougheed et al. (1998). However, the current study provides information on co-occurrence at the

Study Citation	Manley 1999
Additional notes (continued)	watershed and smaller scales, potentially in the Bunster Range, whereas the other sources only provided enough information to determine co-occurrence within the Bunster Range and not at smaller scales. Therefore, the current source will be used in place of both Drever et al (1998) and Lougheed et al. (1998). Methods for locating nests: (pp. 11 and 51) "Radio-telemetry was used to locate nest in 1994 of birds caught on the water in Desolation Sound. In 1995–1996 a combination of surveys and tree-climbing was used. During 1995 5 sites were surveyed for murrelet activity from June 1–July 31 and 89 trees were climbed and searched for nests from August 3–29 (Lougheed et al. 1998). In 1996, 36 sites in the Bunster Range were surveyed from May 13–August 5 (Drever et al. 1998). We also scanned trees to look for murrelet nests and searched under potential trees for eggshell fragments during vegetation plots (n = 36), transects (n = 27) and other field work. MELP inventory crews surveyed 20 stands at other locations in the Sunshine Coast Forest District (Manley and Jones 1996). During 1996, 355 trees were climbed in the Bunster Range and 12 trees were climbed in the Brittain River Watershed. In 1997, 17 sites were surveyed in the Bunster Range at which 11 trees were climbed to search for nests (Lougheed et al. 1998b). During the MELP inventory in 1997, 48 sites were surveyed and 343 trees were climbed to search for nests in plots (Manley 1997)." Re-use of nest trees: (p. 13) "Nest trees were monitored in years following their discovery (1996–97) to determine if murrelets re-used the nest tree. Nest trees were surveyed a minimum of 3 mornings, at least once in each of May, June and July and were climbed at the end of the breeding season to look for evidence of re-use such as eggshells, feathers and fecal rings." (p. 14) "The presence of multiple nest cups within a tree indicates that the tree has been used for more than one breeding attempt. It is not possible to date murrelet nest sites unless evidence such as eggshells are present, but nest cups may remain visible for 4 or more years (I. Manley unpub data, A Burger pers. comm.). I used the proportion of nest trees with >1 nest as a measure of nest tree re-use over multiple years. This measure would not detect re-use of the same nest, or detect multiple nests used within a single year." (p. 92) Marbled Murrelets showed a high degree of nest site aggregation during the study with 52% of nests within 100 m of at least one other nest. The level of aggregation was probably higher but not all trees in a cluster were systematically searched for nests. Regardless, for all but 2 nest clusters there was not direct evidence that nests were active in the same year.

Study Citation	Manley 1999
Additional notes (continued)	(p. 146, Appendix 1) Following observations of murrelets landing at a tree in 1996 the tree was climbed and 2 failed nests from 1996 found. It was not possible to determine if different birds were using the same tree or if a single pair renested in the same tree following loss of the first nest.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, etc.
7 Evidence for nesting.
8 Presence of multiple nests, total number of nests/pairs, nesting density, etc.
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.3.8

Study Citation	Naslund et al. 1995
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Naked Island (Prince William Sound), Kodiak and Afognak islands (Alaska Peninsula), AK
Study area habitat	Old-growth coniferous forest (Western Hemlock, Mountain Hemlock, Sitka Spruce) with muskeg and tundra/alpine areas.
Study design[1]	Both
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing
Years of study	1991 (Naked Island); 1992 (Naked, Kodiak, and Afognak islands)
Within-year study period[4]	13 Jun to 26 Jul 1991; 25 May to 6 Aug 1992
Sample sizes[5]	14 active nests [Naked Island = 10 nests (6 in 1991, 4 in 1992); Kodiak Island = 2 nests; Afognak Island = 2 nests].
Statistical analysis of results	Descriptive statistics only
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Watershed, Forest Stand, Patch, Island
How was nesting determined?[7]	Egg, Nest-cup, Eggshell fragments
Dependent variable[8]	Number of nests
Extent of habitat (area)[9]	Naked Island stand with 17.5 ha continuous habitat. Kodiak Island subjected to small-scale logging so likely continuous. Afognak Island with heavily logged (clear-cut) areas.
Pertinent results, including statistical significance values and measures of variation[10]	Nest searching: (p. 15, Table 1) Researchers located a total of 14 murrelet tree nests on Naked Island (*n* = 6 in 1991, *n* = 4 in 1992), Kodiak Island (*n* = 2 in 1992), and Afognak Island (n = 2 in 1992). There were 19 other trees with possible nest sites (see notes). Overall there was co-occurrence at the island scale at each study area (Naked Island = 4 nests [1991] and 2 nests [1992]; Kodiak Island = 2 nests; Afognak = 2 nests). On Naked Island there was co-occurrence at the watershed and forest stand scale of 3 nests within the same 17.5 ha stand of continuous habitat. The resulting nesting density equates to 4.38 nests/ha. Another 2 nests possibly co-occurred 10 m apart in a different stand of 62.6 ha continuous habitat, but the researchers speculated that these 2 nests could have been multiple nesting attempts (renesting) by the same pair of murrelets. On Kodiak Island there was co-occurrence of 2 nests at the watershed and forest stand scale. The inter-nest distance of the Kodiak Island nests was <50 m. Two nests were found on Afognak Island in 1992 but it was not indicated whether they

Study Citation	Naslund et al. 1995
Pertinent results, including statistical significance values and measures of variation (continued)[10]	occurred in the same watershed or stand. The amount of continuous habitat was not quantified at either Kodiak or Afognak Island, however, the researchers stated that the "…contiguous forest stands tend to be larger on these islands" (p. 76).
Results: Distance(s) between nests and whether in same tree, patch, stand, watershed (if known)	Naked Island: co-occurrence within watershed and forest stand Kodiak Island: co-occurrence within watershed and forest stand; 2 nests <50 m apart
Potential sources of bias or error	Year when nests active were inferred based on evidence at end of the breeding season.
Effects modifiers[11]	Nest searches on Naked Island were focused in areas with suspected nesting activity but were more opportunistic in both forested and non-forested habitats on the other two islands.
Additional notes	Nest searching: (p. 13) On Naked Island nest searching efforts were concentrated in areas with suspected nesting activity, whereas search efforts on Kodiak and Afognak islands were more opportunistic in forested and non-forested areas. Surveys on Kodiak and Afognak were conducted in conjunction with other surveys of murrelet activity. (p. 14) For Naked Island the researchers had access to information on approximate area of contiguous habitat in stands with nests. Continuous forest was generally defined as "the area that contained only forest of tree-size and volume classes similar to the nest stand." (p. 18) In addition to found nest sites Marbled Murrelets were observed landing on 21 trees (Naked Island = 9, Kodiak Island = 6, Afognak Island = 6) where no nests were found. 6 of these trees were climbed and no nest found and the other 15 trees were not climbed. Researchers noted that nesting might actually have occurred in 19 of these trees but could not be determined.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, etc.
7 Evidence for nesting.
8 Presence of multiple nests, total number of nests/pairs, nesting density, etc.
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.3.9

Study Citation	Nelson and Peck 1995
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Coast Range and Siskiyou Mountains, OR
Study area habitat	Mosaic of young and mature forest. Old-growth restricted to small, isolated patches. (Douglas fir and mixed evergreen the dominant species)
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, Climbing, Cameras, Ground-based egg-shell fragment searches in areas with murrelet activity
Years of study	1990–1992
Within-year study period[4]	Not specified for each year but 14 May to 2 Sep 1991
Sample sizes[5]	9 nests.
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Watershed
How was nesting determined?[7]	Nestling, Egg, Incubating adult, Eggshell fragments, Fecal ring, Adult landing, Adult fly in/out of canopy
Dependent variable[8]	Number of nests
Extent of habitat (area)[9]	Not provided
Pertinent results, including statistical significance values and measures of variation[10]	Dawn and dusk surveys were used to find areas with Marbled Murrelet activity and then multiple observers were stationed in these areas to pinpoint nest trees and nest sites. Once a nest tree was located adjacent trees were climbed to conduct nest observations and nest trees were climbed at the end of the breeding season to document signs of nesting. (p. 45) A total of 9 Marbled Murrelet nests were found from 1990–1992. All nests were active when found with either eggs or chicks present. Of the 9 nests, 2 were determined active in the same year in mature/old-growth habitat along the Siuslaw River (p. 44, Figure 1; p. 46, Table 1). Because these nests were found along the Siuslaw River corridor, there was co-occurrence at the watershed scale. Because the distance from the coast was provided, we can infer that the distance between these nests was approximately 1 km, but it is unclear from information provided if these were within the same forest stand. There was no quantitative information provided on the extent or continuity of habitat for these nest sites.

Study Citation	Nelson and Peck 1995
Results: Distance(s) between nests and whether in same tree, patch, stand, watershed (if known)	Co-occurrence within same watershed; 2 nests ~1 km apart
Potential sources of bias or error	None apparent
Effects modifiers[11]	None apparent
Additional notes	The researchers provide some anecdotal information on the reuse of these nests in years subsequent to when found (1991–1993), but does not document any more instances of co-occurrence.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, etc.
7 Evidence for nesting.
8 Presence of multiple nests, total number of nests/pairs, nesting density, etc.
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.3.10

Study Citation	Nelson and Wilson 2002
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Clatsop, Tillamook, and Elliott state forests, (Coast Range) OR
Study area habitat	Mosaic of young, mature, and old-growth forest (Douglas-fir, Sitka Spruce, Western Hemlock)
Study design[1]	Both
Sampling design[2]	Experimental; w/replicates, no controls
Study methods[3]	Audio-visual, Climbing
Years of study	1995–1999
Within-year study period[4]	1 May to 31 Aug depending on year (see notes)
Sample sizes[5]	37 nests (27 old and 10 active)
Statistical analysis of results	Descriptive statistics only
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Watershed, Forest Stand, Survey site, Patch, State Forest
How was nesting determined?[7]	Nest-cup, Eggshell fragments, Fecal ring, Feathers, Adult landing, Landing pad
Dependent variable[8]	Number of nests
Extent of habitat (area)[9]	Size of study areas provided (Clatsop State Forest = 62,323 ha, Tillamook State Forest = 147,309 ha, Elliot State Forest = 37,637 ha) but habitat continuity not specified or described.
Pertinent results, including statistical significance values and measures of variation[10]	Nests found: Nest searching efforts from 1994–1999 resulted in a total of 37 Marbled Murrelet nests found on the Clatsop State Forest (n = 3), Tillamook State Forest (n = 23) and the Elliott State Forest (n = 11), between 1994 and 1999 (Tables 2 and 3). Ten of the nests were active when found and the remaining 27 nests were old. In total researches climbed or observed 1,890 trees and searched 31,778 potential nesting platforms (p. 20) Co-occurrence of murrelet nests: (p. 21, Table 2) At the Tillamook State Forest there were 2 nests active in 1994, 2 nests active in 1997, and 4 nests active in 1998. 1994 (p. 71) Two active nests were monitored concurrently at the North Rector site and were located in trees approximately 30 m apart (North Rector Site). No information provided on the scale of continuous habitat at co-occurring nests.

Study Citation	Nelson and Wilson 2002
Pertinent results, including statistical significance values and measures of variation (continued)[10]	1997 (p. 80–81) Two active nests were monitored at the Big Rackheap site. The distance between these nests and information on habitat continuity was not provided. Nest density (p. 107) The density of murrelet nests across the study sites ranged from 0.1 to 3.0 per hectare, however, presumably this included the larger sample of both active and inactive nests.
Results: Distance(s) between nests and whether in same tree, patch, stand, watershed (if known)	Co-occurrence of 2 murrelet nests was documented at the watershed in 1994 and 1997. In 1994 there was also co-occurrence of 2 murrelet nests at the stand, survey site, and patch scale. The inter-nest distance between 2 of these nests was 30 m.
Potential sources of bias or error	None apparent
Effects modifiers[11]	None apparent
Additional notes	(p. 11) "We used dawn surveys to locate active nests and to augment our tree climbing methods. We conducted these surveys from 22 Jun through 19 Aug 1995 (Elliott and Tillamook only), 1 Jul through 6 Aug 1996 (Elliott only), 12 May to 31 Aug 1997, 1 May to 31 Aug 1998, and 6 May to 23 Aug 1999 (Clatsop and Tillamook only)." (p. 108) "…nest densities from random plot tree climbing in British Columbia and Alaska appeared to be equally as low, even in areas of contiguous old-growth and high detection rates (0.11–4.2/ha; Manley 1999, Rodway and Regehr 1999, Conroy et al. in press, K. Kuletz pers. comm.). Besides requiring tremendous effort for locating nests, low nesting densities indicate that many or larger stands of suitable habitat will be necessary for providing for viable breeding populations of murrelets."

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, etc.
7 Evidence for nesting.
8 Presence of multiple nests, total number of nests/pairs, nesting density, etc.
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.3.11

Study Citation	Ryder et al. 2012
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Elk Creek, BC
Study area habitat	Coniferous forest. Primarily secondary growth with scattered remnant old-growth trees (Douglas Fir, Western Redcedar, Bigleaf Maple)
Study design[1]	Qualitative
Sampling design[2]	
Study methods[3]	Climbing
Years of study	1955
Within-year study period[4]	11–12 Jun
Sample sizes[5]	3 nests (1 adult incubating a nest and 2 findings of eggshell fragments).
Statistical analysis of results	None—n.a.
Statistical power	Not applicable.
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Watershed
How was nesting determined?[7]	Egg, Incubating adult, Eggshell fragments, Fecal ring
Dependent variable[8]	Number of nests
Extent of habitat (area)[9]	Habitat extent not quantified but a qualitative description indicated primarily secondary growth forest with old-growth patches interspersed with younger stands resulting from history of fire and logging.
Pertinent results, including statistical significance values and measures of variation[10]	This paper summarized historical field notes from 1955 that describe a Marbled Murrelet tree nest found in British Columbia. The nest tree was a Bigleaf Maple with an adult Marbled Murrelet incubating an egg. The nest tree was climbed following discovery of eggshell fragments of a Marbled Murrelet egg some distance away on the forest floor. A second observation of eggshell fragments was made following the discovery of the nest site. The spatial scale at which these findings occurred was not well described but the study authors interpreted these field notes as evidence of 3 different Marbled Murrelet nests in the Elk Creek drainage in 1955. Therefore there was co-occurrence of 3 nests at the watershed scale. It is possible that 2 or more of these nests were within the same forest stand but the information provided was not sufficient to determine this. Additionally the scale of continuous habitat was not quantified. A qualitative description of the habitat based on the field notes and historical records of fire and logging was that area was secondary growth forest with old-growth patches.

Study Citation	Ryder et al. 2012
Results: Distance(s) between nests and whether in same tree, patch, stand, watershed (if known)	Co-occurrence of 3 nests within the same watershed, possibly the same forest stand.
Potential sources of bias or error	None apparent
Effects modifiers[11]	The study did not include a systematic search effort for Marbled Murrelet nests.
Additional notes	Marbled Murrelet nests (p. 50) "We provide details of a nest of the Marbled Murrelet discovered in a Bigleaf Maple (Acer macrophyllum) at Elk Creek, British Columbia, in 1955 and also provide other evidence of nesting in this area at this time. Eggshell fragments found on the ground a short distance away from the known nest location, but not directly under coniferous nest trees, suggest two additional tree nests." (p. 54) "These 3 nests occurred in relatively close proximity at Elk Creek in 1955. Although generally considered to nest solitarily, nests have been found in nearby trees in other areas (e.g., Naslund et al. 1995)." Habitat (p. 51) "During our hike through the old-growth forestlands…" (p. 53–54) "About the turn of the 20th century, fire and logging greatly impacted forests in the area, resulting in second-growth forest about 100 years old in the early 2000s or about 50–70 years old in 1955 (Grozier 2003). Large second-growth Douglas-firs predominated by the early 2000s, with a few old-growth Western Redcedars, estimated up to 250 years old, as isolated trees or in small clusters, scattered throughout the area."

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, etc.
7 Evidence for nesting.
8 Presence of multiple nests, total number of nests/pairs, nesting density, etc.
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.3.12

Study Citation	Suddjian 2003
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	South Fork Butano Creek (Santa Cruz Mountains), San Mateo County, CA
Study area habitat	Coniferous forest with remnant old-growth trees (Coast Redwood, Douglas Fir)
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual
Years of study	1991–2001
Within-year study period[4]	27 Apr to 29 Jul
Sample sizes[5]	1 nest, 2 grounded fledglings, eggshells at 2 locations, and 7 observations of adult murrelets carrying fish.
Statistical analysis of results	None—n.a.
Statistical power	Not applicable.
Document type	Unpublished report
Spatial scale(s)[6]	Watershed, Stand
How was nesting determined?[7]	Egg, Incubating adult, Eggshell fragments, Grounded fledgling
Dependent variable[8]	Number of nests
Extent of habitat (area)[9]	Habitat extent not specified but based on qualitative description nesting occurred in stands with remnant old-growth trees.
Pertinent results, including statistical significance values and measures of variation[10]	With the exception of 1 nest site found as part of another study in 2000 (see below) all evidence of nesting was based on observations of adults carrying fish to provision chicks or grounded fledglings. Dates, descriptions, and maps (Figure 25) of these observations from 1991–2001, allowed for determination with a high degree of certainty of probable co-occurrence. Probable co-occurrence of nesting murrelets in the South Fork of the Butano Creek watershed 1991 (p. 15) An adult murrelet was observed carrying a fish on 14 Jun and 17 Jul in or near Unit C. The time period between these observations is highly suggestive of co-occurrence of two different murrelet nests, both presumably in the old growth of Unit C, at the watershed and forest stand scale. 2000 (p. 18) In Unit A an adult murrelet was observed carrying a fish near Station A2 and a grounded fledging was found between stations A3 and A4 on 23 Jul. Meanwhile in the adjacent Unit B a murrelet nest was found near Station B4. This nest was active until at least 26 Jun but failed sometime the following week. An adult murrelet was observed carrying a fish on 19 Jul

Study Citation	Suddjian 2003
Pertinent results, including statistical significance values and measures of variation (continued)[10]	near Station B3 and must have been attending a co-occurring nest in the same unit. The distance between the found nest and grounded chick was ~500 m. Therefore there was co-occurrence of 3 nests at the watershed scale and 2 nests at the forest stand scale. No specific information was provided on extent or continuity of habitat in the study area but based on the study description and map of observations we assume there was continuity of habitat for nests co-occurring at the stand scale.
Results: Distance(s) between nests and whether in same tree, patch, stand, watershed (if known)	1991: co-occurrence of 2 nests in the same watershed and stand (highly likely) 2000: co-occurrence of 3 nests in the same watershed and 2 nests in the same forest stand.
Potential sources of bias or error	With exception of 1 nest found, probable nesting of murrelets and nest locations were determined based on indirect observations (i.e., grounded chicks, eggshell fragments, adults flying with fish).
Effects modifiers[11]	None apparent
Additional notes	Observations of murrelets where co-occurrence could not be inferred 1994 (p. 16) Murrelet eggshell fragments were found near Station A3 on 13 Jun and also 24 Jul. Based on this information it is not possible to determine if there was co-occurrence of murrelet nests and in particular if there was >1 nest whether it was the same pair renesting or 2 different nesting pairs of murrelets. 1998 (p. 16) An adult murrelet was observed carrying a fish on 2 different occasions, on 23 Jun near Station A2 and on 13 Jul near Station D9. It is not possible to determine from these observations if there was co-occurrence of nesting murrelets or if these adults were provisioning a chick at the same nest. 1999 (p. 17) An adult murrelet was observed flying and carrying a fish on 2 different occasions, on 9 Jul near station A1 and on 13 Jul near Station A4. It is not possible to determine from these observations if there was co-occurrence of nesting murrelets or if these adults were provisioning a chick at the same nest.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, etc.
7 Evidence for nesting.
8 Presence of multiple nests, total number of nests/pairs, nesting density, etc.
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.3.13

Study Citation	Waterhouse et al. 2011
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Mathieson Channel (central coast), BC
Study area habitat	Patchy alpine coniferous forest with intermixed avalanche chutes and rocky outcrops.
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Radio-telemetry
Years of study	1992, 1999
Within-year study period[4]	May–June 1992, May–July 1999
Sample sizes[5]	14 nests (1992 = 2, 1999 = 12)
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Agency technical report paper
Spatial scale(s)[6]	Watershed
How was nesting determined?[7]	Telemetry
Dependent variable[8]	Number of nests
Extent of habitat (area)[9]	~40,000 ha study area with >50% comprised of mature/old forest. Habitat continuity not specifically addressed or quantified but qualitative description of watersheds as "unfragmented old-growth forest" suggests continuity.
Pertinent results, including statistical significance values and measures of variation[10]	Examined nesting habitat from two different study years with 14 nests total (1992 = 2 nests, 1999 = 12 nests). Nests located using radio-telemetry and limited audio-visual surveys. (p. 3) "For both projects, potential nest sites were confirmed by triangulation from a helicopter to within 100 m of the radio transmitters on the incubating birds, but nests were not visually confirmed due to limited ground access in the steep terrain." (p. 4, Figure 1) A map of nest sites from both years indicates co-occurrence of all nests within the Mussel Inlet catchment (e.g., watershed). Inter-nest distances measured from the figure provided were approximately 7 km for the two 1992 nests and 2–25 km for the 12 1999 nests.
Results: Distance(s) between nests and whether in same tree, patch, stand, watershed (if known)	Thus it can be concluded that in 1992 two murrelet nests co-occurred at the watershed scale (within ~7 km of each other) and in 1999 12 murrelet nests co-occurred at the watershed scale (~2–25 km from each other). Two of those nests also co-occurred in continuous habitat at the forest stand scale (within ~1 km of each other). It was not possible to infer if nests were in the same stand. Detailed information on habitat continuity (i.e., any breaks in habitat?) were not provided.

Study Citation	Waterhouse et al. 2011
Potential sources of bias or error	Exact nest locations/trees were not determined (with tree-climbing), however, nesting evidence and associated locations were convincing.
Effects modifiers[11]	Radio-telemetry methods eliminated biases (e.g., habitat, topography) often found in other studies of murrelet nesting.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, etc.
7 Evidence for nesting.
8 Presence of multiple nests, total number of nests/pairs, nesting density, etc.
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Table A7.3.14

Study Citation	Zharikov et al. 2007
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Desolation Sound and Clayoquot Sound, (southwestern Vancouver Island), BC
Study area habitat	Coniferous old-growth forest (Western Redcedar, Western Hemlock, Douglas Fir)
Study design[1]	Both
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, Telemetry
Years of study	1998–2001 and 2000–2002
Within-year study period[4]	May to Jun
Sample sizes[5]	157 nests (Desolation Sound = 121 nests; Clayoquot Sound = 36 nests).
Statistical analysis of results	Non-parametric (list tests):
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Desolation Sound and Clayoquot Sound
How was nesting determined?[7]	Telemetry and ground observations
Dependent variable[8]	Number of nests
Extent of habitat (area)[9]	Habitat extent not quantified but 80% of original forest logged at Desolation Sound study area and 15–25% old-growth cover logged at Clayoquot Sound study area.
Pertinent results, including statistical significance values and measures of variation[10]	Nests found: Researchers tracked a total of 157 radio-tagged Marbled Murrelets to nest sites in the years 1998–2003. Analyses included a sample of 108 and 29 nests from the Desolation Sound and Clayoquot Sound study areas, respectively. Co-occurrence of nesting murrelets: Details on the number of active nests of radio-tagged birds found each year were not provided and neither was the scale of possible co-occurrence below the scale of the larger study areas. Distance between nests: (p. 751) "Nest spacing at Desolation was stable among the 4 study years (CV = 27%), with an overall within-year mean nearest nest distance (NND) of 4.6 ± 4.0 (SD) km. The NND was independent of the number of located nests (range 23–38) in a given year (rs = – 0.05, *P* = 0.94). At Clayoquot, fewer nests were located per year (8, 10, and 18) because of a lower sampling effort; on average they were further apart (6.6 ± 4.2 km). However, the NND in the year with the highest sample size (2002, 18) was essentially the same as at Desolation (4.8 ± 4.2 km)."

Study Citation	Zharikov et al. 2007
Pertinent results, including statistical significance values and measures of variation (continued)[10]	In summary, there was not sufficient information provided to determine co-occurrence below the scales of Desolation Sound and Clayoquot Sound, however, overall within-year nearest nest distances for each study area were informative. There was not sufficient information to address the subject of habitat continuity.
Results: Distance(s) between nests and whether in same tree, patch, stand, watershed (if known)	Not known
Potential sources of bias or error	None apparent
Effects modifiers[11]	Radio-telemetry methods eliminated biases (e.g., habitat, topography) often found in other studies of murrelet nesting.
Additional notes	Note that the entire sample of nests used in this study was pulled from previous studies in Desolation Sound and Clayoquot Sound. Therefore the data must be used with caution to prevent pseudoreplication of results. However, the information on inter-nest distances provided and used herein for the larger samples of nests was not provided in any previous sources. Habitat: (p. 749) "The primeval vegetation at either site is/was dominated by coniferous old-growth forest comprising Western Redcedar *(Tsuga plicata Donn.)*, Western Hemlock *(Tsuga heterophylla Sarg)* and Douglas Fir *(Pseudotsuga menziesii Franco)*. At Desolation, industrial-scale logging started early in the 20th century and continues at present. Approximately 80% of the original forest has been logged (F. Huettmann, unpublished data). At Clayoquot, large-scale logging commenced in 1954 and by 1993 15–25% of the old-growth cover had been harvested (Kelson, Manly & Carter 1995)."

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, etc.
7 Evidence for nesting.
8 Presence of multiple nests, total number of nests/pairs, nesting density, etc.
9 Acreage of habitat, continuous or not, and how defined.
10 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
11 Potential factors that may have affected results and comparability relative to other studies.

Appendix 7.4. Data extraction tables for Question 4:

“How is the occurrence of Marbled Murrelet nest sites related to the number and size of potential nest platforms and platform tree density within stands of different age classes (young, mature, and old growth)?”

Table A7.4.1

Study Citation	Baker 2006
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Santa Cruz Mountains, CA
Study area habitat	Coastal redwood
Study design[1]	Quantitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing, Telemetry
Years of study	1989, 1991–2001
Within-year study period[4]	Apr–Jun (1997–2001, telemetry); 1989, 1991–96 dates unknown (AV nest searches)
Sample sizes[5]	17 nest trees; 15 nest platforms
Statistical analysis of results	Parametric: t-tests for differences between tree species; ANOVA include # platforms/tree compared to control site
Statistical power	None
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Tree
Platform definition	"Limbs >10 cm in diameter"
Dependent variable(s)[7]	Platform size, number of platforms
Stand age	Old growth: late seral stage with canopy trees originating earlier than 1850
Pertinent results, including statistical significance values and measures of variation[8]	(Table 1) Number of platforms (mean ± SD) 7.4 ± 4.9, n = 13 nest trees; 5.1 ± 3.5, n = 17 random sites; F = 2.17, P = 0.15 df =1, 24. (p. 944) Number of platforms greater in Douglas-fir (mean = 10.5, SD = 3.4, n = 8) than redwood (x = 2.4, SD = 1.1, n = 5; t = 5.05, P < 0.01, df = 16) nest trees. Mean diameter of the nest limb at the nest cup (including epiphyte cover) was 46.5 cm (SD = 12.1, n = 12; range = 29–70 cm). (p. 945) "Mean nest limb diameter was much greater for Douglas-fir than for redwood nests." 3 of 8 nests in redwood trees were found on broken tops rather than on limbs.
Potential sources of bias or error	Random plots instead of unused plots for comparisons decrease power for small sample sizes; minimum limb size considered as potential platform (10 cm) may be too small, as smallest limb with nest was 29 cm

Study Citation	Baker 2006
Effects modifiers[9]	Forest type
Additional notes	Supersedes Singer et al. 1991, 1992, 1995.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Table A7.4.2

Study Citation	Bradley and Cooke 2001
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	BC mainland: Desolation Sound and Mussel Inlet areas
Study area habitat	Tree nest in mixed coniferous/deciduous forest; also cliff nest and presumed nests in shrub areas
Study design[1]	Qualitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing, Telemetry, Transect surveys, 25 m radius sampling plots
Years of study	1999 & 2000
Within-year study period[4]	Apr & May capture and attach radios; telemetry throughout breeding season
Sample sizes[5]	1 tree nest, 1 cliff nest
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Tree, 500 m transects from nest tree
Platform definition	Potential nesting platform: "tree limbs >15 m above the ground and >18 cm in diameter, including moss"
Dependent variable(s)[7]	Platform size, platform density, number of platform trees
Stand age	Unknown; nest tree = 130 year-old red alder
Pertinent results, including statistical significance values and measures of variation[8]	(p. 53) Transect surveys were used to determine the relative abundance of trees with potential murrelet nesting platforms in 4 classes: 1, 2 to 4, 5 to 9, and >9 platforms/tree. Potential nesting platforms were recorded in 115 trees: 64% were deciduous trees (58% Big Leaf Maple, 6% Red Alder) and 36% were coniferous trees (21% Western Redcedar, 11% Western Hemlock, 4% Douglas Fir). Deciduous trees had a higher proportion of potential nesting platforms than coniferous trees in all 4 density classes (Table 2). In sample plots around the nest tree, 57% of trees (mostly Red Alder) directly adjacent to the nest had no potential nesting platforms. The nest tree was the only Red Alder with potential nesting platforms.
Potential sources of bias or error	Not clear if transects are in same stand or not
Effects modifiers[9]	Habitat, deciduous tree, platform definition

Study Citation	Bradley and Cooke 2001
Additional notes	No information on actual nest platform

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Table A7.4.3

Study Citation	Burger 1994
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Vancouver Island: Carmanah watershed
Study area habitat	"Mature, valley bottom old-growth in the Coastal Western Hemlock biogeoclimatic zone and the West Vancouver Island windward maritime and montane ecoregions"
Study design[1]	Quantitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Climbing
Years of study	1993 (1990–1994 overall)
Within-year study period[4]	Unknown
Sample sizes[5]	1 nest in 1993 (5 others described elsewhere)
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Watershed
Platform definition	Branch containing nest
Dependent variable(s)[7]	Platform size
Stand age	"Many trees were 200–600 years old and some trees exceeding 1,000 years of age are known"
Pertinent results, including statistical significance values and measures of variation[8]	(Table 10) 18 cm diameter branch; nest dimensions 8.3 × 7.5 cm
Potential sources of bias or error	None apparent.
Effects modifiers[9]	None apparent.
Additional notes	Extracted information only pertains to 1993 nest; since others described elsewhere (Manley & Kelson 1995; Jordan & Hughes 1995). Overall study area includes Carmanah and Walbran watersheds, Pacific Rim National Park, Carmanah Pacific Provincial park, and crown land within TFL 44, Vancouver Island.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Table A7.4.4

Study Citation	Burger and Bahn 2001
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	SW Vancouver Island, including Carmanah-Walbran and Klanawa valleys
Study area habitat	Old growth: Coastal Western Hemlock zone
Study design[1]	Quantitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Climbing, 30 × 30 m station plots for habitat measures
Years of study	1996–2001
Within-year study period[4]	Unknown
Sample sizes[5]	11 nests in lower Carmanah and upper Carmanah/Walbran watersheds; 3 nests in east coast Vancouver I; however platform densities only for 2 "watersheds"
Statistical analysis of results	Descriptive statistics only
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Watershed
Platform definition	Limbs >20 cm in diameter
Dependent variable(s)[7]	Density of platforms, density of platform trees
Stand age	Old growth
Pertinent results, including statistical significance values and measures of variation[8]	(Table 2) Platforms/ha: Valley bottom - Lower Carmanah 1513 ± 633; Walbran and Upper Carmanah 1181 ± 1180; trees with 2+ platforms/ha: Valley bottom - Lower Carmanah 123 ± 48; Walbran and Upper Carmanah 98 ± 65
Potential sources of bias or error	Platform densities for habitat sampled across watershed, not necessarily specific to immediate nest area
Effects modifiers[9]	Scale of analyses, platform definition
Additional notes	Preliminary reports in previous years provided more details on nest locations but not on associations with habitat, including nest platform densities. Also more detailed information on habitat types provided in preliminary reports. (p. 9) "Nest trees were all larger and structurally more complex than surrounding trees and were partly damaged, with evidence of senescence."

Study Citation	Burger and Bahn 2001
Additional notes (continued)	No platform information on SE coast nest areas

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Table A7.4.5

Study Citation	Burger et al. 2000
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	SE Vancouver Island: Greater Victoria Water Supply Area
Study area habitat	Old growth; Coastal Douglas Fir and Coastal Western Hemlock very dry maritime biogeoclimatic subzones
Study design[1]	Quantitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Climbing, ground-based estimates of diameter
Years of study	1998–1999
Within-year study period[4]	1998 habitat analyses; Oct 1999 tree-climbing for nests
Sample sizes[5]	3 nests
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Tree, Branch, Platform
Platform definition	Branches, mistletoe growths or limb deformities greater than 18 cm in diameter and higher than 10 m up the tree
Dependent variable(s)[7]	Platform size, number of platforms
Stand age	Old growth; 141–250 years-old
Pertinent results, including statistical significance values and measures of variation[8]	(Table 11) Total Number of Platforms per tree as counted by climber: 6 and 10; by ground observer: 3 and 10 (Table 12) 3 nests in 2 trees Total Number of Platforms per tree: 6 and 10 Limb Diameter at Trunk (cm, including moss): 57, 42, n/a Limb Diameter at Nest (cm, proximal/distal): 57/57; 42/42; n/a Platform (cm): length 30, 30, 30; width 19, 14, 20; depth 6, 4, 3.6
Potential sources of bias or error	None apparent.
Effects modifiers[9]	Platform identification from observers based on ground or in canopy (tree-climbing); platform definition
Additional notes	(p. 23) "Ground observation underestimated the number of limbs as potential platforms compared to those counted by the climber (two-tailed paired t-test, t31 = 2.645, P = 0.01), but the average difference was only one platform limb per tree." See Table 11. Comparisons conducted in stands with nests and/or occupied detections but did not distinguish which trees associated with nest stands

Study Citation	Burger et al. 2000
Additional notes (continued)	Also information on platform density across all study areas (including areas where no nests documented but birds observed)

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Table A7.4.6

Study Citation	Conroy et al. 2002
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Vancouver Island: Ursus Valley, Clayoquot Sound, BC
Study area habitat	Old growth Coastal Western Hemlock and Mountain Hemlock biogeoclimatic zones
Study design[1]	Quantitative
Sampling design[2]	Experimental; no controls/replicates
Study methods[3]	Audio-visual, Climbing; climbers' counts were used to calculate platform density (platforms per tree), and the ground-based observations used to calculate densities of trees with platforms (platform trees per ha)
Years of study	1998–2000
Within-year study period[4]	Unknown
Sample sizes[5]	5 nests
Statistical analysis of results	Parametric: ANOVA
Statistical power	Not described
Document type	Agency technical report paper
Spatial scale(s)[6]	Watershed, Patch, Tree, Branch, Platform
Platform definition	"Branch >18 cm in diameter, including epiphyte, and at least 15 m above the ground."
Dependent variable(s)[7]	Platform size, number of platforms
Stand age	Old growth (300+ years)
Pertinent results, including statistical significance values and measures of variation[8]	(Table 4) Number of potential nest platforms per tree: •Nest trees (5): 9.8 ± 5.2 •Trees without nests (456): 7.2 ± 9.3 F= 0.4 *P* = 0.53 •Trees without nests in "Excellent" habitat (232): 9.5 ± 11.4 F = 0.003 P = 0.96 (Appendix 7-1) Contains characteristics of 5 nests
Potential sources of bias or error	Nests only in high quality habitat
Effects modifiers[9]	Platform identification from observers based on ground or in canopy (tree-climbing); habitat; platform definition

Study Citation	Conroy et al. 2002
Additional notes	Nests only located in "Excellent" habitat: "outstanding in terms of quantities of murrelet-relevant structures within forest stands (HSI score > 0.88; see Bahn and Newsom [2002]"

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Table A7.4.7

Study Citation	Dechesne and Smith 1997
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Haida Gwai: Naden watershed, BC
Study area habitat	Western Redcedar and Western Hemlock (10,852 ha)
Study design[1]	Quantitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Undescribed, presumed tree-climbing; sampled habitat "adjacent or within a station area"
Years of study	1995
Within-year study period[4]	Unknown
Sample sizes[5]	1 nest
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Patch, Branch
Platform definition	Not defined
Dependent variable(s)[7]	Platform size, platform density
Stand age	Unknown
Pertinent results, including statistical significance values and measures of variation[8]	(p. 11) 33 cm diameter branch (Table 10) 0.2 platforms/tree
Potential sources of bias or error	No definition of platform or of sampling area for platform density; single nest
Effects modifiers[9]	Habitat, platform definition
Additional notes	Nest in Western Redcedar, presumed tree climbing method but not stated

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Table A7.4.8

Study Citation	Ford and Brown 1995
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Southeast AK: Log Jam Creek drainage, northern Prince of Wales Island
Study area habitat	Old-growth, uneven-aged stand of Western Hemlock-Western Redcedar
Study design[1]	Quantitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Ground-level nest along cliff face, climbed
Years of study	1993
Within-year study period[4]	Jul & Aug
Sample sizes[5]	1 nest
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Platform
Platform definition	Platform of moss on three intertwining roots of a small Western Hemlock on a cliff edge
Dependent variable(s)[7]	Platform size
Stand age	Old-growth, uneven-aged stand
Pertinent results, including statistical significance values and measures of variation[8]	(p. 179) nest platform 65 cm × 35 cm
Potential sources of bias or error	No definition of platform or of sampling area for platform density; single nest
Effects modifiers[9]	Habitat, platform definition
Additional notes	Nest in Western Redcedar, presumed tree climbing method but not stated

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Table A7.4.9

Study Citation	Golightly and Schneider 2009
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Redwood National and State parks, CA
Study area habitat	Old-growth Coast Redwoods
Study design[1]	Qualitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Climbing, Cameras
Years of study	2001–2008
Within-year study period[4]	9 May–24 Jul 2008
Sample sizes[5]	1 nest
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Tree, Branch, Platform
Platform definition	Not defined—simply additional data on existing known nest
Dependent variable(s)[7]	Platform size
Stand age	Not specified, although Wikipedia indicates that there are 39,000 acres of old-growth forest in the two parks combined
Pertinent results, including statistical significance values and measures of variation[8]	(p. 2) Nest-site on limb 36 cm in diameter
Potential sources of bias or error	Single nest
Effects modifiers[9]	Forest type
Additional notes	Nice small study of 1 nest over 8 years. Unclear if nest included in Golightly et al. 2009 analyses

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Table A7.4.10

Study Citation	Golightly et al. 2009
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Redwood National and State parks, CA
Study area habitat	Old-growth Coast Redwoods, plus Douglas Fir and Sitka Spruce
Study design[1]	Quantitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing, Telemetry
Years of study	2001–2003
Within-year study period[4]	Not specified
Sample sizes[5]	10 nest-sites and 11 random plot locations for comparison
Statistical analysis of results	Non-parametric: Mann-Whitney U test
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Watershed, Stand, Tree, Platform
Platform definition	Small platforms = 10.0–19.9 cm diameter; large platforms ≥20 cm diameter; unclear whether measurement at trunk or at nest, and unclear which group 20.0 cm would fit in
Dependent variable(s)[7]	Platform size, number of platforms
Stand age	Not specified, although Wikipedia indicates that there are 39,000 acres of old-growth forest in the two parks combined
Pertinent results, including statistical significance values and measures of variation[8]	(p. 33; Table 3) Mean diameter of nest branch at trunk for 10 nests = 36 cm. Mean diameter of nest branch at nest for 10 nests = 29 cm (p. 34; Table 3) Mean number of small/large platforms/tree for 10 nests = 18 small/18 large
Potential sources of bias or error	None apparent
Effects modifiers[9]	Forest type; platform size
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Table A7.4.11

Study Citation	Grenier and Nelson 1995
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Oregon Coast Range and Klamath Mountain (Siskiyou Mountains)
Study area habitat	Small, isolated patches of mature and old-growth; Douglas Fir dominant in the north and mixed-evergreen species, including Douglas Fir and Tanoak, dominant in the south.
Study design[1]	Quantitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Climbing, ground-based searches; also sampling plots (nest tree plots and adjacent plots)
Years of study	1990–1993
Within-year study period[4]	Unknown
Sample sizes[5]	22 nests; 10 nest plots (compared to 2–3 adjacent plots associated with each)
Statistical analysis of results	Non-parametric: Wilcoxon paired-sample test for number of platforms; descriptive stats for platform sizes
Statistical power	None
Document type	Agency technical report paper
Spatial scale(s)[6]	Tree, 25 m radius sample plots
Platform definition	≥18 cm in diameter and ≥15 m above ground
Dependent variable(s)[7]	Platform size, platform density
Stand age	Mature (80–200 years) and old growth (200+ years); not differentiated by nest
Pertinent results, including statistical significance values and measures of variation[8]	(Table 5) Branch diameter at trunk: 31.1 ± 2.6 cm; range 15–56 cm; n = 19 Branch diameter at nest: 29.4 ± 2.7 cm; range 10–50 cm; n = 20 Mean (± SE) platform size: 42.2 ± 4.2 (length) by 31.7 ± 2.9 cm (width); range 11–66 (length) by 10–51 cm (width), n = 14 (length), 21 (width) (Table 6) Platforms/tree: nest plots 6.7 ± 1.0; range 0 –11; adjacent plots 4.7 ± 0.8; range 0.3–8.3; P = 0.10
Potential sources of bias or error	None apparent
Effects modifiers[9]	Platform definition

Study Citation	Grenier and Nelson 1995
Additional notes	Platform size data superseded by Hamer and Nelson 1995, although numbers differ slightly. Results supersede Nelson 1992, Nelson and Hardin 1993, Nelson et al. 1994

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Table A7.4.12

Study Citation	Hamer and Nelson 1995
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	CA, OR, WA, BC, AK
Study area habitat	Various
Study design[1]	Quantitative
Sampling design[2]	Comprehensive review
Study methods[3]	Audio-visual, Climbing, Telemetry
Years of study	1974–1993
Within-year study period[4]	Unknown
Sample sizes[5]	Variable, but generally 41 or 42 nests
Statistical analysis of results	Descriptive statistics only
Statistical power	Not applicable
Document type	Agency technical report paper
Spatial scale(s)[6]	Branch, Platform
Platform definition	Limb diameters including moss cover. Nest platform lengths = the length of the nest branch until nesting surface <10 cm wide
Dependent variable(s)[7]	Platform size
Stand age	180–1,824 years old
Pertinent results, including statistical significance values and measures of variation[8]	(p. 76) Mean nest branch diameters at the nest ranged from 27–34 cm: for Pacific Northwest, mean = 32 cm, normally distributed, with a maximal number (22%) of nests on limbs 35–40 cm in diameter. In Alaska, mean diameter = 19 cm, with the smallest 12, 14, and 16 cm (Table 3) mean diameter of nest branches did not vary geographically Mean ± SD and range of nest branch diameter (cm) at trunk (sample sizes in parentheses): CA—35 ± 13; 21–61 (8) OR—31 ± 11; 14–56 (19) WA—36 ± 12; 14–49 (5) BC—32 ± 9; 18–43 (9) All “Pacific Northwest” (south of AK)—32 ± 11; 14–61 (41) AK—15 ± 5; 9–27 (12) (p. 79) Nest platforms in the Pacific Northwest: mean length = 32 cm, mean width = 22 cm, mean total platform area = 842 sq cm.

Study Citation	Hamer and Nelson 1995
Pertinent results, including statistical significance values and measures of variation (continued)[8]	32% of Pacific Northwest nest platforms (n = 44) were created by large primary branches. 23% of the nests were on tree limbs that became larger in diameter when a main limb forked into two secondary limbs, or a secondary limb branched off a main limb. 18% of the nests were where a limb formed a wider area where it grew from the trunk of a tree. Cases of dwarf mistletoe infected limbs (witches' broom) (9%), large secondary limbs (7%), natural depressions on a large limb (7%), limb damage (2%), and an old stick nest (2%) were also recorded as forming platforms
Potential sources of bias or error	None apparent
Effects modifiers[9]	None apparent
Additional notes	Summarizes information on nests known to date. Included here are regional summary statistics. Includes nests not described elsewhere. Supersedes platform size data from Grenier and Nelson 1995, Hamer and Cummins 1991, Nelson 1992, Nelson and Hardin 1993, Nelson et al. 1994

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Table A7.4.13

Study Citation	Jordan et al. 1997
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Vancouver Island: Bulson watershed, Clayoquot Sound, BC
Study area habitat	Coastal Western Hemlock biogeoclimatic zone
Study design[1]	Quantitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, Climbing
Years of study	1996
Within-year study period[4]	Found May 23 and observed until Jul 22, climbed Jul 10
Sample sizes[5]	1 nest
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Tree, Branch, Platform
Platform definition	Not defined
Dependent variable(s)[7]	Platform size, number of platforms
Stand age	Unknown
Pertinent results, including statistical significance values and measures of variation[8]	(p. BN-2) 62 platforms in tree; mossy platform with dimensions 50 × 20 cm, "diameter of limb at the nest 25 cm proximal and 28 cm distal including moss"
Potential sources of bias or error	Platforms undefined; single nest
Effects modifiers[9]	Platform definition
Additional notes	This is an appendix to a report and contains summarized field notes of a nest discovered near a campsite when a bird was observed carrying a fish to a tree

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Table A7.4.14

Study Citation	Manley 1999
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	BC mainland: Sunshine Coast Forest District
Study area habitat	Coastal forest, some old-growth; Western Hemlock, Douglas and Silver firs, Western Redcedar, Yellow Cedar, and Shore Pine
Study design[1]	Quantitative
Sampling design[2]	Experimental; w/controls, no replicates
Study methods[3]	Audio-visual, Climbing
Years of study	1995–1997
Within-year study period[4]	1 Jun–31 Jul and 3–29 Aug 1995, 13 May–5 Aug 1996, not described in 1997
Sample sizes[5]	52 nest-trees found in 1994–1997; variable number of available trees examined for comparison
Statistical analysis of results	Non-parametric: Mann-Whitney U test; also parametric MANOVA, Pearson correlation, stepwise regression
Statistical power	Not described, but numerous significant test results and large sample sizes in most cases implies high power
Document type	Thesis/dissertation
Spatial scale(s)[6]	Patch, Tree, Branch, Platform
Platform definition	Limbs ≥15 cm in diameter at the trunk (on p. 99 adds that the branch must provide a level surface)
Dependent variable(s)[7]	Platform size, number of platforms, density of platforms, density of platform trees
Stand age	Coastal forest, some of which is old-growth
Pertinent results, including statistical significance values and measures of variation[8]	(Table 26) Sunshine Coast totals: •Patches: Mean ± SE platform density = 128 ± 14 platforms/ha (range = 5–321, *n* = 32) •Mean ± SE platform tree density = 32 ± 4 platform trees/ha (range = 5–66, *n* = 32) •Nest tree: Mean ± SE number of platforms = 9 ± 1 platforms/tree (range = 1–30, *n* = 52) •Nest branch: Mean ± SE diameter = 25 ± 1 cm (range = 11–62, *n* = 62) (p. 57, Table 12, Table 25) Nest-limbs were significantly larger in mean diameter (31 cm) and had a greater mean platform area (flat surface; 663 cm^2) than did other limbs in nest trees (20 cm and 350 cm^2, respectively)

Study Citation	Manley 1999
Pertinent results, including statistical significance values and measures of variation (continued)[8]	(p. 60, Table 17, Table 26) For Yellow Cedars, nest-trees (mean of 8–16 platforms/tree, depending on size) had significantly more platforms than available trees (mean of 3–5 platforms/tree, depending on size). Same for Western Hemlocks (mean 11 vs. 6 platforms/tree), but difference not significant, probably because of low sample sizes. No differences for Mountain Hemlocks (2 vs. 3 platforms/tree) or Douglas Fir (1 vs. 2 platforms/tree) (p. 70) Murrelets selected tree-patches with significantly higher mean densities of trees with platforms in nest-plots (32 platform-trees/ha) than what was seen in random plots (19 platform-trees/ha). Also selected tree-patches with significantly higher mean densities of platforms in nest-plots (129 platforms/ha) than what was seen in random plots (48 platforms/ha). These patterns were true regardless of all trees or just Yellow Cedar trees (primary spp. used for nesting in this area) (Table 29) Number of platforms was selected for at multiple scales—greater at nest-tree and at nest-patches (p. 121) Douglas Fir had highest mean number of platforms/tree, but most were covered with lichens or litter, rather than moss. Western Redcedar and Yellow Cedar had high mean number of platforms and platforms that were mossy, making them excellent nesting habitat (Table 42) All trees <51 cm dbh rarely (4%) had platforms; this pattern varied among species, in that Douglas Firs down to 50 cm dbh, Western Redcedars down to 50 cm, Western Hemlocks down to 30 cm, Yellow Cedars down to 22 cm, Silver Firs down to 43 cm, and Mountain Hemlocks down to 33 cm dbh had platforms (p. 126) Although they are uncommon, large-diameter trees provide important source of platforms because both percentage of trees with platforms and number of platforms/tree increase with dbh
Potential sources of bias or error	Excludes inaccessible nests, particularly those on steep slopes and at higher elevations
Effects modifiers[9]	Platform definition
Additional notes	(p. 127) Platform density, especially density of mossy platforms, is a key feature of murrelet nesting habitat from Alaska southward. Importance is consistent throughout the species' range, but the tree species providing these platforms vary among regions. Hence, species is not so important—structure is—in determining distribution and abundance of nesting murrelets

Study Citation	Manley 1999
Additional notes (continued)	(p. 144) Author recommends that potential nesting platforms in particular should take highest priority for maintenance of suitable habitat in areas planned for logging

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Table A7.4.15

Study Citation	Manley 2003
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	BC mainland (Desolation Sound) & W Vancouver Island (Clayoquot Sound); CS nest sites located in drainages inland from Millar Channel, Herbert Inlet and Bedwell Sound
Study area habitat	Coastal Western Hemlock and Mountain Hemlock biogeoclimatic zones
Study design[1]	Quantitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Climbing, Telemetry, 25 m radius circular sampling plots
Years of study	1998–2002
Within-year study period[4]	Unknown
Sample sizes[5]	Nests: *n* = 43 Desolation Sound, *n* = 27 Clayoquot Sound
Statistical analysis of results	Parametric: Pearson correlation matrices, MANOVA
Statistical power	Not described
Document type	Unpublished paper
Spatial scale(s)[6]	Patch, Tree, Branch, Survey plot
Platform definition	Limbs or structures >15 cm in diameter
Dependent variable(s)[7]	Platform size, number of platforms, platform density, platform tree density
Stand age	Not specified
Pertinent results, including statistical significance values and measures of variation[8]	(Table 2) (mean ± SD) Number of platforms in nest tree: Clayoquot Sound—14.9 ± 9.7 (*n* = 27); Desolation Sound—22.5 ± 14.3 (*n* = 39) Nest limb diameter (cm): Clayoquot Sound—29.3 ± 12.6 (*n* = 24); Desolation Sound—27.2 ± 11.6 (*n* = 38) (Table 5) (mean ± SD) Platforms per ha: Clayoquot Sound—223.7 ± 140.8 (*n* = 27); Desolation Sound—237.7 ± 262.2 (*n* = 39) Platform trees/ha: Clayoquot Sound—53.6 ± 20.7 (*n* = 26); Desolation Sound—40.4 ± 29.1 (*n* = 38) Platforms per tree: Clayoquot Sound—4.4 ± 2.5 (*n* = 26); Desolation Sound—5.6 ± 2.9 (*n* = 35) (p. 11) Mean number of platforms/ha did not differ between study areas, although distributions differed. Density of platform trees higher in Clayoquot Sound

Study Citation	Manley 2003
Potential sources of bias or error	Excludes inaccessible nests, particularly those on steep slopes and at higher elevations
Effects modifiers[9]	Tree species, topography, platform definition
Additional notes	(p. 7) "Subsequent univariate testing revealed significant differences in nest tree height, number of platforms in the nest tree, percent moss cover on nest trees and nest limb length between the two locations." "Nest trees were taller, had more potential nest platforms and had higher moss cover in Desolation Sound" (Table 9) Comparisons with results of Conroy et al. 2002 and Manley 1999

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Table A7.4.16

Study Citation	Manley et al. 2001
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Queen Charlotte Island, BC: Skidegate Plateau in the eastern portions and the Windward Queen Charlotte Mountains in the western portions
Study area habitat	Submontane wet hypermaritime Coastal Western Hemlock variant, Montane wet hypermaritime Coastal Western Hemlock variant and Wet hypermaritime Mountain Hemlock leeward variant
Study design[1]	Quantitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Climbing, Telemetry, 200 × 30 m transect
Years of study	2000
Within-year study period[4]	Birds tracked 12 Jun–26 Jul
Sample sizes[5]	7 nest stands (specific nest trees not identified)
Statistical analysis of results	Descriptive statistics only
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Stand
Platform definition	Platforms >18 cm diameter
Dependent variable(s)[7]	Density of platforms & platform trees
Stand age	All stands >250 years old
Pertinent results, including statistical significance values and measures of variation[8]	(p. 13) Mean ± SD density of potential nesting platforms at nesting stands = 126 ± 45 platforms/ha (range 53–182) (Table 5) Platform trees/ha: 38.6, 18.7, 33.3, 21.7, 43.3, 30, 18.3 Platforms/ha: 175.4, 125.3, 128.3, 90, 131.7, 181.7, 53.3 Platforms/tree: 4.5, 6.7, 3.9, 4.2, 3, 6.1, 2.9
Potential sources of bias or error	None apparent
Effects modifiers[9]	Forest type, platform definition
Additional notes	Transmitters on 50 birds, 9 tracked to inland sites, 4 sites searched and climbed, no nests found

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Table A7.4.17

Study Citation	Meekins and Hamer 1999
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	W and N Olympic Peninsula, WA: Washington Department of Natural Resources, US Forest Service, and Rayonier timber lands
Study area habitat	Western Hemlock or Western Hemlock/Silver Fir transition zone
Study design[1]	Quantitative
Sampling design[2]	Experimental; w/controls and replicates
Study methods[3]	Climbing, 25 m radius plots & 40 m radius plots
Years of study	1996–1998
Within-year study period[4]	Fall (1996) & breeding seasons (1997–1998)
Sample sizes[5]	29 total nests in 22 trees: 1996—4 old nests; 1997—3 inactive and 2 active nests; 1998—10 inactive nests; 6 stands, 60 40-m plots
Statistical analysis of results	Parametric: t-tests, one-way ANOVA and Student-Newman-Kuels test for comparison among means
Statistical power	None
Document type	Unpublished report
Spatial scale(s)[6]	Stand, Patch, Tree, Branch, Platform, 40 m plots
Platform definition	Any branch or deformation >10 cm diameter, also differentiated platforms 10–19.9 cm diameter and 20+ cm diameter
Dependent variable(s)[7]	Platform size, number of platforms, platform & platform tree density
Stand age	Old growth and mixed old growth/secondary growth, not defined
Pertinent results, including statistical significance values and measures of variation[8]	(p. 10, Table 5) Average nest limb diameter = 26 cm; average nest platform area = 2,047 sq cm (p. 11, Table 6) Nest trees average of 14 platforms (range = 1–32) in the 10–19 cm category and 14 platforms (range = 1–43) 20+ cm in diameter. Combined, all nest trees had an average of 28 (minimum = 10) potential nesting platforms available in the tree crown. Mean platform diameter for trees in nest plot estimate from ground as 19 cm (p. 12) Nest platforms vs. non-nest platforms - nest platforms greater limb diameter, platform area, cover, moss depth (see Table 5, t-tests) Nest trees had significantly greater numbers of platforms in both size classes (10–19.9 and 20+ cm). Nest trees with 3× higher count in the 20+ platform category compared to other platforms trees in the nest plot and platform trees in non-nest plots (Table 6). Ground personnel reported 2× greater number of 20+ cm platforms in nest trees than non-nest trees inside or outside of nest plots

Study Citation	Meekins and Hamer 1999
Pertinent results, including statistical significance values and measures of variation (continued)[8]	(p. 16 and Table 7) Nest plots had significantly greater mean platform diameters than non-nest plots; number of trees/ha with platforms did not differ between nest plots and non-nest plots (p. 18) "Nest limb diameters at the nest cup for all nests was ≥11 cm, however, one nest limb had a distal diameter of only 9.5 cm directly adjacent to the nest cup" (Appendix 1) # platforms (>10 cm)/tree for 21 nests: mean ± SD = 28 ± 13, range = 10–52.
Potential sources of bias or error	None apparent
Effects modifiers[9]	Platform size
Additional notes	(p. 17) "Comparisons of ground and climber counts of platforms showed a two-fold higher count of platforms in the 10–19.9 cm diameter class by the climbers, although counts were correlated (n = 714, r = 0.439, P = 0.000). For 10.0–19.9 cm platforms, climbers counted an average of 9.8 platforms/tree while ground observers counted and average of 4.8 platforms/tree. For 20+ cm platforms, climbers counted an average of 6.0 platforms/tree while ground observers recorded an average of 1.5 platforms/tree (n = 715, r = 0.479, P = 0.000)" (p. 18) "The small diameters of several nest trees and the low correlation of platform number to tree diameter indicates that murrelets are selecting suitable platforms and not necessarily seeking out large trees"

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Table A7.4.18

Study Citation	Naslund et al. 1995
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Kodiak and Prince William Sound, AK: Naked, Storey, Kodiak, and Afognak islands
Study area habitat	Forested and non-forested areas; nests in old-growth Western/Mountain Hemlock (Naked) & Sitka Spruce (Naked, Kodiak & Afgonak)
Study design[1]	Quantitative
Sampling design[2]	Experimental; w/controls and replicates
Study methods[3]	Audio-visual, Climbing, 50 m radius vegetation plots included the 9 upper canopy trees adjacent to the nest tree
Years of study	1991 & 1992
Within-year study period[4]	Breeding seasons
Sample sizes[5]	14 nests (10 Naked, 2 Kodiak, 2 Afgonak)
Statistical analysis of results	Parametric: t-tests
Statistical power	Not addressed
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Tree, Branch
Platform definition	"Any flat horizontal surface ≥15 cm in diameter (including moss) and >10 m above the ground"
Dependent variable(s)[7]	Platform size, number of platforms
Stand age	Old growth (2 nest trees 424 and 495 years)
Pertinent results, including statistical significance values and measures of variation[8]	(See Table 2 for limb diameters of all nests) (Table 4) •9 nest trees on Naked—8 ± 1.3 (SE) platforms (significantly more than on non-nest trees) •1 nest tree (Sitka spruce) on Kodiak/Afgonak—18 platforms •See table for additional comparisons with non-nest and landing trees (p. 19) nest trees on Kodiak/Afgonak had 8–26 platforms
Potential sources of bias or error	None apparent
Effects modifiers[9]	Study location; platform definition; appeared to be ground-based platform counts

Study Citation	Naslund et al. 1995
Additional notes	Number of platforms significantly correlated with dbh. Species differences with Sitka Spruce having more platforms than hemlocks Stand characteristics (excluding platform number/density) also analyzed

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Table A7.4.19

Study Citation	Nelson and Wilson 2002
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Oregon Coast Range, OR: Clatsop, Tillamook, and Elliott state forests
Study area habitat	Sitka Spruce, Western Hemlock zones; mosaic of young, mature, and old-growth Douglas Fir, Sitka Spruce, and Western Hemlock stands
Study design[1]	Quantitative
Sampling design[2]	Experimental; w/controls and replicates
Study methods[3]	Audio-visual, Climbing, Cameras, Binoculars from ground or adjacent tree
Years of study	1995–1999 (Table 2 says 1994–1999)
Within-year study period[4]	22 Jun–19 Aug 1995, 1 Jul–6 Aug 1996, 12 May–31 Aug 1997, 1 May–31 Aug 1998, 6 May–23 Aug 1999
Sample sizes[5]	37 nest-trees; hundreds of platforms (including random ones) and thousands of platform-trees (including random ones
Statistical analysis of results	Non-parametric: Wilcoxon rank-sum test; Kruskal-Wallis test; logistic regression; also multivariate analyses
Statistical power	Not described, but many significant test results imply high power
Document type	Unpublished report
Spatial scale(s)[6]	Stand, Patch, Tree, Branch, Platform
Platform definition	Limb or structure ≥10 cm in diameter (measured both at tree trunk and at nest) and ≥10 m above ground (followed Hamer and Nelson 1995)
Dependent variable(s)[7]	Platform size, number of platforms
Stand age	Mosaic of young, mature, and old-growth
Pertinent results, including statistical significance values and measures of variation[8]	(p. 24) All 37 nest-trees had ≥4 nest-platforms. Nests were located on limbs ≥11 cm diameter at nest (Table 5) Nest-trees in the 3 forests had 4–92 suitable platforms/tree (Table 6) Limb diameters in the 3 forests ranged from 7 cm to 37 cm at the trunk and from 11 cm to 36 cm at the nest (Tables 8 and 10) 33 nest-trees averaged 25.9 nest-platforms/tree (range 4–92; n = 33 trees) (Table 9) 37 nest-limbs averaged 17 cm diameter at the trunk (range 7–37 cm), 20 cm diameter at the nest (range 11.5–36 cm)

Study Citation	Nelson and Wilson 2002
Pertinent results, including statistical significance values and measures of variation (continued)[8]	(p. 36) Murrelets nested on platforms that were on larger-diameter limbs at platforms (mean 21 cm, range 12–39 cm, *n* = 37; vs. mean 17 cm, range 10–56 cm, *n* = 154) than random platforms available near nest-trees. Platform sizes also were significantly larger for nest-platforms (mean length = 79 cm, range 7–450 cm; mean width = 22 cm, range 7–44 cm) than for random platforms (mean length = 48 cm, range 5–320 cm; mean width = 16 cm, range 4–40 cm) (Table 13) Nest-trees (mean = 29.6, range 6–92, *n* = 23) averaged significantly more platforms/tree than did platform trees in nest-tree plots (mean = 14.7, range = 0–103, *n* = 446) and platform trees in other random plots (mean = 17.4, range = 0–120, *n* = 833). Significantly different similar pattern for number of large platforms, and similar pattern for small platforms, but not significantly different
Potential sources of bias or error	Authors admit that tree-climbers may not find all nests in a tree
Effects modifiers[9]	Platform definition
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Table A7.4.20

Study Citation	Quinlan and Hughes 1990
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Southeast AK: Kelp Bay, NE side of Baranof Island
Study area habitat	Old-growth, uneven-aged, virgin stands of Mountain Hemlock
Study design[1]	Quantitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Climbing, Telemetry
Years of study	1983 & 1984
Within-year study period[4]	18 May–7 June 1984 (telemetry)
Sample sizes[5]	1 nest
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Branch
Platform definition	Moss-covered branch
Dependent variable(s)[7]	Platform size
Stand age	Old growth—undefined
Pertinent results, including statistical significance values and measures of variation[8]	(p. 1,070) 18 cm diameter (at base) branch w/ ~10 cm thick bed of moss
Potential sources of bias or error	Single nest
Effects modifiers[9]	Study location
Additional notes	Nest located for only 1 of 17 radio-tagged birds. Also contained information for Binford et al. 1975

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Table A7.4.21

Study Citation	Silvergieter and Lank 2011a
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	BC mainland (Desolation Sound) & W Vancouver Island (Clayoquot Sound) watersheds
Study area habitat	Not described
Study design[1]	Quantitative
Sampling design[2]	Experimental; w/controls and replicates
Study methods[3]	Telemetry, 25 m radius plots, ground-based counts of platforms
Years of study	1999–2002
Within-year study period[4]	Unknown
Sample sizes[5]	59 nest trees (1,240 non-nest trees)
Statistical analysis of results	Non-parametric: sign tests with weighted Z-method; Kolmogorov-Smirnov 2-Sample test
Statistical power	None
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Tree
Platform definition	Limbs at least 15 m above the ground and at least 15 cm in diameter; platform trees - to canopy trees that contain at least one platform, as determined by observers from the ground
Dependent variable(s)[7]	Number of platforms
Stand age	>140 years of age (all tree heights) for DS; >250 years (tree heights >15 m) for CS (Zharikov et al. 2006)
Pertinent results, including statistical significance values and measures of variation[8]	(Table 1) 8 ± 0.5 (SE) platforms/nest tree (p. 7; Table 2) All nest trees contained more platforms than the average in nearby available trees and significantly more platforms at 68% of the sites (Zw = -14.62, $P < 0.01$), mean = 5 ± 1 ($n = 59$) more platforms than other platform trees "The probability that a tree was used as a nest tree with respect to the number of platforms per tree was not significantly different from what would be expected from the number of platforms available in non-nest trees with different numbers of platforms" "Although it appears that murrelets avoided trees with fewer than three to four platforms, we have no overall statistical support for selection of trees with more platforms per se. Instead, in general, platforms were used as expected based on the proportion of platforms available in trees with different numbers of platforms"
Potential sources of bias or error	Excludes inaccessible nests, particularly those on steep slopes and at higher elevations

Study Citation	Silvergieter and Lank 2011a
Effects modifiers[9]	Elevation, topography, platform definition, ground-based platform counts
Additional notes	Same nests included in Silvergieter & Lank 2011

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Table A7.4.22

Study Citation	Silvergieter and Lank 2011b
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	BC mainland (Desolation Sound) & W Vancouver Island (Clayoquot Sound [CS]) watersheds
Study area habitat	Desolation Sound: fragmented old growth (50% of stands <100 ha); Clayoquot Sound (100% patches >100 ha; much continuous habitat)
Study design[1]	Quantitative
Sampling design[2]	Experimental; w/controls and replicates
Study methods[3]	Telemetry, 25 m radius plots centered on nest trees compared with random plots (25 m and 75 m radius)
Years of study	1999–2002, 2004
Within-year study period[4]	Unknown
Sample sizes[5]	27 nest sites and 43 random sites at CS, and 37 nests and 35 random sites at DS
Statistical analysis of results	Resource Selection Function model: AIC model
Statistical power	None
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Patch
Platform definition	Limbs at least 15 m above the ground and at least 15 cm in diameter; platform trees = canopy trees that contain at least one platform
Dependent variable(s)[7]	Density of platform trees
Stand age	Old growth >140 years old
Pertinent results, including statistical significance values and measures of variation[8]	(p. 10, Fig. 2, p. 13) "Density of trees with platforms, available for CS only, shows a clear nonlinear trend, with the increase in probability of use slowing markedly at densities greater than 100." "This is equal to approximately 20 to 25 platform trees in a 25 m hectare plot"
Potential sources of bias or error	Because of differences in protocol, reliable data for the density of platforms was not available for random plots. Excludes inaccessible nests, particularly those on steep slopes and at higher elevations
Effects modifiers[9]	Elevation, topography; platform definition

Study Citation	Silvergieter and Lank 2011b
Additional notes	(p. 13) "[P]latform tree density did not correlate with measures of nesting success in this dataset" (Silvergieter 2009)

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Table A7.4.23

Study Citation	Waterhouse et al. 2007
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Queen Charlotte Islands/Haida Gwaii, portions of Graham Island and South Moresby Island, BC
Study area habitat	Coastal Western Hemlock submontane wet; Coastal Western Hemlock montane wet; Coastal Western Hemlock central very wet; and Mountain Hemlock wet subzones
Study design[1]	Quantitative
Sampling design[2]	Experimental; w/controls and replicates
Study methods[3]	Telemetry, sampling 100 m radius plots, airphotos and aerial surveys (helicopter circled slowly around each site for 3 to 5 minutes)
Years of study	2000
Within-year study period[4]	Unknown
Sample sizes[5]	7 nest sites, 30 random sites
Statistical analysis of results	Non-parametric: Wilcoxon
Statistical power	"Low" (p. 4); however differences significant for question of interest
Document type	Agency technical report paper
Spatial scale(s)[6]	Patch
Platform definition	Limbs or deformities >15 cm in diameter including any moss cover
Dependent variable(s)[7]	Number of platform trees
Stand age	Forest >140 years old
Pertinent results, including statistical significance values and measures of variation[8]	(p. 7; Fig. 4) "Occurrence of trees with potential nest platforms differ between nest patches and random patches (Z = –2.6, P = 0.009)"
Potential sources of bias or error	None apparent
Effects modifiers[9]	Aerial survey methods; platform definition
Additional notes	(p. 7) "Neither platforms of suitable diameter nor moss development—both of which are key elements for murrelet nesting—can be interpreted from airphotos. It is therefore important to identify which of the airphoto variables significantly correlate with the proportion of trees with platforms and moss development"

Study Citation	Waterhouse et al. 2007
Additional notes (continued)	(p. 12) "Large tree variable alone may not prove a reliable indicator of habitat quality, and that trees with platforms and moss development should be considered when assessing Marbled Murrelet habitat quality"

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Table A7.4.24

Study Citation	Waterhouse et al. 2009
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	W Vancouver Island (Clayoquot Sound) and BC mainland (Sunshine Coast: Desolation Sound and Toba Inlet areas)
Study area habitat	Clayoquot Sound—wetter variants of the Coastal Western Hemlock and Mountain Hemlock biogeoclimatic zones dominant; Sunshine Coast—dominated by drier variants of these zones
Study design[1]	Quantitative
Sampling design[2]	Experimental; w/ controls and replicates
Study methods[3]	Telemetry, sampling 100 m radius plots, aerial surveys (helicopter circled slowly around each site for 3 to 5 minutes)
Years of study	1998–2002
Within-year study period[4]	Unknown
Sample sizes[5]	111 nest sites and 139 random sites
Statistical analysis of results	Resource Selection Function model: AIC model
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Patch
Platform definition	Limbs or deformities >15 cm in diameter including any moss cover
Dependent variable(s)[7]	Number of platform trees
Stand age	Forest >140 years old
Pertinent results, including statistical significance values and measures of variation[8]	(pp. 89-90) "Trees with Platforms" was retained as an explanatory variable in one of four top models only if Study Area was excluded (p. 91) "Resource Selection Functions suggested that murrelet nest habitat was best distinguished from available habitat using topographic variables as well as forest structural variables. Moss Development, Slope Grade, and Elevation proved the best predictors of murrelet nesting habitat following our analysis approach using AICc" "Although strongly intercorrelated, Large Trees and Trees with Platforms were less reliable predictors of murrelet nest habitat than Moss Development in the Resource Selection Functions"
Potential sources of bias or error	None apparent
Effects modifiers[9]	Aerial survey methods; platform definition

Study Citation	Waterhouse et al. 2009
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Table A7.4.25

Study Citation	Witt 1998
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Oregon Coast Range, OR: Rader Creek drainage
Study area habitat	Douglas Fir & Western Hemlock
Study design[1]	Qualitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Climbing
Years of study	1994
Within-year study period[4]	29 Aug
Sample sizes[5]	1 nest
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Branch, Platform
Platform definition	None: "nest was composed of a depression in lichen, moss, and needles," referenced Hamer and Nelson 1995
Dependent variable(s)[7]	Platform size
Stand age	>400 years
Pertinent results, including statistical significance values and measures of variation[8]	(p. 29) limb diameter at trunk = 16.7 cm; platform dimensions: 24.1 cm × 21.6 cm
Potential sources of bias or error	Single nest
Effects modifiers[9]	None apparent
Additional notes	No information on other platforms in the nest tree

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree, branch, platform, other.
7 Number/density of platforms or platform trees, platform size.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 Potential factors that may have affected results and comparability relative to other studies.

Appendix 7.5. Data extraction tables for Question 5:

"How is Marbled Murrelet nesting success affected by habitat characteristics?"

Table A7.5.1

Study Citation	Barbaree et al. 2014
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Port Snettisham (SE of Juneau), Southeastern Alaska
Study area habitat	Small- or medium-productivity old-growth forest (Western Hemlock, Mountain Hemlock, Sitka Spruce) at lower elevations, rocky and alpine habitats above 600 m elevation
Study design[1]	Qualitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Climbing, Telemetry, aerial surveys; some ground-based visits to nests, but were unable to climb trees to look for nest-platforms
Years of study	2007–2008
Within-year study period[4]	15 May–16 (?) Sep 2007, 26 May–16 (?) Sep 2008 [exact dates not presented—these are extremes mentioned]
Sample sizes[5]	35 active nests (but only 33 able to be found)
Statistical analysis of results	Non-parametric (list tests): logistic regression [NOTE: Also use alpha of 0.10 because of small sample-sizes]
Statistical power	Not provided
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Watershed
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	Tree vs. ground nests, nest-limb height, distance inland
Other habitat characteristics described	Tree diameter, nest distance from trunk, tree species
Cause(s) of nest failure[7]	3 ground nests lost when adults were killed by predators
Pertinent results, including statistical significance values and measures of variation[8]	(p. 178) Tree nests were Western Hemlock (4), Mountain Hemlock (1), and Sitka Spruce (1). (p. 178) Nesting success was significantly higher for tree nests (39%) than for ground nests (6%; $P = 0.07$). [NOTE: Table 1 says that $n = 17$ tree nests and 18 ground nests, but text at bottom of page 177 says that $n = 15$ tree nests and 16 ground nests, plus 4 unknown nests; hence, it appears that they combined 2 unknown nests with each of the known categories in that table.] (p. 178) Nesting success was higher for nests farther inland than for nests closer to the coast, but was not significantly so. (p. 180) However, ground nests tended to be found in areas with higher elevation and father inland; hence, there may be a confounding effect of the two factors on nesting success.

Study Citation	Barbaree et al. 2014
Pertinent results, including statistical significance values and measures of variation (continued)[8]	(p. 181) Known predators of murrelets and their nests rarely were seen during visits to nest-sites. However, influence of predation on nesting location and nesting success is unclear. Authors speculate that predators may have been key factor causing murrelets to nest farther inland and causing differences in nesting success between ground and tree nests but admit that issue needs further investigation.
Potential sources of bias or error	Appears to be good random sample of birds on the water early in summer, some of which nested later. In addition, not all nested within a particular area, instead nesting over a broad area in the surrounding vicinity, so appeared to provide a good random sample of birds, nesting, and nesting attempts in this area.
Effects modifiers[9]	Data are from AK, so comparability to OR may be questionable.
Additional notes	Used alpha = 0.10 because of small sample-sizes.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.2

Study Citation	Becking 1991
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Butano State Park, near Pescadero, CA
Study area habitat	Old-growth Coast Redwood and Douglas Fir
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Ground search, Climbing
Years of study	1988
Within-year study period[4]	28 Jun 1988
Sample sizes[5]	1 probable nest
Statistical analysis of results	None–n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Tree
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	None specified
Other habitat characteristics described	Elevation, vegetation, stand density, distance to stream, slope, tree size, tree species, nest-limb height
Cause(s) of nest failure[7]	1 nest believed to have failed
Pertinent results, including statistical significance values and measures of variation[8]	(p. 74) On 28 Jun 1988, eggshell fragments found on forest floor in patch of old-growth Coast Redwood and Douglas Fir trees. Eggshell fragments appeared to have been pierced by bird beak like that of Common Raven or Steller's Jay.
	(p. 75) Eggshells found in grove of large redwood trees. Virgin redwood 169 cm dbh occurred ~8 m from eggshells; tree had broken top that regrew, creating a platform of several new branches that grew to create a new top; this whorl of new branches appeared to be where the nest had been.
Potential sources of bias or error	None apparent.
Effects modifiers[9]	Nest in Redwood tree in CA, so comparison with OR may be questionable.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.3

Study Citation	Bloxton and Raphael 2009
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Olympic Peninsula and Cascade Mountains, WA and Vancouver Island, BC
Study area habitat	Not described
Study design[1]	Quantitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Telemetry, Cameras
Years of study	2004–2008
Within-year study period[4]	Unknown
Sample sizes[5]	20 nests (3 successful, 16 unsuccessful, 1 presumed successful nests)
Statistical analysis of results	None–missing
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Physical characteristics
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	None specified
Other habitat characteristics described	Distance to sea, elevation, topography/slope position
Cause(s) of nest failure[7]	Only one case of suggested predation (jay?)
Pertinent results, including statistical significance values and measures of variation[8]	Table 2 (distance to sea and elevation) & Appendix A (topography/slope position in individual site descriptions). No summary statistics. 5 of the nests occurred in British Columbia. 3 successful nests and 1 presumed successful nest. 16 failed nests. Causes of failure included predation on chick (1 nest presumed), death of chick (2 nests), and nest of abandonment (1 nest). Cause of failure unknown for 12 nests.
Potential sources of bias or error	Effects of transmitters
Effects modifiers[9]	None apparent.

Study Citation	Bloxton and Raphael 2009
Additional notes	Progress report. Anticipated completion of analysis after 2009 season. Final report not available.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.4

Study Citation	Bradley 2002
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Desolation Sound, BC
Study area habitat	Coniferous forest
Study design[1]	Quantitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Climbing, Telemetry
Years of study	1998–2001
Within-year study period[4]	Early May to early Aug
Sample sizes[5]	84 nests (37 climbed)
Statistical analysis of results	Parametric (list tests): Correlation matrix, logistic regression (univariate, multivariate), chi-square. AIC model.
Statistical power	Small number of artificial versus natural edges so little power to detect differences.
Document type	Thesis/dissertation
Spatial scale(s)[6]	Watershed, Study site
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	Commuting distance from nests to marine foraging areas, nest site slope, nest site elevation, distance from edge, edge type (artificial vs. natural).
Other habitat characteristics described	None specified
Cause(s) of nest failure[7]	Information on success and failure including nest fate at different stages of breeding. No information on cause of failure.
Pertinent results, including statistical significance values and measures of variation[8]	Capture results and number of nests found: 290 murrelets were radio-marked over the duration of the study but not all used in the analyses. (pp. 10–11) "Of the 207 radio-marked birds used in analyses, 84 were identified as breeder with inland nest sites located. 25 of these breeders were confirmed based on tree-climbing and the rest inferred through radio-telemetry. Nest success: (p. 11) "Our cumulative estimated success probabilities for all breeding birds were as follows: incubation success: 82%, "Mid-Chick" Rearing success: 62%, Fledging success: 46%. Note that the fledging success data were only available from nests in climbed trees." Effects of timing of breeding, commuting distance, slope, and elevation of nesting sites on reproductive success: (p. 48–49) "Except for one analysis of fledging success from ground accessible nests, our measure of reproductive success in all analyses was that of "mid-chick rearing" success from radio

Study Citation	Bradley 2002
Pertinent results, including statistical significance values and measures of variation[8]	telemetry data. This is a measure of success based on adult visitation to the nest up to at least the mid-chick rearing period. "Mid-chick rearing" success was used because it could be determined at all active nest sites as many nests were physically inaccessible and we were unable to determine final fledging success." Univariate analysis: (p. 54) "higher elevation, steeper slope, and longer commuting distance were associated with higher reproductive success (Tables 3.3, 3.4)." Multivariate analysis: (p. 54, Tables 3.5, 3.6) Same variables included in highest ranking models. Edge effects: (p. 54, Table 3.7) No difference in fledging success of nests near (within 50 m or 100 m) of habitat edge and those further away. Sample sizes too small for accessible nest trees to determine effect of edge type. (p.55, Table 3.8) From telemetry data, mid-chick rearing success greater for nests within 200 m of "natural" edge than nests further from edge. No differences in success found between nests near "artificial" edges (e.g., roads, clearcuts) and either nests near artificial edges or interior nests. Predator numbers: (p. 70, Figures 3.5–3.9) Probability of occurrence of Marbled Murrelet nest predators (overall and avian only) decreased with elevation, except Steller's Jays, which peaked at mean nesting elevation.
Potential sources of bias or error	For 38% of suspected nests sites, which were accessible from the ground, presence of nests and fledging was confirmed by tree climbing. However, for the remainder of the sample nest sites were inaccessible and fledging assessed with radio-telemetry.
Effects modifiers[9]	For all analyses except one, radio-telemetry data for mid-rearing success during chick-phase to determine nest success. Habitat characteristics based in part on GIS data.
Additional notes	There is some overlap with Hull et al. 2001 that used the larger dataset from 1998–2001 to investigate relationships. Although Hull et al (2001) used a smaller dataset the results provided were more detailed and informative in some instances.

Study Citation	Bradley 2002
Additional notes (continued)	Progress report. Anticipated completion of analysis after 2009 season. Final report not available. Number of marked birds: (p. 48) "In 4 years of study, 290 Marbled Murrelets were marked with radio transmitters (1998 n = 40, 1999 n =100, 2000 n = 75, 2001 n = 75)." Nest fate determination: (p. 48) "Except for one analysis of fledging success from ground accessible nests, our measure of reproductive success in all analyses was that of "mid-chick rearing" success from radio 48 telemetry data. This is a measure of success based on adult visitation to the nest up to at least the mid-chick rearing period. "Mid-chick rearing" success was used because it could be determined at all active nest sites as many nests were physically inaccessible and we were unable to determine final fledging success." For some analyses: (p. 8) Nest fate was determined by climbing accessible trees at the end of the breeding season. Cues to determine chicks fledged included a fecal and down ring around the nest cup. Nests assumed to have failed during chick rearing exhibited various signs of hatching but an absence of a large fecal ring and down. Nests assumed to have failed during incubation had no evidence of hatching or chick presence and often had remnants of a predated or unhatched egg. Analyses: Commuting distance: (p. 50) "Two distance measures were calculated. The first was direct distance from foraging centre to the nest, which served as a minimum estimate of commuting distance. Another distance measure, flyway distance, took into account flight path of individual birds obtained from telemetry observations of transit corridors used by chick rearing birds." Since both were highly correlated flyway distance was used as the measure of commuting distance because it seemed more biologically relevant. Terrestrial habitat use: (p. 51) "All nests sites were found by helicopter telemetry, and locations were determined to an accuracy of approximately 100 m from the air. Thus, all locations were available for landscape level GIS habitat analyses." Edge effects, Small scale: (p. 51) "At the small scale, we examined forest edges in relation to fledging success at 37 accessible nest trees climbed after the breeding season from 1999–2001. For these sites, edges were classified as natural or artificial. Natural edges included rivers,

Study Citation	Bradley 2002
Additional notes (continued)	avalanche chutes, and large natural openings, but not small canopy gaps. Artificial edges were forest clearcuts and logging roads. Two sets of analyses were conducted, one with adjacent edges 50 m from the nest tree and another with edges up to 100 m away. Edge effects, large scale: (p. 52) "At a larger, coarser scale, we used GIS to determine the edge type adjacent to 98 nests with known "mid-chick" rearing success from 1998–2001. Nearest edge within 200 m was classified by edge type. Adjacent edge types included natural edges and artificial edges. For these analyses, natural edges were classed as: alpine, barren surfaces, avalanche chutes, wetlands, and ocean. Unnatural edges were clearcuts and transitions between old and second growth forest. Sites with no edge within 200 m were classified within old forest or within second growth forest. Edge classifications were coarse and high resolution landscape classification maps were not available." Effects of timing of breeding, commuting, distance, slope, and elevation of nest sites on reproductive success: (p. 52) "We examined the effects of timing of breeding, commuting distance (both direct and estimated flyway), slope, and elevation of nest sites on "mid-chick rearing" success."

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.5

Study Citation	Bradley and Cooke 2001
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Theodosia Sound and Toba Inlet; Desolation Sound area of SW BC
Study area habitat	Tree nest in mixed coniferous/deciduous forest; also cliff nest and presumed nests in shrub areas
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Climbing, Telemetry
Years of study	1999 & 2000
Within-year study period[4]	Apr & May capture and attach radios; telemetry throughout breeding season
Sample sizes[5]	1 tree nest, 1 cliff nest
Statistical analysis of results	None–n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Stand, Tree, physical features
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	None specified
Other habitat characteristics described	Distance to ocean, forest habitat, slope, elevation, platform tree density
Cause(s) of nest failure[7]	Unknown
Pertinent results, including statistical significance values and measures of variation[8]	(Table 1) Successful nest: cliff, shrub-like yellow cedar & mountain hemlock, 1300 m elevation, 90-deg slope, 15 km inland Unsuccessful nest: 130-yo red alder, previously unlogged mixed coniferous & deciduous forest, 200 m elevation, 40-deg slope, 0.3 km inland, most platforms in sample plots in deciduous trees, nest in only alder with platforms (Table 3) 13 platform trees in 25 m radius plot around nest tree
Potential sources of bias or error	None apparent
Effects modifiers[9]	Elevation, substrate

Study Citation	Bradley and Cooke 2001
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.6

Study Citation	Burger 1994
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Carmanah-Walbran watersheds, southwestern Vancouver Island, BC
Study area habitat	Valley-bottom old-growth coastal forest; dominant tree species included Western Hemlock, Sitka Spruce, Western Redcedar, and Amabilis Fir; many trees 200–600 yr old, and some >1000 yr old
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, Climbing
Years of study	1990–1993
Within-year study period[4]	Mid-May-early Aug 1990, late Apr-early Aug 1991–1993
Sample sizes[5]	6 nests found (1 in 1990, 1 in 1991, 3 in 1992, and 1 in 1993)
Statistical analysis of results	None—n.a.
Statistical power	Not provided
Document type	Unpublished report
Spatial scale(s)[6]	Watershed
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	None specified
Other habitat characteristics described	Distance inland, elevation, aspect, dominant vegetation, stand density, distance to edge of stand, distance to stream, position on slope, tree height, tree size, tree condition, tree species, nest-limb height, nest-limb diameter, nest-limb length, nest-limb orientation, nest distance from trunk, epiphytes, witch's broom
Cause(s) of nest failure[7]	4 nests appeared to be successful (see below); 2 nests were from previous year, so no inferences about success could be made
Pertinent results, including statistical significance values and measures of variation[8]	(p. 21) Found 6 nests total over 4 years; 3 were in Sitka Spruce trees in broad valley bottom in West Walbran Valley. All within 200 m of logging road; 1 nest was in giant Sitka Spruce tree ("Maxine's tree") in South Walbran Valley; 1 nest was in Western Hemlock tree in upper Carmanah Valley; 1 nest was in Sitka Spruce tree in central Carmanah Valley. (p. 22) All 6 nest-trees were near streams in valley-bottom old-growth forest. 5 of 6 nests were in unusually large conifers that were declining in vigor and had broken tops or broken primary branches. (p. 22) 4 of the 6 nests had large rings of fresh feces, indicating large chicks that may have fledged; 2 nests were from previous year, so no comments on success in them. (Table 10) Because no information on success of 2 nests from previous years was available, no inferences can be made about stand-level effects on success.

Study Citation	Burger 1994
Pertinent results, including statistical significance values and measures of variation[8]	(p. 24–25) Even in valley bottoms, very large trees likely to support murrelet nests were rare; trees with dbh >1.0 m composed 14% of 697 trees sampled, and trees >2.0 m dbh (5 of 6 nests were in trees this size) composed 1.4% of all trees sampled. (p. 27–28) Suggested that all of the vegetation that they sampled was suitable nesting habitat--6 nests in 4 widely-spaced locations and occupied behaviors at all 12 sites that were sampled.
Potential sources of bias or error	Authors indicated that valley-bottoms were sampled well but valley-sides were not. Sampling appeared to have been well-designed and -conducted.
Effects modifiers[9]	Data are from BC, so comparability to OR may be questionable.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.7

Study Citation	Burger et al. 2000
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Southeastern Vancouver Island, BC
Study area habitat	Old-growth dry coastal Douglas Fir and Western Hemlock forest
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, Climbing
Years of study	1998–1999
Within-year study period[4]	Not specified in 1998; 13 May–16 Jul in 1999
Sample sizes[5]	3 nests
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Stand, Tree
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	None specified
Other habitat characteristics described	Distance inland, canopy cover, stand size, aspect, slope, distance to stream, vegetation types, stand density, tree sizes, tree height, tree size, number of platforms, tree condition, tree species, nest-limb height, nest-limb diameter, nest-limb length, nest limb orientation, tree condition, nest distance from trunk, nest cover, epiphytes, mistletoe, nest predators (corvids, raptors, and squirrels)
Cause(s) of nest failure[7]	All nests were ≥1 year old, so nesting success not known; however, one nest suspected of being unsuccessful because of small nest-cup and large eggshell fragments
Pertinent results, including statistical significance values and measures of variation[8]	(p. 7) The breeding biology of MAMU has to a great extent been affected by the risk of nest predation, which is the major cause of nest failure; predation is the reason for the cryptic, secretive characteristics of the main aspects of their nesting biology (e.g., behavior, activity patterns, nesting habitat use). (p. 22) Most common predators in the forest were Common Raven, Northwestern Crow, Steller's Jay, and Red Squirrel. Crows had highly significant positive correlation with human disturbance and highly significant negative correlation with stand area—less stand edge for predators to associate with. Clearly, murrelets nesting in fragmented, disturbed patches of forest in SE Vancouver Island face higher predation risks than those in old-growth forests of W Vancouver Island.

Study Citation	Burger et al. 2000
Pertinent results, including statistical significance values and measures of variation (continued)[8]	(p. 23–24) Found 3 nests, all in Douglas Firs. Nests were estimated at 1–3 years old, so determination of nesting success was not possible with certainty; however, third nest was suspected to be unsuccessful because of small nest-cup and large eggshell fragments. (p. 25–26) Predators, especially corvids, are main cause of breeding failure in both Pacific NW (43% of 32 nests—Nelson and Hamer 1995) and BC (66% of 21 nests—Manley 1999). Authors recommend that no parking lots, campsites, buildings, etc., be placed ≤1 km of suitable murrelet nesting habitat, hiking trails be placed ≥500 m from suitable nesting habitat, and (because Steller's Jays are associated with forest edges) that forest edges be minimized and kept away from suitable nesting habitat (i.e., so that edges do not abut suitable nesting habitat). Even buffers of mature second-growth forest would help. (p. 27–28) Authors indicate that forest needs to be maintained and managed at scale of watersheds or drainages; management at scale of small patches of forest or individual trees is likely to cause failure in murrelet conservation because forest edges at smaller scales result in higher predation rates. (p. 28) Indicated that there are no plans for logging, so habitat will only get better in the future but recommend that human access be minimized to reduce further increases in number of predators and, hence, to keep nesting attempt from failing because of predators.
Potential sources of bias or error	Appears to be carefully developed sampling design for looking at patches of old-growth forest near Victoria by first screening for suitability for nesting, then surveyed the area intensively and climbed trees after 1999 breeding season.
Effects modifiers[9]	Data are from BC, so comparability to OR may be questionable. However, tree species used for nesting and nest predators same as those found in OR.
Additional notes	(p. 11–12) Description of dates on which stands were visited is somewhat confusing (13 May–10 Jun for first visit, 3 Jun–6 Jul for second visit).

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.8

Study Citation	Burger et al. 2004
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Carmanah, Walbran, and Klanawa valleys, SW Vancouver Island, BC
Study area habitat	Mostly contiguous old-growth coastal forest in Carmanah and Walbran (a few clearcuts); heavily logged mosaic forest in Klanawah
Study design[1]	Quantitative
Sampling design[2]	Experimental; w/controls and replicates
Study methods[3]	Audio-visual, experimental nests
Years of study	1994–2000; egg predation experiment in 2001
Within-year study period[4]	1 May–7 Aug, but primarily 15 May–16 Jul
Sample sizes[5]	40 artificial nests
Statistical analysis of results	Non-parametric (list tests): Mann-Whitney, Kruskal-Wallis, G-test
Statistical power	Not described, but many significant results
Document type	Book/book chapter
Spatial scale(s)[6]	Watershed, Stand, Study site, Patch, clearcut vs. natural opening vs. intact forest
Natural or artificial nests?	Artificial
Habitat characteristics compared in relation to nesting success	Windstorm, and distance from edges of roads and clearcuts
Other habitat characteristics described	None specified
Cause(s) of nest failure[7]	13 (32%) of 40 experimental eggs lost; 8 lost from predation (week 1) and 5 lost from combination of predation and wind-storm (week 2)
Pertinent results, including statistical significance values and measures of variation[8]	(p. 5, 12, Figure 1) Conducted tests of predation rates by distance from edge on 8 transect lines going into the interior of old-growth forest from edges of stands. Significant decrease in rate of egg loss as nests got farther away from forest edges: after 14 days, 5 of 8 nests lost at nests 10 m from forest edges, 4 of 8 lost at nests 40 m from edges, 3 of 8 lost 80 m from edges, 1 of 8 lost 130 m from edges, and 0 of 8 lost 200 m from edges. (p. 6–7) Compared rates of occurrence of various predators on surveys in essentially undisturbed Carmanah and Walbran valleys with rates in heavily disturbed Klanawah Valley. Steller's Jays were predator recorded most often, and Common Ravens were second in frequency, in Carmanah-Walbran surveys; owls were uncommon; Red Squirrels were only mammal species recorded and were seen almost as frequently as Steller's Jays. (p. 8) Disturbed sites had significantly higher relative abundance of Steller's Jays (mean 1.2/survey), Common Ravens (0.3/survey), and all predators combined (2.0/survey) than did undisturbed sites (0.5/survey, 0.1/survey, and 1.0/survey, respectively).

Study Citation	Burger et al. 2004
Pertinent results, including statistical significance values and measures of variation (continued)[8]	(p. 10) Mean relative abundance of all predators combined was ~2× higher in Klanawa (mean 2.62/survey) than in Carmanah-Walbran (0.83/survey); significantly higher relative abundances of Bald Eagle (0.14/survey vs. 0.01/survey), Steller's Jay (1.96/survey vs. 0.71/survey), Common Ravens (0.27/survey vs. 0.04/survey), Red Squirrels (0.15/survey vs. 0.01/survey), and all predators combined (2.62/survey vs. 0.83/survey) in disturbed Klanawah than in undisturbed Carmanah-Walbran. (p. 11, Table 5) Steller's Jays were recorded significantly more often at stations within clearcuts and road edges than at stations within undisturbed interior forest and along river edges. (p. 13) Many more predators were recorded during multiyear dawn-watch surveys (≥2 h long) than during 10-min point-counts. In particular, owls were recorded during dawn-watch surveys because they began 1 hr before sunrise. (p. 14) Most of the predators recorded in this study were more likely to take eggs and chicks than to take adults; however, loss of an adult has much greater effect on population than does loss of egg or chick. (p. 14) Telemetry study found that Steller's Jays spent most foraging time ≤50 m of forest edges and foraged in high canopy, where murrelets nest. (p. 14) Much higher relative densities of Steller's Jays and Common Ravens along clearcuts and roads than in undisturbed forest; same for Red Squirrels, although other studies have shown opposite trends. (p. 15) Murrelets nesting in watersheds on Vancouver Island that are modified by clearcuts and roads will experience higher rates of predation caused by increased numbers of jays and ravens and caused by increased numbers of corvids and squirrels at logging camps and recreational campsites.
Potential sources of bias or error	None apparent
Effects modifiers[9]	Data are from BC, so comparability to OR may be questionable. However, tree species used for nesting and nest predators same as those found in OR.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.9

Study Citation	Drever et al. 1998
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Bunster Range, Desolation Sound, British Columbia
Study area habitat	Old-growth coniferous forest
Study design[1]	Both
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Ground search, Climbing, Telemetry
Years of study	1996
Within-year study period[4]	20 May to 14 Aug
Sample sizes[5]	32 nest trees with 41 nesting attempts (includes multiple nests in a tree and renesting attempts).
Statistical analysis of results	Parametric (list tests): t-test, chi-square test, Wilcoxon paired sample test
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Patch, Tree
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	None specified
Other habitat characteristics described	Habitat variables investigated at nest sites but not broken out by successful versus failed nests. Tree dbh, tree height, platforms/tree, mossy platforms, protected platforms, tree vigor and top condition, tree density, snag density, canopy density.
Cause(s) of nest failure[7]	Information on proportion of successful nests but no information on cause of nest failure.
Pertinent results, including statistical significance values and measures of variation[8]	Nest fate: (p. 56) Of 41 nesting attempts evaluated, 80.4% failed and 19.6% were determined successful. Failed nesting attempts included 21 attempts (51.2%) where the egg was removed and 12 attempts (29.2%) with eggshell fragments. Presumably predation and/or abandonment was the cause of failure. Successful nesting attempts included four attempts (9.8%) with evidence of fledging in 1996 and four attempts (9.8%) that were evaluated in 1996 but showed evidence of presumed fledging in 1995 (not the current year). The successful attempts from 1996 had a complete fecal ring and chick down whereas the successful attempts from 1995 had small amounts of down but the fecal ring had disappeared, presumably over the winter. Habitat: (p. 56–57) The study provided information on habitat at the nest tree (element) and patch scale. However, habitat analyses

Study Citation	Drever et al. 1998
Pertinent results, including statistical significance values and measures of variation (continued)[8]	focused on nesting sites versus random sites and did not include comparisons or information on habitat at successful versus unsuccessful nests. (p. 56) "At the element scale, murrelets selected nest trees with larger diameters, higher numbers of potential nesting platforms, and higher proportions of mossy and protected platforms than other trees within surrounding 25 m (Table 15). Nest trees did not differ in height, vigor, or tree top condition from other nearby trees." Specifically, the mean dbh of trees was 101 +/- 3.5 cm for nest trees (n = 32) and 78 +/- 2.0 cm for other trees (n = 165); the mean number of platforms per tree was 2.7 +/- 0.17 for nest trees and 1.5 +/- 0.05 for other trees; the mean number of mossy platforms was 2.1 +/- 0.21 for nest trees and 1.1 +/- 0.07 for other trees; and the mean number of protected platforms was 1.1 +/- 0.14 for nest trees and 0.34 +/- 0.05 for other trees. All comparisons were significant at the $p < 0.05$ level based on t-tests or chi-square tests. Patch scale: (p. 56) "Paired comparisons show that nest patches had higher densities of larger diameter trees and higher numbers of platforms per tree than random patches. Nest patches also had significantly lower densities of smaller diameter trees and total densities than random patches (Table 16). Thus, murrelets may be selecting the more open areas for nesting in the Desolation Sound area."
Potential sources of bias or error	In a small number of cases success/failure of nests was determined at old nests that were likely active the previous year.
Effects modifiers[9]	None apparent
Additional notes	The study results include the proportion of successful (fledged) versus unsuccessful nesting attempts. Therefore results also included cases of renesting and also multiple nests within the same tree. In almost all cases results were for the study year but in a small number of cases nest sites were old and success/failure was determined for the previous year. Note that habitat analyses focused on nesting sites versus random sites and did not include comparisons or information on habitat at successful versus unsuccessful nests.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.10

Study Citation	Ford and Brown 1995
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Log Jam Creek drainage, northern Prince of Wales Island, SE AK
Study area habitat	Old-growth, uneven-aged stand of western hemlock-western red cedar
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Ground-level nest along cliff face, climbed
Years of study	1993
Within-year study period[4]	Jul & Aug
Sample sizes[5]	1 nest
Statistical analysis of results	None--n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Stand, Study site, Tree
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	None specified
Other habitat characteristics described	Distance from water, stand age class, slope, aspect, mean dbh,
Cause(s) of nest failure[7]	Assumed predation based on egg fragments and lack of fecal ring
Pertinent results, including statistical significance values and measures of variation[8]	(p. 179) "The tree was on a westfacing (260°) 38° slope, at 195 m elevation. The bird(s) departed from and approached the nest on the down-slope side of the cliff (245°), and we observed one possible landing pad on this side, a worn area on a moss-covered root about 40 cm from the nest. The tree was approximately 13 km from the nearest salt water in an old-growth, uneven-aged stand of western hemlock-western red cedar *(Thuja plicata)*. The mean dbh of the trees (>2.5 cm dbh) within a 25 m radius plot was 23.6 cm (SD = 20.4, range = 2.5–114.3 cm, n = 184)."
Potential sources of bias or error	None apparent
Effects modifiers[9]	Nest substrate
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.11

Study Citation	Golightly et al. 2009
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Redwood National and State parks, northern CA
Study area habitat	Old-growth Coast Redwoods, plus Douglas Fir and Sitka Spruce
Study design[1]	Quantitative
Sampling design[2]	Experimental; w/controls, no replicates
Study methods[3]	Audio-visual, Climbing, Telemetry
Years of study	2001–2003
Within-year study period[4]	Not specified
Sample sizes[5]	10 nests (11 nesting attempts) and 11 random locations for comparison
Statistical analysis of results	Non-parametric (list tests): Mann-Whitney test, Pearson correlation (parametric), AIC screening of models
Statistical power	Not provided
Document type	Unpublished report
Spatial scale(s)[6]	Watershed, Stand, Tree, platform
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	Distance inland, canopy cover, canopy height, distance to disturbance, elevation, slope, aspect, distance to stream, distance to canopy gap, number of canopy layers, stand density, tree sizes, tree height, tree diameter, tree diameter at nest limb, number of platforms in tree, nest-limb height, nest-limb diameter, nest-limb length, nest-limb orientation, tree condition, nest-distance from trunk, nest shielding, number downed logs
Other habitat characteristics described	Nest material
Cause(s) of nest failure[7]	Unknown
Pertinent results, including statistical significance values and measures of variation[8]	(p. 4–5) Authors quantified habitat (at scales of stand, nest-tree, and nest-site [limb]) at murrelet nest-sites and at random locations to see if habitat differed between nest-sites and random sites and between successful and failed nests. Also quantified noise levels, which may affect decisions to nest and (surprisingly) may affect presence of predatory corvids. (p. 6) Located 10 nests and generated 11 random locations to compare habitat with the nest-sites. (p. 12) Nest-sites were located farther from paved roads and had lower canopy heights than did random sites. (p. 13) Of 10 nests located, 6 successfully fledged a chick, 3 were unsuccessful, and 1 failed in 2002 but was successful in 2003. Although 3 habitat characteristics initially differed significantly between successful and unsuccessful nests (number of downed logs, distance to nearest campground, tree density), only the model with number of downed logs in plot provided best discrimination between successful and unsuccessful nests.

Study Citation	Golightly et al. 2009
Pertinent results, including statistical significance values and measures of variation (continued)[8]	(p. 16) Distance to nearest paved road was best habitat correlate of nest-site use at the stand scale (positive relationship), but number of downed logs was best habitat correlate of nesting success (positive relationship). Authors suggest that greater number of downed trees create greater number of openings in the forest to access nest-trees directly, reducing chances of detection by predators (i.e., predators are not common in intact forest, instead preferring forest edges). (p. 16–17) Authors suggest that nesting success also may have been higher in habitats with more downed logs, less horizontal cover over the nest, and lower tree density because these habitats may contain fewer corvids, which prefer fragmented, edge, and seral habitats because they contain a wider range of food resources than do intact forests.
Potential sources of bias or error	Authors compare nest-trees with trees in randomly located plots; however, they do not indicate whether they actually searched any of those random-plot trees thoroughly to determine whether nesting occurred; as a result, comparisons between nesting and random locations are questionable.
Effects modifiers[9]	Data are from redwood trees in CA, so comparability to OR may be questionable.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.12

Study Citation	Hamer and Cummins 1991
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Mt. Baker-Snoqualmie National Forest and Olympic National Parks
Study area habitat	Fragmented and continuous old growth in Western Hemlock, Mountain Hemlock, and Silver Fir zones
Study design[1]	Qualitative and quantitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, Sampling plots
Years of study	1990 & 1991
Within-year study period[4]	9 May–9 Aug
Sample sizes[5]	3 nests
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Stand, physical habitat
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	None specified
Other habitat characteristics described	Distance from coast, stand age class, primary forest type (zone), elevation
Cause(s) of nest failure[7]	1 nestling "fell 53 m, apparently without injury" (p. 15), raised in captivity for 11 days
Pertinent results, including statistical significance values and measures of variation[8]	(p. 15 & Table 2) North Cascades nests (Lake 22): successful 34 km inland, 366 m elevation, silver fir zone, old growth Olympic National Park (Heart of the Hills) nest: "failed", 9 km inland
Potential sources of bias or error	None apparent
Effects modifiers[9]	None apparent
Additional notes	Other tree/limb attributes also provided for all three nests. Limited information provided on search effort and habitat associations with specific nests. Report focuses on efforts in 1991; however, two of the three nests were found in 1990, and

Study Citation	Hamer and Cummins 1991
Additional notes (continued)	the third (found in 1991) was not associated with the study areas described in the report.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.13

Study Citation	Hirsch et al. 1981
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Barren Islands, northern Gulf of Alaska, AK
Study area habitat	Heath- and grass-covered slope overlooking the ocean, under rock ledge
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Visiting nest
Years of study	1979 (but compares w/1978 data)
Within-year study period[4]	On or before 6 Jul to 16 Aug (night of fledging)
Sample sizes[5]	1 nest
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Nest-cup
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	None specified
Other habitat characteristics described	Stand aspect, distance inland, tree species, nest-limb height, nest cover
Cause(s) of nest failure[7]	Not applicable (nest successful)
Pertinent results, including statistical significance values and measures of variation[8]	(p. 264) Nest was located 10 m south of 1978 nest described by Simons (1980), indicating reuse of nesting area by murrelets. (p. 264) Nest-cup was located below rock ledge that appeared to provide some protection from elements and that provided more protection than 1978 nest. (p. 265) Both adults arrived on night of fledging; chick was gone next morning, indicating nocturnal fledging; 3 days later, adult and juvenile seen in nearby cove, <0.5 km from nest-site.
Potential sources of bias or error	None apparent; simple description of nest and chick.
Effects modifiers[9]	Nest on the ground in area without trees in AK, so comparability to OR questionable.
Additional notes	Adds to data published by Simons (1980) for a nearby nest 1 year earlier; presumably the same pair.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.14

Study Citation	Hull et al. 2001
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Desolation Sound, British Columbia
Study area habitat	Coniferous forest
Study design[1]	Quantitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Climbing, Telemetry
Years of study	1998
Within-year study period[4]	4 May to 4 Jul
Sample sizes[5]	23 nest sites
Statistical analysis of results	Parametric (list tests): Logistic regression
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Watershed
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	Elevation of nest sites and commuting distance (distance of nest site from telemetry locations on water).
Other habitat characteristics described	None specified
Cause(s) of nest failure[7]	No information on cause of failure.
Pertinent results, including statistical significance values and measures of variation[8]	Summary information: Nest success: (p. 1,039) "Sixteen of the 23 nests were active during incubation, 12 were active during chick rearing (3 unknown), and 3 fledged chicks (11 unknown)." Commuting distance: (p. 1,040) "Commuting distance from nest sites to locations on the water ranged from 12 to 102 km (mean 39 km)." Nesting elevations in the study ranged from 150–1,300 m. (p. 1,043) "Most of the low elevation old-growth forests at Desolation Sound have been removed by industry. Marbled Murrelets in this study nested at a mean elevation of over 800 m, which is much higher than other sites (332 m, Gaston and Jones 1998) where less habitat modification has occurred."

Study Citation	Hull et al. 2001
Pertinent results, including statistical significance values and measures of variation (continued)[8]	Factors related to nest success (results not conclusive): (p. 1,039) "Logistic regressions revealed that mass, elevation of nests, and commuting distance were not significantly related to breeding success during the three stages (incubation: G-test, G = 12.3, df = 4, *P* > 0.02, but Hosmer- Lemeshow goodness-of-fit test was significant chi-sq = 20.4, df = 8, *P* > 0.09 [indicating the model was an inadequate fit], chick rearing: G = 7.7, df = 4, *P* < 0.05; chick fledged: G = 6.9, df = 4, *P* < 0.05, Fig. 6)."
Potential sources of bias or error	None apparent
Effects modifiers[9]	None apparent
Additional notes	Bradley (2002) used data from the current study (1998) and also an expanded data set that included the study years 1998–2001. Therefore, there is presumably some overlap in the nest sites used and analyses in Bradley (2002) covered a larger sample. However, Bradley (2002) did not provide summary statistics for distance of nest sites and marine locations or nest site elevations so that is informative here. (p. 1,040) "Nests located using radio telemetry are unique in that they are located without a biased expectation of suitable nesting habitat (1995)."

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.15

Study Citation	Jones 2001
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Spipiyus Park, Caren Range, coastal British Columbia
Study area habitat	Old growth coniferous forest (western and mountain hemlock, Amabilis fir, and yellow cedar), surrounded by some recently logged areas
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, Cameras
Years of study	1991–1994 and 1996–1997
Within-year study period[4]	May-early Aug, variable
Sample sizes[5]	3 young fledged from 2 nests
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Book/book chapter
Spatial scale(s)[6]	Study site, Tree
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	None specified
Other habitat characteristics described	Elevation, age class, tree species
Cause(s) of nest failure[7]	Not applicable (all nests successful)
Pertinent results, including statistical significance values and measures of variation[8]	(p. 95) 11,00 m and 1,075 m elevation, ancient forest (1,000–1,200 years), yellow cedars
Potential sources of bias or error	None apparent
Effects modifiers[9]	Elevation
Additional notes	In a somewhat fragmented landscape but no information on patch sizes or other delineation of habitat. Specific location information not provided.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.16

Study Citation	Kerns and Miller 1995
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Southern Humboldt County, CA
Study area habitat	3 coastal redwood/Douglas-fir stands in commercial forest
Study design[1]	Qualitative and quantitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing, Sampling plots
Years of study	1992
Within-year study period[4]	Mid-Apr through Aug
Sample sizes[5]	1 nest (second nest with unknown nest fate)
Statistical analysis of results	None--n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Stand, Study site, Tree, Sample plot
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	None specified
Other habitat characteristics described	Stand size, distance from coast, elevation, aspect, distance from road, relative tree size, mean stand canopy closure
Cause(s) of nest failure[7]	Failed "nestling collapsed and died of a heart aneurysm caused by pulmonary edema."
Pertinent results, including statistical significance values and measures of variation[8]	(p. 41–42) "The nest at Elk Head Springs was in a 106-ha stand 25 km from the ocean at 341 m elevation. Stand aspect was north and east." 70 m from logging road. Nest height above other trees in 0.1 m sampling plot. "The nest tree was the largest tree in the 0.1-ha plot in height, dbh, % live crown, and live crown diameter. Mean dbh of 16 other redwood and 1 Douglas-fir was 70 cm and mean height was 36 m. Canopy closure in the plot was 42%, slightly less than the stand canopy closure (from aerial photographs) of 50–75%."
Potential sources of bias or error	Death of nestling due to "natural causes" or presence of observers?
Effects modifiers[9]	None apparent

Study Citation	Kerns and Miller 1995
Additional notes	(p. 42) "With this small sample size, it is difficult to relate nesting success to habitat characteristics." Second nest with fecal ring but nest fate uncertain.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.17

Study Citation	Kuletz et al. 1994
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Prince William Sound, Kenai Peninsula, and Afognak Island, all of northern Gulf of Alaska
Study area habitat	Diverse, ranging from coastal old-growth forest to glaciers and recently deglaciated areas
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, stumbled across nest while doing morning dawn watches
Years of study	1993
Within-year study period[4]	11–30 Jul 1993
Sample sizes[5]	1 nest
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Study site
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	None specified
Other habitat characteristics described	Slope, aspect, elevation, dominant vegetation, percent vegetation cover, distance inland, tree height, nest-limb height, nest cover
Cause(s) of nest failure[7]	Nestling predation speculated
Pertinent results, including statistical significance values and measures of variation[8]	(p. 36) Nest found in recently deglaciated area at head of Northwestern Lagoon, Harris Bay, Kenai Fjords NP, on 11 Jul 1993. (p. 36–37) Nest 30 m from ocean at 20 m elevation, near the edge of steep rock ledge. Slope 60% vegetation cover. Nest-cup concealed by alder and willow branches and leaves. (p. 37–38) Egg on 11 Jul; 122 g chick on 21 Jul; nest empty on 30 Jul. Because it takes ~5 days for hatching after egg first pips, chick was ≤9 days old on 21 Jul and 18 days old on 31 Jul—too young to have fledged. (p. 38) Authors speculate that chick was lost to predation. Although no predators were seen, there is a large list of predators occurring in this area.

Study Citation	Kuletz et al. 1994
Potential sources of bias or error	None apparent.
Effects modifiers[9]	Data are from AK, so comparability to OR may be questionable.
Additional notes	Relevant information presented in Appendix B of report.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.18

Study Citation	Luginbuhl et al. 2001
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Western Olympic Peninsula, WA
Study area habitat	"Mixed-conifer forest ranging in age from 80–250 yr and in size from 37–106 ha"
Study design[1]	Quantitative
Sampling design[2]	Experimental; w/ replicates, no controls
Study methods[3]	Cameras, artificial nests (eggs and nestlings) with motion-sensitive radio transmitters, paraffin coating to record predator marks
Years of study	1995–1998
Within-year study period[4]	Unknown
Sample sizes[5]	905 nests (454 with nestling, 451 with egg) in 49 plots, representing 12 landscape categories ("two classes of forest fragmentation, three classes of forest structure, and two classes of proximity to human-use areas").
Statistical analysis of results	Parametric (list tests): correlation, regression
Statistical power	None
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Study site, Patch, Landscape (combined forest structure, fragmentation, distance from human use areas)
Natural or artificial nests?	Artificial
Habitat characteristics compared in relation to nesting success	Corvid abundance
Other habitat characteristics described	None specified
Cause(s) of nest failure[7]	Predation
Pertinent results, including statistical significance values and measures of variation[8]	No clear relationship between numbers of corvids and predation rates at smaller scales (study plots). Only significant correlation found between average corvid abundance for each landscape type (as determined by point counts using attractant calls) and mean number of days eggs survived. Corvids primarily depredate eggs, not nestlings.
Potential sources of bias or error	Some difficulty in determining fates and predator identification; "210 correlative relationships" examined; significant relationship at landscape level specific to particular measure of corvid abundance and only for number of days eggs survive in nest. Predation rates appear to include all types of predation, not just corvids. Low rates of corvid predation of chicks might reflect response to carcasses rather than live nestlings. Egg predation rates likely influenced by presence/absence of incubating adult. Timing of experiments within breeding season.

Study Citation	Luginbuhl et al. 2001
Effects modifiers[9]	Measures of corvid abundance, variable spatial scales, artificial eggs and nestling models
Additional notes	Biological significance of relationship between maximum corvid abundance of plots lumped by landscape category and number of days eggs survive unclear.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.19

Study Citation	Malt and Lank 2007
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Desolation Sound and northern Vancouver Island, British Columbia
Study area habitat	Old-growth forest (western hemlock, western red cedar, amabalis fir, Douglas fir, Sitka spruce, mountain hemlock, yellow cedar)
Study design[1]	Quantitative
Sampling design[2]	Experimental; no controls/replicates
Study methods[3]	Climbing, Telemetry, Cameras
Years of study	2004–2005
Within-year study period[4]	Jun to Aug
Sample sizes[5]	Examined fate of artificial nests at 52 paired sites with edge and interior locations. For artificial vs. real nests compared edge type at 40 artificial nests and 57 real nests.
Statistical analysis of results	Parametric (list tests): Generalized linear models.
Statistical power	For comparison of edge type between real and artificial nests a reverse power analysis indicated power of 0.122 and effect size 0.046. "In order to have a power of 0.8 with this sample size, the effect size would have to be at least 0.151."
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Watershed, Stand, Study site, Tree
Natural or artificial nests?	Both
Habitat characteristics compared in relation to nesting success	Nest location (interior vs. edge) and edge type (i.e., hard, soft, and natural edges).
Other habitat characteristics described	Distance to disturbance, stand density, vegetation,
Cause(s) of nest failure[7]	Nest fate analyzed for artificial nests during current study and summarized for real nests from other studies. Nest predation was the cause of failure at all nests and composition of nest predators (avian and mammalian) provided.
Pertinent results, including statistical significance values and measures of variation[8]	Artificial nest experiment Predator activity and composition: (p. 165) "Sixty-five of 136 nests (40%) were discovered by predators in Nimpkish, including 47 nests (35%) that were physically disturbed. At Desolation Sound, 23 of 56 nests (35%) were disturbed." Cameras at the Nimpkish site documented activity by all potential nest predators in the area including Steller's Jay (*n* = 4), Gray Jays (*n* = 4), red squirrels (*n* = 12), mice (*n* = 15), Common Raven (*n* = 1), and Sharp-shinned Hawk (*n* = 1). At Nimpkish site 51% of predator disturbances were avian, 43% mammalian, and 1% both. At the Desolation Sound site 57% of predator disturbances were avian, 39% mammalian, and 4% both.

Study Citation	Malt and Lank 2007
Pertinent results, including statistical significance values and measures of variation[8]	"For all predators combined, disturbances of nests were higher at edges relative to interiors (Table 1), with no significant edge-type interaction, suggesting detrimental edge effects at all three edge-types [hard, soft, natural]." For avian predators of eggs, disturbance between edge and interior locations differed between edge-type. Post-hoc testing showed detrimental edge effects at hard-edged sites (Fig. 5). In contrast, there was no significant edge effect at soft-edged sites, and soft edges had significantly less disturbance than hard edges. There were no edge effects at natural-edged sites, although disturbance rates were high overall at these sites. There was a significant positive relationship between % old-growth and avian disturbance rates. Squirrels disturbed eggs more often than nestlings (Table 1), and caused detrimental edge effects at all three edge-types (Fig. 6a and b). In contrast, mice disturbed nestlings more often than eggs (Fig. 6c and d). Similar to squirrels, mice caused detrimental edge effects at all three edge-types, but this trend was not significant (Table 1). Artificial versus real nests: (p. 166) "Real nests "failed" in 33%, 40%, and 33% of cases at hard, natural, and soft-edged sites, respectively. Comparable artificial nests were disturbed in 25%, 14%, and 35% of cases at hard, natural, and soft-edged sites, respectively. When comparing these patterns between real and artificial nests, the effect of edge-type on nest fate was independent of study type." Predator type: (p. 166) "Steller's jay detections were more probable at edges compared to interiors around Desolation Sound (Table 2). This effect differed among edge-types however, occurring only at hard-edged sites, and not at soft-edged sites. There were no significant treatment effects on Steller's jay observations in the Nimpkish Valley, nor with gray jays (Table 2)." "Within edge transects, Steller's jays and gray jays were distributed differently among gap, border, and forest margin locations (Fig. 8). Steller's jays were observed at all locations at both hard and soft-edged sites, although their highest densities were observed in gaps of hard edges (Fig. 8a). In contrast, gray jays were observed infrequently, and were never observed in gaps of any kind (Fig. 8b)." (p. 170) "…patterns of nest fates between sites with different edge-types were not significantly different from those observed at real nests at sites of similar edge-types and elevation. However, the power of this test was low, and patterns would have to be highly divergent between the nest types in order for us to have a reasonable probability of yielding a significant result. Thus, these data are not sufficient for assessing potential differences in patterns between artificial and real nests, and consequently cannot be used to validate or invalidate our approach."

Study Citation	Malt and Lank 2007
Potential sources of bias or error	In some cases made comparisons among artificial nests (current study) and real nests (summarized from other studies). Locations and fate of real nests were determined using radio-telemetry in most cases.
Effects modifiers[9]	The study experiments used artificial nests (eggs and nestlings) in comparisons of edge vs. interior locations and predator type, whereas most other studies used real nests.
Additional notes	Researchers used cameras at artificial nests at Nimpkish study area and bite marks at Desolation Sound area to determine types of predators at nests. The study investigated three different edge types including: "Hard-edged" sites located adjacent to recent clearcuts (5–11 years old), "soft-edged" sites next to regenerating stands (17–39 years old), and "natural-edged" sites next to large rivers or avalanche chutes.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.20

Study Citation	Manley 1999
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Sunshine Coast (Bunster Range, Theodosia and Brittain valleys), southwestern (mainland) British Columbia
Study area habitat	Coniferous (late-successional) forest (yellow-cedar, mountain hemlock, Pacific silver fir, western hemlock, western redcedar, Douglas-fir)
Study design[1]	Both
Sampling design[2]	Experimental; w/replicates, no controls
Study methods[3]	Audio-visual, Ground search, Climbing, Telemetry
Years of study	1994–1997
Within-year study period[4]	13 May–29 Aug (varied depending on study year)
Sample sizes[5]	68 nest attempts at 52 nest trees
Statistical analysis of results	Parametric (list tests): Mann Whitney U-tests, Chi-square tests, Fisher's exact tests
Statistical power	Not provided
Document type	Thesis/dissertation
Spatial scale(s)[6]	Stand, Study site, Patch, Tree
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	None specified
Other habitat characteristics described	Tree density and various characteristics as the tree scale (e.g., platform size, density, etc.). None related directly to nests of known fate.
Cause(s) of nest failure[7]	Information on nest fate (success and failure) for a subset of nests. Some information on cause of failure. Habitat characteristics not analyzed for successful versus failed nests.
Pertinent results, including statistical significance values and measures of variation[8]	Nest searching results: (p. 20) “Fifty-two nest trees of Marbled Murrelets were located during the study from 1994–1997. Seven nests were active (nests where birds were incubating or feeding chicks when they were located in 1995 and 1996.” “Nest visitation was observed at 6 nest trees where birds were not actively incubating or feeding a chick (inactive nests). Four of these trees were identified as nest trees following landing, one was a nest tree from the previous year, and one had been an active nest earlier that year. Forty-one nest trees were discovered after the breeding season during tree climbing. 1 had no information on behaviour for these nests but evidence at these nests was used to assess nesting success.”

Study Citation	Manley 1999
Pertinent results, including statistical significance values and measures of variation (continued)[8]	Nest success: (p. 34–36, Tables 8 and 9) Nest outcome was assessed for 68 nesting attempts at 52 nest trees from 1994–1997. Nesting attempts included 4 re-used nests and 10 trees with multiple nest cups. Nesting success was determined for 21 nests, and outcome was not determined for the remaining nests (n = 47) due to timing of discovery, limited evidence or inadequate monitoring. Two-thirds of the observed nests failed (14 of 21) and predation of eggs was the most frequent cause of nest failure (12 of 14). Eggs were depredated and eaten at 4 nests, leaving entire eggshells at or beneath the nest. This type of predation is most likely caused by Steller's Jays or Gray Jays. Very few, small fragments of eggshells were found at 8 nests where the egg had presumably been removed by Common Ravens. Additional evidence that predators remove eggs and eat them elsewhere included a depredated egg located on the ground away from a known nest site. Trees in the stand where the egg was found were searched but no nest site was located. Habitat analyses: (p. 58–60, Tables 12–15) At the microsite level there was selectivity for nest limbs that were larger in diameter and with a larger platform area than other limbs in nest trees. Cover above platforms and greater amounts of lichen litter were also preferred over exposed platforms and platforms with less epiphyte cover. (p. 60–70, Tables 16–21, Figures 9–10) At the element level murrelets selected nest trees that were larger in diameter than other trees in nest plots with potential nest platforms, particularly for yellow-cedar and western hemlock. Nest trees also had a larger number of potential nest platforms. Yellow-cedar were the most frequently used nest trees (92%). Western hemlock and other species combined were used less frequently than availability and murrelets were not found nesting in western redcedar or Pacific silver in this study. For yellow cedar and western hemlock there was selectivity for trees with fewer exposed platforms and more covered platforms. Murrelets used canopy gaps disproportionate to availability; industrial gaps were preferred and tree gaps were avoided. Most likely differences in gap types were related to size of gaps with selectivity for larger gaps. (p. 70–75, Tables 22–23, Figures 11–12) At the patch level murrelets selected patches with lower tree density, higher density of trees with nesting platforms, and more epiphyte cover on nest limbs. There was no evidence for selection of gap type, gap size, or frequency of vegetation site associations.

Study Citation	Manley 1999
Pertinent results, including statistical significance values and measures of variation (continued)[8]	Comparisons of nest characteristics with sites in BC, Washington, Oregon, and California: Murrelet nest trees in the Bunster Range were approximately half the dbh and height of other nest trees in BC and Washington, Oregon and California PNW. Nest trees were more similar in size to nest trees in Alaska (Table 26). The height and diameter of nest branches were intermediate between nests in Alaska and nests from the US Pacific Northwest. Nest sites in the current study were located much closer to the tree trunk than nests in other regions and nest trees in the current study ranged from 688–1,260 m in elevation. Most other murrelet nest trees have been in lower elevation habitats. Sizes of nest stands in the current study ranged from 2–566 ha and nest trees were located between 0–503 m from forest edges.
Potential sources of bias or error	None apparent
Effects modifiers[9]	None apparent
Additional notes	Note, the study provided information on nest fate and also habitat level analyses, but did not link the two and therefore did not provide information on habitat characteristics associated with success/failure. Study site descriptions: (p. 5) "Nest sites of Marbled Murrelets described in this thesis were located in three areas; the Bunster Range, Theodosia valley and the Brittain valley. The Bunster Range and Theodosia valley occur in the Bunster Landscape Unit This landscape unit has a forested area of 35,404 ha, has 4,874 ha (13.8%) late-successional forest, and is adjacent to Desolation Sound. During the breeding season, Desolation Sound supports one of the highest densities of Marbled Murrelets in southern B.C. (Burger 1995a). An estimated 2,500 to 4,300 murrelets forage in this area (Drever et al. 1998). Murrelets use Theodosia Inlet as a flight corridor between marine habitat and inland forests (Kaiser et al. 1995). The Brittain River is located on the north side of Jervis Inlet. This Landscape Unit contains 28,809 ha of forested area and has 8,859 ha (30.8%) of late-successional forest." Habitat in study areas: (p. 5) "Late-successional forests are now uncommon at low elevations. Estimates of forest cover for the Sunshine Coast District indicate that 2.4% of the CWHxrn and 5.3% of the CWHdm forested area are late-successional forest. Forest harvesting is occurring in the CWvm2 and the MHmm 1. Late-successional forests comprise 26.7% and 28.1% of the forested area in these variants respectively."

Study Citation	Manley 1999
Additional notes (continued)	Methods for locating nests: (p. 10) "To locate nests, I focused on areas where I detected occupied behaviours (birds flying below or into the canopy and landing in trees). Survey effort was increased in the immediate area of the occupied behaviour to locate trees where murrelets were landing. When occupied behaviours were observed but we could not locate a nest from the ground, we returned to these areas at the end of the breeding season and climbed trees to search for nest sites." Approach to nesting habitat analyses: For selection at the patch level the study compared habitat characteristics at the tree and forest scale for comparisons of nest patches to paired, random patches within the same stands. For element level analyses the study compared trees that murrelets used for nesting to the larger pool of trees available within nest patches. At the microsite level the study compared nest limb characteristics to other limbs within nest trees. At the stand and landscape level the habitat analyses focused on murrelet activity and occupancy sampled over a larger area than the nest sites and therefore is not relevant for the question of interest. Microsite level: (p. 53–54) In 1995 researchers climbed 9 nest trees and recorded the following information for limbs >15 cm (possible nest platforms): height of limb, limb diameter, platform area, depth of epiphytes on limb, orientation of limb, and cover above platforms. In 1996 and 1997 data collection was simplified to the following: total number of platforms, epiphyte substrate, cover above platform, and platform type. Element level: (p. 54) Using data from 37 nest patches the study examined tree and forest characteristics with 25 m radius plots centered on nest trees. Habitat characteristics measured included: species, diameter, height, number of potential nest platforms, canopy stratum and top condition for all trees and snags >10 cm in diameter.

Study Citation	Manley 1999
Additional notes (continued)	Patch level: (p. 55) Patches were defined as the area within a 25 m radius vegetation plot. The same measurements used at the element level (see above) were collected at the patch level, centered on a sample of 34 nest trees and paired random points within 60–200 m of nest trees. Other measurements collected included slope and aspect of each plot.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.21

Study Citation	Manley 2003
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Desolation Sound and Clayoquot Sound, British Columbia
Study area habitat	Coniferous forest
Study design[1]	Both
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Climbing, Telemetry
Years of study	1998–2002
Within-year study period[4]	Early May to early Aug
Sample sizes[5]	70 nest locations (Desolation Sound = 43 locations, Clayoquot Sound = 27 locations)
Statistical analysis of results	Parametric (list tests): multivariate ANOVA, t-tests, chi-square tests, binary logistic regression.
Statistical power	Not provided
Document type	Unpublished report
Spatial scale(s)[6]	Patch, Tree
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	Significant factors = elevation, slope (at tree scale also includes: tree height, platform density, moss cover limb height, etc.). Non-significant factors = platform density, height of canopy trees, mistletoe rating.
Other habitat characteristics described	None specified
Cause(s) of nest failure[7]	Information on nest fate (success and failure). Effect of habitat on nest fate analyzed. Cause of nest failure not addressed.
Pertinent results, including statistical significance values and measures of variation[8]	Nest site habitat characteristics: (p. 6–7) "Multivariate testing of the suite of 12 nest site variables (Table 2) showed significant differences between the Desolation and Clayoquot locations (MANOVA: F = 2.64, df = 14 & 27, *P* = 0.015). Subsequent univariate testing revealed significant differences in nest tree height, number of platforms in the nest tree, percent moss cover on nest trees and nest limb length between the two locations (Table 2). Nest trees were taller, had more potential nest platforms and had higher moss cover in Desolation Sound (Table 2). Nest limbs in Clayoquot Sound were longer than those in Desolation Sound (Table 2). The most frequent tree species used for nesting were western hemlock in Clayoquot Sound and Douglas-fir in Desolation Sound (Table 3). There were no significant differences in tree species used for nesting in the two study areas (chi sq = 5.27, df = 5, *P* = 0.384)."

Study Citation	Manley 2003
Pertinent results, including statistical significance values and measures of variation (continued)[8]	Nest patch characteristics: (p. 9) "The frequency of tree species providing platforms in nest patches varied between study areas (chi sq = 54.08, df = 6, $P < 0.001$). In both study areas, western hemlock and western red cedar provided the majority of platform structures. In Clayoquot Sound, there was a greater representation of yellow-cedar and mountain hemlock as platform trees. Desolation Sound had higher proportions of western hemlock, Pacific silver fir and Douglas-fir platform trees." "Comparisons of nest tree species frequency (Table 3) with the availability of platform trees in each species (Table 4) provide an indication of trees species preference in each study area. In Clayoquot Sound, Douglas-fir and western hemlock appear to be preferred species. Douglas-fir made up a greater proportion of nest trees (18.5%) than what was available (6.3%). A similar trend was observed for western hemlock (Table 3,4). Yellowcedar was used and available in similar proportions. Western redcedar and Pacific silver fir were both used less than they were available (Table 3,4). In Desolation Sound Douglas-fir and yellow-cedar appear to be selected more for nesting, both were used more frequently than expected based on their availability. Western red cedar was neither avoided nor preferred. Western hemlock and Pacific silver fir were used less frequently for nesting than expected based on their availability." "Multivariate testing showed significant differences in the suite of 14 habitat patch variables (Table 5) with location (MANOVA: F = 2.78, df = 14 & 41, $P = 0.006$). In univariate tests: mean and standard deviation of canopy tree height, standard deviation in height for all trees and mean mistletoe ranking were higher in Desolation Sound. The number of platforms per tree was higher in Desolation Sound and the number of platform trees per hectare was higher in Clayoquot Sound (Table 5). Pearson Correlation coefficients are presented for all nest patch variables in Appendix 1, Elevation had significant negative correlations with mean height all trees (r =-0.47 $P < 0.01$) and mean height of canopy trees (r = 0.39, $P < 0.01$). Slope had a significant negative correlation with the number of platforms per hectare (r = -0.34, $P = 0.01$). (p. 20–21) Previous studies in Desolation Sound also included inaccessible nest sites and found that these sites did not differ in tree height or vertical complexity but slopes had higher nesting success". In contrast, "The results of this study apply only to tree nests in accessible stands. It is apparent from other studies that the influence of slope on nesting success is stronger when inaccessible nests are included (many of them are on steeper slopes). However, in Clayoquot Sound where all tree nests were accessible, slopes did not differ for successful and failed nests. Further analyses should investigate whether slope itself or some other co-variate of slope is influencing nesting success."

Study Citation	Manley 2003
Pertinent results, including statistical significance values and measures of variation (continued)[8]	Nesting success and habitat characteristics: (p. 17) "Nesting success as measured by the proportion of nests that fledged a chick was similar for the two study areas (48% of 27 nests in Clayoquot Sound and 51% of 43 nests in Desolation Sound were successful). Overall there were no significant differences in the nest patch and nest tree characteristics of successful and unsuccessful nests (MANOVA: $F = 1.21$, $df = 17\& 28$, $P = 0.32$). Location was a significant covariate in this analysis (MANOVA: $F = 2.06$, $df = 17 \& 28$, $P = 0.044$)." "In the logistic regression, the number of platforms in the nest tree was the only significant predictor of fledging success (Table 6). Successful nests had more platforms within the nest tree than unsuccessful nests (Tables 6–7). Successful nests occurred on sites with steeper slopes than unsuccessful nests, however slope was only significant at the 0.10 level (Tables 6–7). Because location was a significant covariate, further analyses were done for each location separately. In Desolation Sound successful nests occurred on steeper slopes, successful nest trees had more platforms and higher nest limbs (Table 8). In Clayoquot Sound percent moss cover was the only attribute showing differences between successful and failed nests (Table 8)." Summary (p. 21) "This study did not find any significant relationships between nest patch and nest site habitat attributes and nesting success in multivariate testing. Study area was a significant covariate in analyses and may indicate that trends are not consistent between the two study areas. Differences between locations suggest that landscape pattern or habitat availability may determine how nest patch and nest site variables influence nesting success." "In Desolation Sound successful nests were on higher limbs, had more nest platforms in the nest tree and occurred on steeper slopes than unsuccessful nests. The same trends were not apparent at Clayoquot Sound nests. Analyses of all nest sites (inaccessible and accessible) in Desolation Sound found that nests that were further inland and on steeper slopes."
Potential sources of bias or error	The proportion of inaccessible nest sites was higher in Desolation Sound than Clayoquot Sound resulting in a potential sampling bias in habitat variables.
Effects modifiers[9]	None apparent
Additional notes	Habitat variables at the nest patch and nest site scale were examined within and among sites (Desolation Sound and Clayoquot Sound) and effects on nesting success were investigated.

Study Citation	Manley 2003
Additional notes (continued)	Nest patch scale: (p. 6) "Tree and forest characteristics were measured in a 25 m radius circular plot centred on the nest tree. General characteristics were measured at plot centre including elevation, mean slope, aspect and canopy cover (average of four densiometer measurements). Within these plots, species, diameter, height, canopy stratum and top condition were recorded for all trees and snags >10 cm in diameter." "Additional characteristics of each tree were assessed following the RIC protocol (RIC 2001). These characteristics included; number of potential nest platforms (limbs or structures >15 cm in diameter) epiphyte cover rated from 0–4 (0 = trace, 1 = 1–25%, 2 = 25–50%, 3 = 50–75%, 4 ≥ 75%) and mistletoe index rated from 0, with no affected limbs, to 6 where more than 50% of limbs are effected in each 113 of the tree crown (see RIC 2000 for details)." Nest tree scale: (p. 6) "An experienced tree climber documented nest tree and nest site characteristics (e.g., nest branch, nest cup) once the nest was no longer active. The same tree climber documented nests in all years and both study areas. Data were collected following the Pacific Seabird Group Marbled Murrelet Nest Structure Form. Tree height, dbh, number of platforms, moss abundance % and lichen abundance % were measured for the nest tree. The height, platform, and moss and lichen abundance levels differ from those measured for the nest plot because they were assessed by the climber from within the tree instead of estimated from the ground. Nest limb height, diameter and length were measured from within the tree. Nest cup dimensions, nest distance from trunk, moss depth at nest and vertical percent cover above the nest were also measured by the tree climber. In cases where more than one nest cup were found in a nest tree only the most recently active nest cup were used in the analysis."

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.22

Study Citation	Manley et al. 2001
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Queen Charlotte Islands/Haida Gwaii, British Columbia
Study area habitat	Old-growth coniferous forest
Study design[1]	Qualitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Climbing, Telemetry
Years of study	2000
Within-year study period[4]	23 May to early Aug
Sample sizes[5]	Seven nests from 50 radio-marked birds
Statistical analysis of results	Descriptive statistics only
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Stand, Patch
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	None specified
Other habitat characteristics described	Tree species composition, average tree height, dbh, epiphyte cover, and platform density.
Cause(s) of nest failure[7]	Information on success and failure including nest fate at different stages of breeding. No information on cause of nest failure.
Pertinent results, including statistical significance values and measures of variation[8]	Murrelet capture results: (p. 7) "A total of 52 birds were captured in western Skidegate Narrows between May 23 and Jun 6, 2000. Radio-transmitters were attached to 50 of the 52 captured birds." Nest locations and fate: (p. 16) "The majority of the radio-tagged murrelets (85.5%) in this study did not appear to attempt to breed. These birds were located on the water consistently during telemetry surveys. Only 14.5 % (7 of 48 live murrelets) were tracked to inland sites." In contrast in Desolation Sound 50–60% of radioed birds were non-breeders. "All nesting areas occurred within a 10 km radius of the capture area, except for the Weeping Willy nest which was approximately 20 km east of the main capture area." "We were unable to obtain any concrete information on nesting success in this study."

Study Citation	Manley et al. 2001
Pertinent results, including statistical significance values and measures of variation (continued)[8]	(p. 10, Table 2) Of the seven birds tracked to inland sites, four birds were detected inland over an estimated minimum period of 34 and 52 days, sufficient time for fledging chicks. In fact, three of these birds may have been at the nest for close to 60 days. "Two birds were only detected inland at suspected nest sites on one day (rf5303, 5263). The latest nesting bird (rf 5263) was detected inland over a period of 8 days. These three attempts may represent birds that abandoned before egg laying or failed very early during nesting." (p. 11) "We attempted to locate nest sites by climbing and searching nest trees for the four sites that were visited on foot. We searched between 8 and 20 trees at each site but were unable to locate any nests." Because the researchers failed to locate exact nest sites during tree-climbing the fate of nests can only be estimated/assumed based on date ranges of telemetry activity. Based on the above observations it appeared that 4 of 7 nests advanced well into the chick-rearing period and potentially successfully fledged chicks and another three nests failed early or nesting was never attempted (i.e., no eggs laid). Habitat at nesting areas based on forest cover maps and habitat transect measurements: (p. 12, Table 3) The location of nesting areas averaged 1.1 km from the coast with three of seven nests <300 m from shore (range = 25 m–4.2 km). The average elevation for the seven nesting areas was 219 m (st.dev. 197 m; range = 0–460 m). Nesting areas occurred on relatively steep slopes (mean 60%, st.dev. 30) with five of the seven nests were located on slopes of >70%. Platform densities across sites averaged 126 (range = 90–182 [platforms per transect?]). Nesting areas were located in three Biogeoclimatic variants. (p. 13, Table 4) Based on forest-cover polygons for the nesting areas three nest sites were classified as age class 9 (>250 yr) and three site were classified as age class 8 (141–250 yr). One nest site was located in an area where age and height were not available. (p. 13, Table 5) "Habitat transects in nesting stands provided additional information on forest characteristics. Nesting stands were dominated by western hemlock (3 stands), Sitka Spruce (3 stands) and Yellow-cedar (1 stand) (Table 5). The average diameter of trees with platforms in nesting stands ranged from 87–121 cm. The height of trees with platforms ranged from an average of 26–48 m. Shorter tree heights were found at the higher elevation nesting sites (*n* = 3). Although the 7 nesting stands were quite diverse and differed in tree species, height, elevation and location, platform density was quite consistent for the seven stands. The density of potential nesting platforms averaged 126+/- 45(sd) platforms/ha (range 53–182) at the nesting stands."

Study Citation	Manley et al. 2001
Pertinent results, including statistical significance values and measures of variation (continued)[8]	Habitat suitability classifications of nesting areas: (p. 14, Table 4) "Using forest cover information (Ministry of Forests 1:20000 maps), polygons containing nests were classified as unsuitable (n = 4), potentially suitable (n = 1) and suitable (n = 2) with the 'Revised Marbled Murrelet Algorithm' in McLennan et al (2000) (Table 4). To verify the forest cover map classification, forest cover age and height class were revised using data collected at habitat transects. Data from transects showed substantial differences from the forest cover map information. Three nesting areas were mapped as mature age class 8 stands. However, observations on transects suggest that these were all age class 9 stands. Measured height class was higher (n = 3) and lower (n = 1) than map height class at 4 of the 7 nesting areas. Using measured attributes from transects causes considerable changes in the Suitability Classifications. Suitability Classifications from measured data were higher than those from map data for 4 of the 7 nesting areas. "Platform density classes are based on the density of platforms/ha measured in transect. Five platform density classes were delineated to correspond with the five habitat suitability classes; None = 0, Low = 1–50, Medium = 51–150, High = 151–300, Very High = >300. (McLennan et al. 2000). Nest stands were rated as either Medium (n = 5) or High (n = 2) platform density."
Potential sources of bias or error	The proportion of inaccessible nest sites was higher in Desolation Sound than Clayoquot Sound resulting in a potential sampling bias in habitat variables.
Effects modifiers[9]	Nest locations and inference on nest success were inferred based on tracking data of radio-marked murrelets.
Additional notes	Information on habitat at all nest sites was provided but there was not sufficient detail in the report to determine habitat at nests of different known/inferred fate. Habitat descriptions: (p. 6) "We planned to describe habitat at nest sites at various spatial scales: the level of habitat sampling completed depended on how accurately nest sites were located. For those sites at which we were able to narrow the potential nest location to one to a few trees during a ground visit, we used a professional tree climber to climb potential trees in the area and search for nests, or nesting evidence. If a nest or evidence of nesting were found, micro-habitat characteristics of nests would be documented following the Pacific Seabird Group (PSG) protocol and dataforms (Hamer 1993). The next level of habitat sampling involves 25 m radius circular plots centered on the nest tree and at a random location within 200m of the nest tree and within the same forest cover polygon. Data on forest structure within these plots would be collected following the Resource Inventory Committee (RIC) habitat sampling standards (RIC 2001)."

Study Citation	Manley et al. 2001
Additional notes (continued)	(p. 6) "At all sites, aerial and/or ground telemetry results enabled us to locate nesting sites within one forest cover polygon even if the actual nest tree was not located. Habitat within the forest cover polygon containing the nest tree was assessed using a 200x30 meter transect as described in (McLennan et al. 2000)." (p. 7) "All trees with murrelet nesting potential (i.e. with platforms >18 cm diameter) within the transect were measured and recorded. From the transect data, platform, tree species composition, average height, dbh, epiphyte cover, and platform density were determined. The use of these transects allows for direct comparison with habitat suitability mapping of (McLennan et al. 2000). Other features recorded at nests and nesting areas include slope, aspect, distance inland, elevation, Biogeoclimatic variant, and forest cover polygon code."

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.23

Study Citation	Marks and Naslund 1994
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Storey Island, Prince William Sound, AK
Study area habitat	Old-growth coastal forest with large trees; Western and Mountain hemlocks and Sitka Spruce
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual
Years of study	1991
Within-year study period[4]	11 Jul 1991
Sample sizes[5]	1 adult
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Study site, Patch
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	None specified
Other habitat characteristics described	Stand distance inland, canopy cover, elevation, tree height, tree species
Cause(s) of nest failure[7]	1 adult killed at what presumably was a nest, although no nest was found
Pertinent results, including statistical significance values and measures of variation[8]	(p. 565–566) During dawn watch AV surveys, heard a murrelet calling/landing, then heading to sea; 1 min later, heard Sharp-shinned Hawk calling; 11 min later, heard a second murrelet calling/landing in tree, then immediately flying out of tree. It then was heard flapping on its way to the ground. After survey was over, Sharp-shinned Hawk was flushed from murrelet carcass. [NOTE: Sounds as though murrelet tried to land in tree but Sharp-shinned Hawk was there and it followed the murrelet, which flushed immediately, and killed it.] (p. 566) Murrelet was 200-g male with large vascularized brood patch; hawk was adult female, which could have weighed as much as 210 g. Authors cite Sealy 1974 as evidence that vascularized brood patch indicated that murrelet was or recently had been incubating. However, climbed 3 upper-canopy trees in the vicinity but found no murrelet nest, so it is possible that it was a prospecting bird. In addition, paper by Tranquilla et al. 2004 indicates that brood patch is poor evidence of incubation.

Study Citation	Marks and Naslund 1994
Pertinent results, including statistical significance values and measures of variation (continued)[8]	(p. 566) Along with breeding experience, nest-site quality probably is critical to breeding success. Suggested aspects of nest-site quality include cover over nest, ease of accessibility, and stand size, along with environmental aspects such as light level. Authors point out that adult murrelets are vulnerable to predation at nests and helps to explain the murrelet's cryptic plumage and crepuscular activity patterns at nests.
Potential sources of bias or error	Authors state in one place that it was a bird at a nest, then state elsewhere that no nest was found. Prospecting birds may visit the forest, especially at this time of the year. Although authors indicate that the vascularized brood patch = recent incubation, so it is possible that they climbed the wrong tree to look for nest, work by Tranquilla et al. 2004 indicates that brood patch is poor evidence of incubation.
Effects modifiers[9]	Data are from AK, so comparability to OR may be questionable. However, Sharp-shinned Hawks occur in OR too, so they may exert similar predation pressure there.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.24

Study Citation	Marzluff and Neatherlin 2006
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Lower elevations (<600 m) in the Hoh, Soleduck, Quinault, and Queets River drainages, on the western side of the Olympic Peninsula, Washington
Study area habitat	Forest patches >50 ha in area with dominant coniferous trees 50 to >200 years old
Study design[1]	Quantitative
Sampling design[2]	Experimental; w/replicates, no controls
Study methods[3]	Artificial nests (eggs and nestlings) with motion-sensitive radio transmitters, paraffin coating to record predator marks
Years of study	1995–2000
Within-year study period[4]	Unknown
Sample sizes[5]	585 egg and 464 chick trials; six trees within each of 56 study sites, each year; 474 nests within 1 km of settlements and campgrounds and 575 nests >5 km from settlements and campgrounds.
Statistical analysis of results	Parametric (list tests): chi-square and correlation
Statistical power	None
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Tree
Natural or artificial nests?	Artificial
Habitat characteristics compared in relation to nesting success	Distance from campgrounds/settlements
Other habitat characteristics described	None specified
Cause(s) of nest failure[7]	Predation
Pertinent results, including statistical significance values and measures of variation[8]	(p. 310) "Large corvids (crows and ravens) were rare nest predators (5.7% of all predation, 17.6% of corvid predation), but they were more important within 1 km of settlements and campgrounds than >5 km from it (8.2% of all predation within 1 km of settlements and campgrounds vs. 3.6% >5 km from settlements and campgrounds; chi-sq = 8.34, df = 1, $P < 0.01$). Jays (Steller's and gray) preyed on 26.8% of nests and were responsible for 82.4% of corvid predation." However, no relationship between abundance of jays and predation rates. Only significant relationship was number of crows and days until nests depredated for sites < 1 km from settlements/campgrounds.

Study Citation	Marzluff and Neatherlin 2006
Potential sources of bias or error	Predation rates appear to include all types of predation, not just corvids. Low rates of corvid predation of chicks might reflect response to carcasses rather than live nestlings. Egg predation rates likely influenced by presence/absence of incubating adult. Timing of experiments within breeding season.
Effects modifiers[9]	Artificial eggs and nestling models
Additional notes	Unclear relationship between "days before nests were preyed upon" for artificial eggs/nestlings and probability of MAMU nest success.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.25

Study Citation	Marzluff et al. 1999
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Western Olympic Peninsula, WA; Oregon Coast Range between Lincoln City and Newport, in the Siletz -Yaquina, Alsea, and Upper Willamette sub-basins
Study area habitat	Commercial forests managed by Boise Cascade Corporation, Willamette Industries, The Timber Company, and the Oregon Department of Forestry
Study design[1]	Quantitative
Sampling design[2]	Experimental; w/replicates, no controls
Study methods[3]	Artificial nests (eggs and nestlings) with motion-sensitive radio transmitters, paraffin coating to record predator marks
Years of study	1997 & 1998
Within-year study period[4]	Unknown
Sample sizes[5]	223 total nests; 11 study sites in 1997 and another 10 sites in 1998, representing 2–3 replicates of all possible combinations of stand size, shape and surrounding landscape type
Statistical analysis of results	Parametric: multiple regression
Statistical power	None
Document type	Unpublished report
Spatial scale(s)[6]	Stand, Tree
Natural or artificial nests?	Artificial
Habitat characteristics compared in relation to nesting success	Distance from edge, adjacent habitat type, stand size, stand shape
Other habitat characteristics described	None specified
Cause(s) of nest failure[7]	Predation (corvids)
Pertinent results, including statistical significance values and measures of variation[8]	(p. 25) Of 223 nests, 194 (87%) were disturbed. 110 of 142 (77.5%) "nests with identified predators were disturbed by potential predators." (p. 41) "nests >250 m from stand edge had significantly higher survivorship that those within 50 m of edge ($X2_{(1)} = 5.88$, $P = 0.02$)" "In stands surrounded by young regeneration with forage-producing shrubs, nests close to the stand edge were preyed on significantly faster than those farther from the stand edge ($r = 0.41$, $n = 74$, $P < 0.01$)" "Stands surrounded by young regeneration without forage shrubs did not show any significant effect of distance to stand edge on rate of predation" "These results are consistent with an increase in risk of nest predation in stands surrounded by vegetation that offers forage to jays."

Study Citation	Marzluff et al. 1999
Pertinent results, including statistical significance values and measures of variation (continued)[8]	(p. 47) "Nests in stands surrounded by young regenerating forest with a heavy berry-shrub layer had significantly lower nest survivorship than either young regeneration without berry-shrubs ($X2_{(1)} = 7.72$, $P = 0.01$) or older stem exclusion stage regeneration ($X2_{(1)} = 3.56$, $P = 0.05$)." "Although stand size has no evident affect on predation rate, either at the stand level ($X2_{(1)} = 0.23$, $P = 0.63$) or nest level ($X2_{(1)} = 0.01$, $P = 0.94$), stand shape does appear to have a weak effect when individual nests are used as the independent sample ($X2_{(1)} = 3.16$, $P = 0.08$). This is likely a reflection of the increase in nest survivorship for nests located in stand core areas. With our study design, core areas 200–250 m from stand edge, while available in both large and small stands, are only available in stands of compact shape (linear stands were delineated such that no area within the stand was >180–200 m from edge). This suggests that where edge effects do occur, they may extend >200 m from edge."
Potential sources of bias or error	Non-independence of variables
Effects modifiers[9]	Artificial eggs and nestling models
Additional notes	Included here (with permission of the lead author) are unpublished results of the initial two years (1997 and 1998) of studies conducted in Oregon. The report primarily focuses on studies conducted in Washington (western Olympic Peninsula) 1995–1998 that were later published and are included in this study as results in Luginbuhl et al. 2001 and Raphael et al. 2002.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.26

Study Citation	Naslund et al. 1995
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Naked, Afognak, and Kodiak islands, northern Gulf of Alaska, AK
Study area habitat	Coastal old-growth forest (Western Hemlock, Mountain Hemlock, and Sitka Spruce in PWS; only Sitka Spruce on other 2 islands)
Study design[1]	Qualitative
Sampling design[2]	Descriptive
Study methods[3]	Audio-visual, Climbing, viewing nests from nearby trees
Years of study	1991 (Naked I)–1992 (Naked, Afognak, Kodiak I.)
Within-year study period[4]	"During the breeding season"
Sample sizes[5]	7 of 14 nests with known fates on 3 islands (Naked—6 in 1991, 4 in 1992; Afognak—2 in 1992; Kodiak—2 in 1992)
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Watershed, Tree, platform
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	None specified
Other habitat characteristics described	Distance inland, canopy cover, stand size, elevation, slope, aspect, distance to stream, stand vegetation, stand density, tree size, tree height, number of platforms, tree condition, tree species, nest-limb height, nest-limb diameter, tree condition, nest
Cause(s) of nest failure[7]	Of the 7 nests for which fate was known, 6 (86%) failed during incubation and 1 (14%) made it to the chick stage but died; the fate of 1 other chick was unknown
Pertinent results, including statistical significance values and measures of variation[8]	(p. 15, Table 1) Located 14 nest-trees on the 3 islands (Naked—6 in 1991, 4 in 1992; Afognak—2 in 1992; Kodiak—2 in 1992). Of these, the fate was known for only 7 nests. Of these 7 nests for which fate was known, 6 failed during incubation and 1 made it to the chick stage but died; the fate of 1 other chick was unknown. Hence, fate was failure in 7 (100%) of the 7 nests. Of the 6 nests that failed during incubation, 1 definitely was abandoned, 2 others were suspected of being abandoned, 1 was suspected of being lost because of predation, and 2 failed for unknown reasons. Of the 2 nests that made it to the chick stage, 1 chick definitely died and the fate of the other was unknown. In addition, 1 presumed nest on Story Island was lost because 1 adult was killed by Sharp-shinned Hawk.

Study Citation	Naslund et al. 1995
Pertinent results, including statistical significance values and measures of variation (continued)[8]	(p. 24) Suggested the possibility that nests that are easy to find might not be optimal nests (easier for predators to find, more exposed to weather). Indicated that predation appears to be a factor in failure; also examined the possibility that disturbance led to nest failure because of predation and rejected that possibility. Suggested that abandonment and high failure rate may have reflected poor environmental conditions in 1991 and 1992.
Potential sources of bias or error	Authors admit that extremely well concealed nest-sites may have been too hard to find, biasing samples of nest-site characteristics. Also, not clear how good they were at detecting nests that actually were there but were missed--no double-blind trials were conducted.
Effects modifiers[9]	Data are from AK, so comparability to OR may be questionable.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.27

Study Citation	Nelson 1992
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Siuslaw National Forest, Bureau of Land Management (Salem and Coos Bay Districts), Oregon State Parks, and Oregon Department of Forestry lands; Central Coast from Tillamook County south to Curry County
Study area habitat	Small, isolated patches of mature and old-growth trees; dominated by Douglas-fir in the north and mixed-evergreen species in the south, inc1uding Douglas-fir and tanoak
Study design[1]	Quantitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing, Sampling plots, audio recording equipment
Years of study	1991
Within-year study period[4]	16 Apr–3 Sep
Sample sizes[5]	5 nests
Statistical analysis of results	Descriptive statistics only
Statistical power	None
Document type	Unpublished report
Spatial scale(s)[6]	Stand
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	23 variables in each plot: elevation, distance inland, slope, aspect, canopy closure in each quarter, exact diameter of all trees and snags, snag decay class, tree and snag species, position on slope, number of canopy layers, distance to nearest stream or river, distance to nearest opening, and canopy height of 5 dominants. The total number of nest platforms, percent moss cover on limbs, mistletoe abundance, and crown ratio were determined on the nest or center trees.
Other habitat characteristics described	None specified
Cause(s) of nest failure[7]	(p. 7) "Two of the five nests (40%) were successful in fledging young; the others failed because of predation by Steller's Jay and Common Ravens."
Pertinent results, including statistical significance values and measures of variation[8]	See Table 4
Potential sources of bias or error	None apparent
Effects modifiers[9]	None apparent

Study Citation	Nelson 1992
Additional notes	Only copy of report available is missing some tables. Most relevant results in Table 4 (except elevation). Methods indicate statistical comparisons of characteristics of nest trees/plots and randomly selected controls, but results not found in report.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.28

Study Citation	Nelson and Hamer 1995b
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Alaska to California (literature review)
Study area habitat	Coastal old-growth forest, unlogged to heavily fragmented
Study design[1]	Quantitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Not specified
Years of study	1984–1993
Within-year study period[4]	Not specified (literature review)
Sample sizes[5]	32 nests for which fate was known
Statistical analysis of results	Non-parametric (list tests): Mann-Whitney U-test
Statistical power	Not provided
Document type	Agency technical report paper
Spatial scale(s)[6]	All scales (literature review)
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	Stand percent canopy cover, stand size, distance from edge of stand, nest distance from trunk, and nest concealment (shielding). Stand size and canopy closure higher, and distance of nests from trunk smaller, in successful nests-but not significant.
Other habitat characteristics described	None specified
Cause(s) of nest failure[7]	9 (28%) of 32 nests for which fate was known were successful
Pertinent results, including statistical significance values and measures of variation[8]	Paper is literature review summarizing what is known about effects of predation on nesting success. (p. 89) Compiled information on 65 tree nests, but fate was known for only 32 of them; those 32 nests form the core of this paper. (p. 90) Only 9 (28%) of 32 nests for which fate was known were successful; known causes of nest failure include predation on eggs and chicks, nest abandonment, chicks or eggs falling from nests, and natural death of nestlings. This estimate of success is lower than that recorded for any other alcid and most forest-nesting Neotropical migrants. (p. 90) 52% of all nests failed during incubation, but most loss for nests in WA/OR/CA occurred in nestling stage—high abandonment rate for nests in AK. Failure during incubation caused by abandonment/neglect and predation. Failure during nestling stage caused by natural death of chick, chick falling from nest, and predation.

Study Citation	Nelson and Hamer 1995b
Pertinent results, including statistical significance values and measures of variation (continued)[8]	(p. 93) Because some chicks are unable to fly from nest to the ocean during fledging and fall to the ground, where they almost certainly are lost, true nesting success actually has to be lower than this estimate of 28%. Authors use the phrase "much lower," but there frankly is no evidence to suggest that a great majority of chicks do not make it to sea. (p. 93) Major cause of nest failure is predation, all of which is from avian predators; no documented predation by mammalian predators. (p. 93–94) Most predation occurs during incubation, most often because of neglect or abandonment of egg. [NOTE: Technically, this means that the egg was lost because of abandonment, not because of predation.] However, when predators chase the adult from egg and then prey on the egg, it truly is predation. (p. 94) Murrelets have limited defenses against predation at the nest; primary method is avoiding detection (cryptic plumage, behavior, and nest). Chicks actually will defend themselves against predators, although probability of successful defense is lower if chick is small. (p. 94) Nests also may fail if adults are killed at or on way to nest-sites. Documented deaths caused by Sharp-shinned Hawk, Northern Goshawk and birds being chased by Peregrine Falcons and Common Ravens. In addition, Sharp-shinned Hawk in AK killed adult that had just landed on limb, and Common Raven in CA was believed to have killed murrelet from nest being studied—although evidence that it was adult was equivocal. (p. 94) Authors admit that nests that they found may have been easier for predators to find too, making these estimates of nesting success biased. However, believe that effect of researchers on nesting success were small (they suggested that it was only 2 of 32 nests). (p. 95–96) Populations of corvids and Great Horned Owls in western US are increasing because of increases in habitat fragmentation. (p. 96) Successful nests were located significantly farther from nest edges than were unsuccessful nests (means 166 m vs. 27 m); successful nests had significantly higher nest concealment than did unsuccessful nests (means 87% vs. 68%). Stand size and canopy closure were higher and nests were closer to the trunk in successful than unsuccessful nests, but differences were not significant. (p. 96) Authors present a case that habitat fragmentation increases populations of predators at edges and enables them to penetrate forests; effects commonly seen on forest passerines. (p. 96–97) Authors suggest that low nesting success, coupled with low fecundity rates and small population sizes in some areas, may impact survival and recovery of populations of this species.

Study Citation	Nelson and Hamer 1995b
Potential sources of bias or error	Authors seem to include nests (in Alaska) in which adults abandoned or neglected the nest, resulting in predation of the egg, as part of predation. These are 2 different phenomena. Authors admit that the sample of nests that have been studies was biased—nests were easy for both scientists and predators to find—so true nesting success may be underestimated.
Effects modifiers[9]	None apparent
Additional notes	Paper summarizes literature in large number of other publications and reports and, hence, supersedes them. Manley and Nelson (1999) discuss 77 nesting attempts with known fates and, hence, supersede this paper.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.29

Study Citation	Nelson and Hardin 1993
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Central OR Coast Range
Study area habitat	Mosaic of young to old-growth stands of Douglas Fir, Western Hemlock, and Sitka Spruce
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, Climbing
Years of study	1992
Within-year study period[4]	15 May–15 Aug
Sample sizes[5]	3 nests found in 1992
Statistical analysis of results	None–n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Stand, Patch, Tree
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	None specified
Other habitat characteristics described	Distance inland, canopy cover, stand size, elevation, slope, aspect, distance to stream, stand density, distance to edge of stand, distance to disturbance, position on slope, tree height, tree size, number of platforms, tree condition, tree species, nest-limb height, nest-limb diameter, nest-limb length, nest-limb orientation, tree condition, nest distance from trunk, nest cover, nest material
Cause(s) of nest failure[7]	Of 3 nests found, 1 was successful and the other 2 were unsuccessful or almost certainly unsuccessful
Pertinent results, including statistical significance values and measures of variation[8]	(p. 18–19) None of the 7 previously discovered nests were active in 1992, but found 3 new nests. (p. 20–22) 1 nest that was successful (Copper Iron) was in large stand with >90% canopy cover, few predators, and was >100 m from nearest man-made opening (road). (p. 22–24, Table 10) Boulder Warnicke nest had chick hatch, but it disappeared; nest fate was not known with certainty but was suspected of being unsuccessful as a result of predation of the chick. Chick had plumage that was similar to that of 3-week chick, so it probably did not fledge. In addition, Steller's and Gray jays were aware of the nest location, and Common Ravens and Sharp-shinned Hawks were seen nearby. Tree was in a 3-ha stand surrounded by clearcuts; tree was on the edge of the stand, adjacent to the road and clearcut boundary.

Study Citation	Nelson and Hardin 1993
Pertinent results, including statistical significance values and measures of variation[8]	(p. 24–25) Valley of the Giants 1992 nest was believed to have been lost to predators—eggshell fragments, no fecal ring, albumen on some of the eggshell fragments. Nest-tree was 15 m from natural opening in forest cover; no information on predators or other aspects that may have affected success.
Potential sources of bias or error	None apparent
Effects modifiers[9]	Paper describes nests in OR, so highly relevant to study.
Additional notes	Includes nests discussed in Nelson et al. (1994), but it has 1 additional year of data and some new nests. Hence, that document supersedes this one.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.30

Study Citation	Nelson and Peck 1995
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Coast Range and Siskiyou Mountains, western OR
Study area habitat	Mosaic of young trees and mature forests with small, isolated patches of old-growth forests; Douglas Fir is primary canopy-forming tree in the N and variety of conifers is in the S
Study design[1]	Qualitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing, nest cameras; finding eggshells on ground
Years of study	1990–1992 (checked for reuse in 1993)
Within-year study period[4]	Not specified
Sample sizes[5]	9 nests in 7 trees
Statistical analysis of results	Descriptive statistics only
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Tree, branch, platform
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	Nest specified
Other habitat characteristics described	Distance inland, tree species
Cause(s) of nest failure[7]	Of 9 nests examined, 3 (33%) were believed to be successful and the other 6 failed
Pertinent results, including statistical significance values and measures of variation[8]	(p. 45) 9 active nests located between 1990 and 1992 in Coastal and Siskiyou ranges. 8 were in Douglas Fir trees, 1 was in Sitka Spruce tree.
	(p. 45) Of 9 nests found, young were believed to have fledged from 3 nests (based on size/age of nestling, loss of down, and presence of juvenal plumage); believed that predation caused loss of 5 of 6 of the failed nests (2 predation on egg, 3 predation on chick), as indicated by albumen or blood on eggshell fragments or premature disappearance of egg or chick; in 1 of 6 nests that failed, chick fell from nest and was lost.
	(p. 52–53) Despite the extensive efforts of murrelets to avoid predation, 5 (56%) of 9 nests were thought to have been depredated. [Interestingly, this is exactly the same percentage of 32 nests with known outcomes discussed by Nelson and Hamer 1995b in this paper.]

Study Citation	Nelson and Peck 1995
Pertinent results, including statistical significance values and measures of variation (continued)[8]	(p. 53) Authors suggest that habitat fragmentation and increased edges could be causing increase in nest failure because many predator species, especially corvids, are more abundant at edges than in intact forests. Suggest that this increased predation rate may be having a significant effect on depressing murrelet nesting success.
Potential sources of bias or error	None apparent.
Effects modifiers[9]	Paper describes nests in OR, so highly relevant to study.
Additional notes	Authors indicate that the study was conducted 1990 to 1992, then present some additional data from 1993. Data on some nests from Valley of Giants appears to be presented in Nelson et al. (1994), but that latter report includes data from other nests in the same area.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.31

Study Citation	Nelson and Wilson 2002
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Clatsop, Tillamook, and Elliott state forests, western OR
Study area habitat	Sitka Spruce, Western Hemlock zones; mosaic of young, mature, and old-growth Douglas Fir, Sitka Spruce, and Western Hemlock stands
Study design[1]	Qualitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Audio-visual, Climbing, Cameras, binoculars from ground or adjacent tree
Years of study	1995–1999 (Table 2 says 1994)
Within-year study period[4]	22 Jun–19 Aug 1995, 1 Jul–6 Aug 1996, 12 May–31 Aug 1997, 1 May–31 Aug 1998, 6 May–23 Aug 1999
Sample sizes[5]	10 active nests in 37 nest trees
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Stand, Study site, Tree
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	Tree size, density of snags, canopy cover (qualitative analysis)
Other habitat characteristics described	Tree density, tree height, # trees with platforms, # platforms, platform tree density, slope, distance to stream, distance to edge, height of nest-limb, number of platforms in tree, diameter of nest-limb, distance of nest from trunk, mistletoe
Cause(s) of nest failure[7]	Of 10 active nests, 4 (40%) were successful and 6 (60%) failed; however, one nest may not have even been active that year (authors suggested it might have failed early in incubation)
Pertinent results, including statistical significance values and measures of variation[8]	(p. 20) Located 37 nest-trees between 1994 and 1999; however, only 10 of the nests were active. (p. 31, Tables 10 and 11) Of 10 active nests, 4 (40%) were successful and 6 (60%) failed. Because of small sample sizes, authors were unable to conduct statistical analyses. However, based on looking at means and SE's, appears that successful nests occur in slightly larger trees (~15% larger), occur higher in the tree (~37%), occur in trees with more platforms (~10% more), have smaller nest-limb diameters at the nest (~23% smaller), and have nest-cups closer to the trunk (~53% closer) than do failed nests. (p. 59) Small sample size precluded statistical analyses, but it appeared that successful nests occurred in areas with larger trees (~15% larger), lower density of snags (~79% lower), and less canopy cover (~30% less) than failed nests.

Study Citation	Nelson and Wilson 2002
Pertinent results, including statistical significance values and measures of variation (continued)[8]	(p. 71–79) In first nest at North Rector, chick was believed to have fledged. In second nest at North Rector, chick was killed by predator (believed to be Sharp-shinned Hawk). In third nest at North Rector, chick died in nest from renal failure/dehydration, possibly because it was being fed by only 1 adult and not getting enough food/water. In fourth nest at North Rector, egg appeared to have been preyed upon; predators in this area included Steller's Jays and Common Ravens.
	(p. 80–83) In first nest at Big Rackheap, chick appeared to have been preyed on when small; suggested that it may have been a small owl because half-eaten carcass of deer mouse also was found on branch, but Steller's Jays were only predators definitely recorded near the nest. In second nest at Big Rackheap, chick was killed when ~2.5 weeks old; predators recorded in area were Common Raven, Steller's Jay, and Northern Pygmy-Owl. In third nest at Big Rackheap, chick fledged successfully.
	(p. 83) Bearly Backheap nest either was nest from previous year or was depredated early in incubation stage (but no eggshell fragments were found).
	(p. 83–84) In Low Simmons nest, chick fledged successfully; Common Ravens, Steller's Jays, Western Screech-Owls, and unidentified hawk were recorded near nest.
	(p. 85–86) In Elk Creek nest, chick fledged successfully; Steller's Jays, Common Ravens, and Great Horned Owls were recorded near nest.
Potential sources of bias or error	Authors admit that tree-climbers may not find all nests in a tree.
Effects modifiers[9]	Paper describes nests in OR, so highly relevant to study.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.32

Study Citation	Raphael et al. 2002
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Western Olympic Peninsula (artificial nests); range-wide analysis
Study area habitat	Variable; artificial nests in 80- to >200-yr-old forests
Study design[1]	Quantitative
Sampling design[2]	Experimental; w/replicates, no controls
Study methods[3]	Cameras, artificial nests (eggs and nestlings) with motion-sensitive radio transmitters, paraffin coating to record predator marks
Years of study	1995–1999?
Within-year study period[4]	Unknown
Sample sizes[5]	71 nests with known fates throughout range (including 48 nests in Oregon and BC); 923 artificial nests placed in 49 stands
Statistical analysis of results	Non-parametric (list tests): Kaplan-Meier estimates for the survival rate of nest contents; log rank test used to compare survival among groups
Statistical power	None
Document type	Book/book chapter
Spatial scale(s)[6]	Stand
Natural or artificial nests?	Both
Habitat characteristics compared in relation to nesting success	Forest structure (simple, complex, and very complex), proximity to human activity <1 km and >5 km), landscape fragmentation, corvid abundance
Other habitat characteristics described	Stand size and shape
Cause(s) of nest failure[7]	Predation at artificial nests
Pertinent results, including statistical significance values and measures of variation[8]	(p. 226) "For the subsample of nests from Oregon and B.C., distance to edge (roads, clearcuts) was the most important predictor of nest fate. Successful nests were significantly further from edges (mean = 141 m) than failed nests (mean = 56 m, $P = 0.02$). Nest failure, and predation, were highest within 50 m of an edge compared with >50 m. All nests >150 m from an edge were successful or failed from reasons other than predation." $n = 48$ nests. "While there was a trend ($P = 0.12$) for successful nests in Oregon and British Columbia to occur in larger stands (mean = 491 ha) compared with unsuccessful nests (mean = 281 ha), the relatively limited sample of murrelet nests precludes a reliable region-wide analysis of the relationship between stand size and reproductive success." (p. 228–229) Overall predation rates after 30d did not differ between fragmented and continuous stands ("stands in continuous forest versus those surrounded on at least 3 sides by 1–15 yr-old regenerating forest").

Study Citation	Raphael et al. 2002
Pertinent results, including statistical significance values and measures of variation (continued)[8]	(p. 229) "the daily pattern of nest loss over the 30-d period of exposure was nearly identical in fragments and continuous forest (Fig. 2A; chi-sq (1) = 0.64, $P = 0.42$)."
	"Far (>5 km) from human activity, nests in fragments had slower rates of predation than nests in continuous forest (Fig. 2B; chi-sq (1) = 2.45, $P = 0.12$). In contrast, nests in fragments near < 1 km) human activity had rates of predation similar to nests in continuous forest (Fig. 2C; chi-sq (1) = 0.25, $P = 0.65$)."
	Number of days to predation decreased as abundance of corvids increased in continuous but not fragmented stands.
	Fragmentation effects minimal for both egg (corvid) and nestling (small mammal) predation.
	"Total corvid abundance was similar among stands varying in proximity to human activity and fragmentation" although Steller's jays most abundant in forest fragments away from human activity.
	(p. 230) "The distance of a nest from the edge of the forest-matrix interface was not consistently related to the rate of nest predation." Higher predation rates near edge only near human settlements.
	(p. 230–231) Citing Luginbuhl (unpublished):
	"Stand size did not affect predation rates." "Stand shape did have a weak affect on predation rates, with higher rates of predation in linear versus compact stands (chi-sq (1) = 3.16, $P = 0.08$)."
Potential sources of bias or error	None apparent.
Effects modifiers[9]	Artificial eggs and nestling models
Additional notes	(p. 226) "Murrelet nests are difficult to locate, and the sample of active nests on which to assess effects of forest fragmentation on nest fate is relatively small."

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.33

Study Citation	Silvergieter 2009
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Clayquot (Vancouver Island) and Desolation Sound (mainland), southwestern British Columbia
Study area habitat	Coniferous forest
Study design[1]	Quantitative
Sampling design[2]	Experimental; w/controls and replicates
Study methods[3]	Climbing, Telemetry
Years of study	2000–2002 (Clayoquot Sound); 1999–2001 (Desolation Sound)
Within-year study period[4]	Not specified
Sample sizes[5]	64 nests (Clayoquot Sound = 27, Desolation Sound = 37)
Statistical analysis of results	Parametric (list tests): t-test, Pearson chi-square test, logistic regression, AIC, Mann-Whitney U-test, Kolmogorov-Smirnov 2-sample test.
Statistical power	Not applicable
Document type	Thesis/dissertation
Spatial scale(s)[6]	Study site, Patch
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	Site elevation, slope location (edge vs. interior) and edge type. At tree scale included nest platform dimensions, overhead cover, platform height, and platform density).
Other habitat characteristics described	None specified
Cause(s) of nest failure[7]	Information on nest fate (success and failure) was provided. Little information on cause of failure.
Pertinent results, including statistical significance values and measures of variation[8]	Nest success: (p. 57) Overall fledging success for the set of nests considered was 53% (n = 58 total nests). At Clayoquot Sound fledging success was 52% (13 of 25 nests) and the minimum predation rate was 20%. Unsuccessful nests included five predated nests (1 = predated adult remains, 4 = predated chick remains), one nest had an abandoned unfertilized egg, and the cause of failure for the remaining six nests was unknown. At Desolation Sound fledging success was 55% (33 total nests) and the minimum predation rate was 6%. Cause of nest failure at five nests included predation (n = 2 chicks) and unknown factors (n = 2 intact eggs, n = 1 intact deceased chick). Success was not determined at four nests.

Study Citation	Silvergieter 2009
Pertinent results, including statistical significance values and measures of variation (continued)[8]	Edges: (p. 57) At Clayoquot Sound there were no anthropogenic edges within 50 m of nests. One ocean-edge nest was successful, two river-edge nests (n = 5) were successful, and no avalanche chute nests (n = 3) were successful. Ten of 16 (63%) interior nests were successful. At Desolation Sound there were four nests near anthropogenic edges (1 road, 1 hard, 2 soft) and of these only the nest near a road was successful. At natural edges 2 of 5 river nests, 2 of 4 avalanche chute nests and one ocean-edge nest were successful. Twelve of 19 (63%) interior nests (located >50 m from an edge) were successful. At both sites success there was a higher proportion of successful nests at interior vs. edge sites but the difference was not statistically significant (P = 0.08). Platform characteristics: (p. 58) Very few nests (n = 1 at Desolation Sound) occurred on exposed platforms. Success of partial and exposed nests did not differ from nests on covered platforms. At Clayoquot Sound successful nests did not differ from failed nests for any continuous habitat variables but at Desolation Sound successful nests were on platforms that were significantly larger and in trees with more platforms, than failed nests. Platform length was longer at Desolation Sound than Clayoquot Sound. Based on modeling efforts (e.g., AIC) variation in fledging success at both sites was primarily due to variables not included in the model set.
Potential sources of bias or error	Small sample size (low power) for edge effects.
Effects modifiers[9]	The current study used inferred fate of nests based on tree-climbing at the conclusion of the breeding season as opposed to mid-chick rearing success in numerous other telemetry studies.
Additional notes	(p. 52) "The two areas also differ in their degree of forest habitat loss, with over 80% loss of original old growth forest cover in Desolation Sound, compared to 25% loss in Clayoquot (Zharikov et al. 2006)." Crews located nest sites of radio-marked birds by helicopter and then after the breeding season climbed trees to confirm nest location, nest fate, and habitat features.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.34

Study Citation	Singer et al. 1991
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Big Basin Redwoods State Park, CA
Study area habitat	Largest remaining stand (~1700 ha) of old-growth Coast Redwood-Douglas Fir forest in Santa Cruz Mountains
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, Ground search
Years of study	1989
Within-year study period[4]	3 Jun–31 Jul 1989
Sample sizes[5]	2 nests
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Tree, branch
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	Corvid abundance (suggested)
Other habitat characteristics described	Canopy cover, slope, position on slope, aspect, vegetation, stand density, distance to disturbance, tree height, tree size, nest-limb height, nest-limb diameter, nest-limb orientation, tree condition, nest-distance from trunk, nest cover, nest material, witch's broom
Cause(s) of nest failure[7]	2 (100%) of 2 nests failed, both because of predators (Common Raven, Steller's Jay)
Pertinent results, including statistical significance values and measures of variation[8]	(p. 331) Reports on 3rd and 4th tree-nests found in N America, in 1989, both in Big Basin Redwoods State Park. First nest was at Opal Creek picnic area, second (Waddell Creek) was near park sewage-treatment plant. Interestingly, in both nesting pairs, one adult was much darker than the other, making determining incubation shifts easy.
	(p. 331) Opal Creek nest monitored 3–24 Jun; Waddell Creek nest monitored 28 Jun–31 Jul.
	(p. 332–333) At Opal Creek nest, bird was incubating an egg; on 24 Jun, Common Raven landed on branch and displaced the adult from the nest; 15 min later, was seen carrying what appeared to be a carcass in its bill. [NOTE: Although authors suggest that the carcass could have been of embryo or part of adult, it almost certainly was from egg or young chick.] Steller's Jays seen picking at eggshell fragments in nest later that day, suggesting that it was embryo or newly hatched chick, not an adult. Power line and foot trail passed within 10 m of nest-tree.

Study Citation	Singer et al. 1991
Pertinent results, including statistical significance values and measures of variation (continued)[8]	(p. 333–335) At Waddell Creek nest, bird was incubating an egg; on 31 Jul, Steller's Jay killed and removed 2-day-old chick. Unofficial hiking trail and service road passed <20 m from nest-tree. Nest-limb had large knob that created a vertical wall.
	(p. 337) Opal Creek nest is new type of nest with a cup constructed of twigs and lichens. Bird actually was seen breaking off twigs and adding to nest and adjusting twigs.
	(p. 337–338) Picnic areas and visitors' facilities may affect nesting success of murrelets, both by disturbance and noise (although these birds rarely responded) and especially by increased predator populations via feeding by table scraps and garbage. Common Ravens did not nest in this park prior to 1987 and actually nested near Opal Creek nest in 1989. Increased populations of Steller's Jays also have led to reduced populations of passerines in the park. Authors suggest that activities that favor increases in corvid populations should be minimized.
Potential sources of bias or error	It is possible that nests that humans could find were easy for predators to find.
Effects modifiers[9]	Data are from CA, so comparability to OR may be questionable.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.35

Study Citation	Singer et al. 1995
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Big Basin Redwoods State Park, CA
Study area habitat	Largest remaining stand (~1700 ha) of old-growth Coast Redwood-Douglas Fir forest in Santa Cruz Mountains
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, Ground search, Climbing, spotting-scope
Years of study	1991–1994
Within-year study period[4]	5 May–3 Jul 1991, 24 May–7 Jun 1992, 3 Apr–1 Aug 1993, 2 Apr–31 Jul 1994
Sample sizes[5]	1 nest tree with 4 different nests
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Tree, branch, platform
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	Corvid abundance (suggested)
Other habitat characteristics described	Canopy cover, vegetation, distance to disturbance, distance to stream, tree height, tree size, tree condition, tree species, nest-limb height, nest-limb diameter, nest-limb length, nest-limb orientation, tree condition, nest distance from trunk, nest cover
Cause(s) of nest failure[7]	Nests successful in 2 (50%) of 4 years
Pertinent results, including statistical significance values and measures of variation[8]	(p. 54) Monitored nests in various parts of the same Coast Redwood tree in 1991–1994.
	(p. 55) Nests successfully fledged young in 1991 and 1992; 1993 nest failed (believed to be because of predation—eggshell fragments contained puncture marks), as did 1994 nest (reason for loss not specified).
	(p. 55) 1991 and 1994 nests in same nest-cup; 1992 nest on another branch; 1993 nest not discovered, but eggshell fragments found on ground beneath the tree.
	(p. 55) Tree was on flat alluvial plane 69 m from two-lane paved highway and beside heavily used foot-trail. Tree was one of largest in the stand and had many potential nest-platforms.
	(p. 61) In Santa Cruz Mountains, most of remaining old-growth forest occurs in heavily visited parks. Despite human disturbance, including loud talking, yelling, and car noise, authors never saw any reactions of murrelets; however, calls of Common Raven always elicited immediate and visible reaction.

Study Citation	Singer et al. 1995
Pertinent results, including statistical significance values and measures of variation (continued)[8]	(p. 61) Steller's Jays visited nest in 1991 and 1992 and harassed chick in 1992 nest, but it was partially protected by tree trunk, so it was able to defend itself. Authors suggest that concealing cover and location of nest-cup on limb may decrease chances of failure caused by predators. (p. 61) Of greater concern is ravens and jays feeding on food from overturned garbage cans and being fed by hikers—results in inflated corvid densities.
Potential sources of bias or error	No bias or error in study design—followed same nest-tree for use over 4 consecutive years.
Effects modifiers[9]	Data are from CA, so comparability to OR may be questionable.
Additional notes	

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.36

Study Citation	Suddjian 2003
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Butano Creek Watershed, San Mateo County, central CA
Study area habitat	Remnant stands of old-growth Coast Redwoods and Douglas Firs; area had been intensively logged, with scattered old trees left as "seed trees"
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, Climbing
Years of study	1992–2001
Within-year study period[4]	3 May–27 Jul (Butano Creek); 27 Apr–29 Jul (control areas at Hidden Gulch and Dearborn Creek)
Sample sizes[5]	5 nests
Statistical analysis of results	None—n.a.
Statistical power	Not applicable
Document type	Unpublished report
Spatial scale(s)[6]	Watershed, Stand
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	None specified
Other habitat characteristics described	Distance to edge of stand, distance to disturbance, number of platforms, tree species, nest-limb height, nest material
Cause(s) of nest failure[7]	Of 5 nests, 1 definitely was taken by predator (raven), 1 appeared to have been abandoned because adult was believed to be killed by predator (Peregrine), and 3 appeared to be eggshell fragments presumably from eggs that had been taken by predators
Pertinent results, including statistical significance values and measures of variation[8]	(p. 15–17, Appendices 5 and 6) At South Fork of Butano Creek in 1994, eggshell fragments were found on forest floor beneath Coast Redwood (13 Jun) and Douglas Fir (24 Jul); nests were considered not to be active, so implication is that eggs had been taken by predators. In 2000, telemetry work found nest in Redwood in early Jun (exact date not specified); nest appeared to have been abandoned after radio-tagged bird was killed (they hypothesized Peregrine Falcon on 17 Jun); nest-tree climbed and unhatched egg found in it, plus eggshell fragments and bones believed to be from prior year's nesting. (p. 18–19) At Dearborn Creek, eggshell fragments found at nest in Douglas Fir on 9 Jun 1994; no active nest was found, and authors speculated that egg had been preyed upon before hatching. At Hidden Gulch, Common Raven flushed adult murrelet from nest in Douglas Fir and took off with egg on 28 Jun 1995.

Study Citation	Suddjian 2003
Potential sources of bias or error	None apparent
Effects modifiers[9]	Data are from CA, so comparability to OR may be questionable.
Additional notes	Detailed information on habitat presented in earlier reports

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.37

Study Citation	Waterhouse et al. 2008
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Sunshine Coast (Desolation Sound and Toba Inlet) and Clayoquot Sound, British Columbia
Study area habitat	Old-growth forest
Study design[1]	Both
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Telemetry, Aerial photography
Years of study	1998–2002
Within-year study period[4]	Not specified
Sample sizes[5]	118 nest sites across all three study areas
Statistical analysis of results	Parametric (list tests): ANOVA, logistic regression, AIC
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Study site
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	Large trees, meso-slope, vertical complexity, canopy complexity, habitat quality, tree height, vegetated cover
Other habitat characteristics described	None specified
Cause(s) of nest failure[7]	Information on nest fate (success and failure) inferred from "mid-chick rearing". No information provided on cause of nest failures.
Pertinent results, including statistical significance values and measures of variation[8]	Nest success and habitat variables: (Table 7) The study results found that 7 of 13 variables described sites more likely to be successful at mid-rearing stage. (p. 28) "Successful sites had significantly shorter trees and higher probabilities of Sporadic Large Trees; sites with taller trees and Prevalent Large Trees tended to fail (Table 7, Figures 5a and 5b). Success was more likely on Upper Meso-slopes and less likely on Mid Meso-slopes. Lower slopes showed no effect (Figure 5c). Successful nest sites also tended to be classified lower for Canopy Complexity, while nest sites with High Complexity more often failed (Figure 5d)." "At Desolation Sound only, successful nest sites had significantly higher Non-vegetated Cover than failed sites. This trend was similar for Toba Inlet, but appeared opposite for Clayoquot Sound (Figure 5e). For all study areas, successful nest sites also appeared more likely to have some vegetated cover in the plot (Figure 5f). Nest sites in Non-Uniform Vertically Complex stands more often failed, while those in Moderately Uniform and Uniform stands more often succeeded at the midrearing stage (Figure 5g). Few nest sites were classified as Uniform (n = 10), and of these, none failed."

Study Citation	Waterhouse et al. 2008
Pertinent results, including statistical significance values and measures of variation (continued)[8]	"For the combined study areas, overall Habitat Quality produced an unexpected result: success at midrearing was less probable at High Quality sites than at Moderate and Low Quality sites, and although trends were similar among study areas, differences were least detectable at Toba Inlet (Table 7, Figure 5h)." Possible interpretations of discrepancies between nest site selection and mid-chick rearing models: (p. 31) "…access into the stand and cover are more important predictors of nest success than platform availability. Therefore, of the range of nests sites used by murrelets, those with access and cover are more likely to succeed." (p. 32) "…forests at higher elevations and steeper locations will often have shorter trees (i.e., tree height is negatively correlated with elevation). Thus it is more likely that these sites would be classified as lower in habitat quality by air photo interpretation. But such sites may still contain more complex stand structure and larger trees relative to their topographic location and meet habitat needs of murrelets at the patch level." (p. 32) "…nest site selectivity may differ from productivity because murrelets are in an ecological trap—they select nest sites susceptible to failure owing to changes in external factors such as predators."
Potential sources of bias or error	Samples from different years were combined on the assumption that habitat selection at the scale tested was not detectably affected by potential inter-annual variation of other factors (e.g., forage and climate).
Effects modifiers[9]	Used radio-telemetry data for mid-rearing success during chick-phase to determine nest success. Used aerial photo interpretation to measure various habitat characteristics.
Additional notes	The nest sites used in this study were the same sample (or at least overlapped) as Bradley et al and Zharikov. Therefore use caution. However, the approach (i.e., photointerpretation), habitat variables/classes, and scales differed. The study focused on forests greater than 140 years old and a sample of 118 nest sites previously collected by telemetry methods from 1998 to 2002 in two regions in southern British Columbia: the Sunshine Coast and the west coast of Vancouver Island. (p. 21) "Nests were located by tracking of radio-mounted birds, from 1998 to 2001 on the Sunshine Coast, and from 2000 to 2002 on the west coast of Vancouver Island." Airphoto interpretation of habitat variables: Variables examined included the following: airphoto habitat quality index, forest cover (% >140 yrs old), vegetated cover, tree height, % large trees, canopy complexity, vertical complexity, large/small gaps, ranked crown closure, meso-slope (position of the plot on the slope within catchment area).

Study Citation	Waterhouse et al. 2008
Additional notes (continued)	(p. 21) "Nest samples from different years were combined on the assumption that habitat selection at the scale tested was not detectably affected by potential inter-annual variation of other factors (e.g., forage and climate)."

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.38

Study Citation	Witt 1998
Does the study specifically address the focal question?	No, but study contains relevant data
Study location (region/state or province)	Rader Creek drainage of the Coast Range Mountains, 34 km NW of Roseburg, Douglas Co., Oregon
Study area habitat	Douglas-fir & western hemlock
Study design[1]	Qualitative
Sampling design[2]	Anecdotal observations
Study methods[3]	Audio-visual, Climbing, Sampling plots
Years of study	1994
Within-year study period[4]	Unknown until 29 Aug
Sample sizes[5]	1 nest
Statistical analysis of results	None–n.a.
Statistical power	Not applicable
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Stand, Tree
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	None specified
Other habitat characteristics described	Aspect, elevation, slope, slope position, stand size, % composition low-elevation tree species, total tree density, canopy height, canopy layers, canopy closure, distance to coast, distance to stream, distance to nearest opening, stand age
Cause(s) of nest failure[7]	Fledged
Pertinent results, including statistical significance values and measures of variation[8]	(p. 29) Dominant canopy tree in stand (Table 2) Aspect: 90° Elevation: 183 m Slope: 19% Slope position: lower third Stand size: 440 ha % composition lower elevation trees: 100% Total tree density: 255/ha Canopy height: 66.4 m Number of canopy layers: 3 Canopy closure: 60% Distance to coast: 49 km Distance to stream: 20 m Distance to nearest opening: 200 m Stand age: >400 year

Study Citation	Witt 1998
Potential sources of bias or error	None apparent
Effects modifiers[9]	None apparent
Additional notes	Table 2 includes comparisons with Oregon nests reported in Hamer and Nelson 1995.

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.39

Study Citation	Zharikov et al. 2007
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Clayoquot Sound and Desolation Sound, British Columbia
Study area habitat	Old-growth coniferous forest. (western redcedar, western hemlock, Douglas fir, Sitka spruce.
Study design[1]	Quantitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Climbing, Telemetry
Years of study	1998–2001
Within-year study period[4]	Late Apr early Jun
Sample sizes[5]	137 nests (108 at Desolation Sound and 29 nests at Clayoquot Sound)
Statistical analysis of results	Parametric (list tests): Binary logistic regression, AIC, probability threshold-free receiver operating curves (ROC)
Statistical power	Not provided
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Watershed, Stand, Patch, 2–3 km radius sampling plots at nests
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	12 landscape metrics were grouped into four factors to test for the effects of habitat area, edge, landscape composition and old-growth habitat distribution and shape.
Other habitat characteristics described	None specified
Cause(s) of nest failure[7]	Information on nest fate (success and failure) inferred from "mid-chick rearing". No information provided on cause of nest failures.
Pertinent results, including statistical significance values and measures of variation[8]	Nest site habitat selection: (p. 754) “At Desolation Sound, Marbled Murrelets were more likely to nest in landscapes with a greater proximity of old-growth forest patches, higher artificial and natural old-growth edge density and contrast, and higher proportions of old-growth (or core) and logged habitat. The landscapes used were also characterized by higher interspersion of old-growth patches (among other land-cover classes) and smaller average old-growth patch size (as defined in this study; Table 4). These patterns suggested birds were overutilizing patchy forest and underutilizing the most extensively logged and remaining larger areas in this fragmented landscape. Birds were less likely to nest in landscapes with a higher proportion of ocean but, when nesting in the coastal zone, they selected landscapes with a higher than random density of natural edge (interaction term in model 2).”

Study Citation	Zharikov et al. 2007
Pertinent results, including statistical significance values and measures of variation (continued)[8]	(p. 755) "These models suggested that, at Clayoquot, murrelets nested in landscapes with higher than random proportions of young and old-growth forest, a greater proportion of core habitat and smaller average forest patch size. In used landscapes, the proportions of oldgrowth and young forest were independent, while in random landscapes there was a negative relationship between the two (interaction term model 1)." Nest success and habitat: (p. 755) "MRS was negatively associated with the total edge contrast index and the proportions of a landscape under ocean and young forest (Table 5)." The mean % (± SD) of young forest was 6.2 ± 6.6 at successful nests (n = 71 nests) an 11.2 ± 9.3 at failed nests (n = 36 nests). The mean % ocean was 3.2 ± 8.8 at successful nests and 6.7 ± 13.1 at failed nests. (p. 757) Murrelets "nested more successfully in landscapes with lower edge contrast and a lower proportion of landscape under young forest and outside the immediate coastal zone."
Potential sources of bias or error	Edge contrast correlated with distance from coast and elevation.
Effects modifiers[9]	Used radio-telemetry data for mid-rearing success during chick-phase to determine nest success.
Additional notes	Study questions relative to question of interest: (1) Are the choice of a nest site and the outcome of a nesting attempt predicted by the pattern of the surrounding landscape? (2) How do artificial and natural edges of the old-growth forest influence breeding distribution and success in the species? The study included Clayoquot Sound for nest site selection analyses but the sample of nests there was later determined too small for the MRS analysis so the Clayoquot Sound study area was not included in those analyses. GIS was used to create land-cover maps with nine different classes relating to murrelet habitat. Nesting areas were located using radio-telemetry and then nest locations were confirmed by ground crews where logistically possible. Due to the remote and difficult terrain many nests (76 out of 121) at Desolation and eight out of 36 at Clayoquot) could not be accessed from the ground. Thus, mid-rearing success (MRS) during the chick-rearing phase was used as a proxy for nest success/failure. The Clayoquot sample of 29 nests with known MRS outcome was considered too small for a meaningful test of the effects of landscape pattern on breeding success.

Study Citation	Zharikov et al. 2007
Additional notes (continued)	Analysis: (p. 753) "Breeding distribution and success were studied by comparing the distributions of used nest plots to random plots with unknown usage and successful to failed nests, respectively, using binary logistic regressions." "…12 individual landscape metrics were grouped into four factors to test for the effects of habitat area (HA), edge (EDGE), landscape composition (LC) and old-growth habitat distribution and shape (DS) (Tables 2 and 3). Ten preliminary candidate models (plus the null) assessing individual and combined effects of these four factors on breeding distribution and success were parameterized (Table 3)."

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Table A7.5.40

Study Citation	Zharikov et al. 2006
Does the study specifically address the focal question?	Yes
Study location (region/state or province)	Clayoquot Sound and Desolation Sound, British Columbia
Study area habitat	Old-growth coniferous forest. (western redcedar, western hemlock, Douglas fir, Sitka spruce.
Study design[1]	Quantitative
Sampling design[2]	Descriptive, designed to address question
Study methods[3]	Climbing, Telemetry
Years of study	Desolation Sound (1998–2001), Clayoquot Sound (2000–2002)
Within-year study period[4]	Late Apr early Jun
Sample sizes[5]	137 nests (108 at Desolation Sound and 29 nests at Clayoquot Sound)
Statistical analysis of results	Parametric (list tests): Generalized linear models, AIC
Statistical power	Not provided
Document type	Paper in peer-reviewed journal
Spatial scale(s)[6]	Study site, Patch
Natural or artificial nests?	Natural
Habitat characteristics compared in relation to nesting success	Distance to edge of stand
Other habitat characteristics described	Calculated forest patch area (nest and random) and measured distance of the nest/random forest patch to the following features: three hard-edge clearcuts, three fuzzy-edge clearcuts, logging road, stream, subalpine area, cliff, glacier, and ocean.
Cause(s) of nest failure[7]	Information on nest fate (success and failure) inferred from "mid-chick rearing". No information provided on cause of nest failures.
Pertinent results, including statistical significance values and measures of variation[8]	Nest site and habitat: (p. 113) At Desolation Sound "…models suggested that Marbled Murrelets nested closer to streams and hard-edge clearcuts, at lower elevations, on steeper slopes and farther from the glaciers than expected." At Clayoquot Sound "…birds nested closer to streams, hard-edge clearcuts and the seashore, on steeper slopes and farther from subalpine areas than expected." Nest success: (p. 114) "At Desolation Sound and Clayoquot Sound 71 (of 108) and 17 (of 29) nests survived through day the 20 of chick-rearing period respectively. The difference in MRS between the two locations was not significant (*p* = 0.48)."

Study Citation	Zharikov et al. 2006
Pertinent results, including statistical significance values and measures of variation (continued)[8]	Nest fate and habitat analyses: (p. 114) At Desolation Sound "…successful breeders nested earlier in the season, closer to hard-edge clearcuts, farther from fuzzy-edge clearcuts and closer to subalpine areas than unsuccessful breeders." At Clayoquot Sound "…At Clayoquot Sound, none of the eight predictors participating in the Desolation Sound breeding success models…differed significantly between the active and failed treatment groups…." Conclusions on correlates of nest success: (p. 117) "Our results suggest a positive correlation between MRS and forest fragmentation, again implying that fragmentation itself does not immediately devalue the nesting habitat of these birds or, perhaps, that they respond adaptively to logging in their environment." (p. 118) "Breeding success was likely driven by distribution patterns of potential nest predators, which themselves could be responding to local landscape characteristics (clearcuts and elevation). Marbled Murrelets did not respond to habitat fragmentation by either selecting for larger patches or avoiding recent clearcuts. Our results imply that Marbled Murrelets can continue nesting in highly fragmented old-growth forests, successfully using patches ≥10 ha. However, we caution that breeding success in such areas may decrease as adjacent clearcuts overgrow."
Potential sources of bias or error	None apparent
Effects modifiers[9]	Used radio-telemetry data for mid-rearing success during chick-phase to determine nest success.
Additional notes	Used radio-telemetry to locate nesting areas. (p. 110) Not all nests could be monitored through day 20 of chick-rearing, restricting MRS (mid-rearing success) analyses to 108 nests. At Clayoquot Sound, MRS data were available for 29 nests. Thus, breeding success was modelled only for Desolation Sound; one-way ANOVAs with sequential Bonferroni corrections were applied to the Clayoquot Sound sample since it was too small for modelling." Landscapes were defined as "convex polygons encompassing the distribution of all nest sites in each area with an external buffer (2.3 km, Desolation Sound; 3.1 km, Clayoquot Sound), representing the mean annual nearest-nest distance. Landscapes defined in this way accounted for the distribution of individuals and are assumed to represent available terrestrial environment for the populations."

Study Citation	Zharikov et al. 2006
Additional notes (continued)	Landscape features were defined as "spatially explicit elements of the environment, mapped in a GIS as polygons or polylines, representing geomorphological, vegetative and hydrological phenomena hypothesized to be relevant to habitat selection and breeding success of Marbled Murrelets." Habitat variables: (p. 111) "We placed 1000 (DS) and 350 (CS) random points within the old growth stratum of a landscape. We recorded forest patch area (PA, ha) for each nest and random site and measured Euclidean distance (to 0.01 km) to the nearest edge of the following features: (1) the nest/random site forest patch (PED), (2) three hardedge clearcuts (HEC), (3) three fuzzy-edge clearcuts (FEC), (4) logging road (RD), (5) stream (STR), (6) subalpine area (SA), (7) cliff (CL), (8) glacier (GL) and (9) ocean (OC). Point-to-edge distances for the three nearest features (2) and (3) were measured to account for a possible density effect of logging operations on the birds." "To test for possible altitudinal and topographic effects, elevation above sea level (to 10 m, EL) and slope (to 1°, SL) indices (and their quadratic terms) were derived for nest and random sites from a 25 × 25 m Digital Elevation Map…"

1 Brief description of study design (e.g., qualitative, quantitative).
2 Anecdotal, descriptive, or experimental, control groups, replicates.
3 Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
4 How often were data collected within a season?
5 Number of birds, nests, sites, replicates, visits.
6 Watershed, forest stand, survey site, patch, tree.
7 Predation (list predators if known), abandonment, etc.
8 List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
9 List potential factors that may have affected results and comparability relative to other studies.

Appendix 8—Relevance/Confidence Tables

Appendix 8.1. Scores of relevance and confidence factors for Question 1: "How are individual behaviors (subcanopy flight, circling, landing, vocalizations) of Marbled Murrelets indicative of nesting in the forest stand where those behaviors occur?"

	Relevance			Confidence									
Study	Study objectives	Nest habitat	Study design	Sampling design	Study methods	Statistically robust	Statistical power	Study duration (years)	Study duration (season)	Sample size	Spatial coverage	Document type	Study Evaluation Score (% of maximum possible)
Dechesne and Smith 1997	0	1	0	0	4	1	1	1	2	1	1	0	12 (31%)
Hamer and Cummins 1990	0	2	0	0	4	1	1	0	2	5	1	0	16 (41%)
Jones 2001	0	1	0	1	4	1	1	3	2	1	1	0	15 (38%)
Lougheed et al. 1998	2	1	0	1	4	1	1	0	2	3	1	2	18 (46%)
Manley and Kelson 1995	0	1	0	0	4	1	1	1	2	1	1	2	14 (36%)
Manley 1999	2	1	3	1	4	1	1	3	2	3	1	2	23 (59%)
Naslund 1993	2	1	3	1	4	1	1	1	2	1	1	2	20 (51%)
Nelson and Hardin 1993	2	2	0	1	4	1	1	0	0	1	1	0	13 (33%)
Nelson and Peck 1995	2	2	0	1	4	1	1	3	2	3	1	2	22 (56%)
Nelson and Wilson 2002	2	2	3	1	4	1	1	3	2	5	1	0	25 (64%)
Nelson et al. 1994	2	2	3	1	4	1	1	0	2	3	1	0	20 (51%)
Singer et al. 1991	0	1	3	1	4	1	1	0	2	1	1	2	17 (44%)
Singer et al. 1995	0	1	3	1	4	1	1	3	2	1	1	2	20 (51%)
Suddjian 2003	0	1	0	0	4	1	1	3	2	5	1	0	18 (46%)
Varoujean et al. 1989	0	2	3	0	4	1	1	0	1	0	1	2	15 (38%)
Witt 1998	2	2	3	1	4	1	1	0	2	0	1	2	19 (49%)
Maximum possible score	***2***	***2***	***3***	***4***	***4***	***5***	***4***	***3***	***2***	***5***	***3***	***2***	***39***

Relevance Rating Factors:

Study objectives: Was the study designed to address specifically the primary review question? (Scoring: 0 = no, but study contains relevant data; 2 = Yes).

Nest habitat: How similar is the nesting habitat (i.e., forest structure and composition) to that found in Oregon? (Scoring: 0 = not similar [treeless or lacking trees with platforms]; 1 = forested habitat in Alaska, British Columbia, and/or California; 2 = forested habitat in Oregon and/or Washington).

Confidence Rating Factors:

Study design: Was overall nature of the study qualitative (score = 0) or quantitative (score = 3) in regard to the review question?

Sampling design: What was the sampling design as it pertains to the question of interest? (Scoring: 0 = anecdotal or peripheral observations; 1 = descriptive study without control groups, 2 = descriptive study with control/reference groups OR experimental study without replicates OR control groups; 3 = experimental study with replicates OR control groups; 4 = experimental study with replicated sampling AND control groups).

Study methods: Were the study methods (e.g., audiovisual, radar, telemetry) appropriate for the question of interest? (Scoring: 0 = no; 1 = unknown; 4 = yes).

Statistically robust: Were the statistical analyses that were conducted appropriate to address the objectives and the data collected? (Scoring: 0 = no; 1 = not applicable [i.e., for a descriptive study]; 5 = yes).

Statistical power: Did the study have adequate power to detect significant differences if they occurred? (Scoring: 0 = no [power < 0.8]; 1 = not applicable or unknown; 4 = yes [power ≥ 0.8]).

Study duration: How many years was the study conducted? (Scoring: 0 = 1 year, 1 = 2 years, 3 = ≥3 years).

Within-season study duration: Were study efforts within seasons sufficient for the question of interest? (Scoring: 0 = no, sampling insufficient for seasonal variation; 1 = unknown or not applicable; 2 = yes).

Sample size: How large was/were the sample size(s) of interest (e.g., number of nests, number of flight behaviors; number of sites)? (Scoring: 0 = single [1]; 1 = small [2–9]; 3 = medium [10-29]; 5 = large ≥30]).

Spatial coverage: What was the relative spatial extent of data collection within each study area? (Scoring: 0 = low—included <25% of focal watershed, stand, site, etc.; 1 = unknown or not applicable; 2 = medium—included 25–75% of focal watershed, stand, site, etc.; 3 = high -- included >75% of focal watershed, stand, site, etc.).

Document type: Was the study document peer-reviewed? (Scoring: 0 = no [i.e., unpublished reports, articles in non-peer-reviewed serials, or manuscripts in review]; 2 = yes [i.e., published articles, agency reports, Ph.D. or M.S. theses, or manuscripts in press that have undergone peer review]).

Appendix 8.2. Scores of relevance and confidence factors for Question 2: "To what extent do Marbled Murrelets exhibit nest-site fidelity at various spatial scales (i.e., at the scale of a watershed, forest stand, tree, branch, and platform), and how does the spatial extent of continuous potential habitat affect nest-site fidelity?"

	Relevance			Confidence										
Study	Study objectives	Nest habitat	Continuous habitat	Study design	Sampling design	Study methods	Statistically robust	Statistical power	Study duration (years)	Study duration (season)	Sample size	Spatial coverage	Document type	Study Evaluation Score (% of maximum possible)
Barbaree et al. 2014	0	1	3	0	1	4	1	1	1	2	1	3	2	20 (48%)
Bloxton and Raphael 2009	0	2	0	0	0	4	1	1	3	2	0	1	0	14 (33%)
Burger 1994	0	1	2	0	1	4	1	1	3	2	1	0	0	16 (38%)
Burger et al. 2000	0	1	3	0	0	4	1	1	1	2	0	1	0	14 (33%)
Burger et al. 2009	2	1	2	0	1	4	1	1	3	2	5	1	2	25 (60%)
Conroy et al. 2002	0	1	0	0	0	4	1	1	3	2	1	3	2	18 (43%)
Divoky and Horton 1995	0	0	0	0	1	4	1	1	3	1	3	1	2	17 (40%)
Drever et al. 1998	0	1	3	0	0	4	1	1	3	2	1	3	0	19 (45%)
Golightly and Schneider 2011	0	1	0	0	0	4	1	1	3	2	0	1	0	13 (31%)
Hébert and Golightly 2006	2	1	0	0	1	4	1	1	3	2	3	1	0	19 (45%)
Hébert et al. 2003	0	1	0	0	1	4	1	1	1	2	1	1	2	15 (36%)
Hirsch et al. 1981	0	0	0	0	0	4	1	1	1	2	0	1	2	12 (29%)
Jones 2001	0	1	2	0	0	4	1	1	3	2	0	1	0	15 (36%)
Lougheed et al. 1998	0	1	0	0	1	4	1	1	3	2	3	1	0	17 (40%)
Manley 1999	0	1	0	0	1	4	1	1	3	2	5	1	2	21 (50%)
Manley 2003	0	1	2	0	1	4	1	1	3	1	1	1	0	16 (38%)
Meekins and Hamer 1999	0	2	0	0	0	4	1	1	3	2	3	1	0	17 (40%)
Naslund et al. 1995	0	1	2	0	1	4	1	1	1	2	1	1	2	17 (40%)
Nelson and Peck 1995	0	2	0	0	0	4	1	1	3	1	1	1	2	16 (38%)
Nelson and Wilson 2002	0	2	2	0	0	4	1	1	3	2	3	1	0	19 (45%)
Ryder et al. 2012	0	1	0	0	0	4	1	1	0	0	0	1	2	10 (24%)
Singer et al. 1995	0	1	3	0	0	4	1	1	3	2	1	3	2	21 (50%)
Spickler and Sillett 1998	2	1	0	0	0	4	1	1	0	1	0	1	0	11 (26%)
Maximum scores	2	2	3	3	4	4	5	4	3	2	5	3	2	42

<u>Relevance Rating Factors:</u>

Study objectives: Was the study designed to address specifically the primary review question? (Scoring: 0 = no, but study contains relevant data; 2 = Yes).

Nest habitat: How similar is the nesting habitat (i.e., forest structure and composition) to that found in Oregon? (Scoring: 0 = not similar [treeless or lacking trees with platforms]; 1 = forested habitat in Alaska, British Columbia, and/or California; 2 = forested habitat in Oregon and/or Washington).

Continuous habitat: Are blocks of continuous habitat defined in the study areas? (Scoring: 0 = no; 2 = yes, but continuity undefined; 3 = yes, with continuity defined).

<u>Confidence Rating Factors:</u>

Study design: Was overall nature of the study qualitative (score = 0) or quantitative (score = 3) in regard to the review question?

Sampling design: What was the sampling design as it pertains to the question of interest? (Scoring: 0 = anecdotal or peripheral observations; 1 = descriptive study without control groups, 2 = descriptive study with control/reference groups OR experimental study without replicates OR control groups; 3 = experimental study with replicates OR control groups; 4 = experimental study with replicated sampling AND control groups).

Study methods: Were the study methods (e.g., audiovisual, radar, telemetry) appropriate for the question of interest? (Scoring: 0 = no; 1 = unknown; 4 = yes).

Statistically robust: Were the statistical analyses that were conducted appropriate to address the objectives and the data collected? (Scoring: 0 = no; 1 = not applicable [i.e., for a descriptive study]; 5 = yes).

Statistical power: Did the study have adequate power to detect significant differences if they occurred? (Scoring: 0 = no [power < 0.8]; 1 = not applicable or unknown; 4 = yes [power ≥ 0.8]).

Study duration: How many years was the study conducted? (Scoring: 0 = 1 year, 1 = 2 years, 3 = ≥3 years).

Within-season study duration: Were study efforts within seasons sufficient for the question of interest? (Scoring: 0 = no, sampling insufficient for seasonal variation; 1 = unknown or not applicable; 2 = yes).

Sample size: How large was/were the sample size(s) of interest (e.g., number of nests, number of flight behaviors; number of sites)? (Scoring: 0 = single [1]; 1 = small [2–9]; 3 = medium [10-29]; 5 = large ≥30]).

Spatial coverage: What was the relative spatial extent of data collection within each study area? (Scoring: 0 = low—included <25% of focal watershed, stand, site, etc.; 1 = unknown or not applicable; 2 = medium -- included 25-75% of focal watershed, stand, site, etc.; 3 = high—included >75% of focal watershed, stand, site, etc.).

Document type: Was the study document peer-reviewed? (Scoring: 0 = no [i.e., unpublished reports, articles in non-peer-reviewed serials, or manuscripts in review]; 2 = yes [i.e., published articles, agency reports, Ph.D. or M.S. theses, or manuscripts in press that have undergone peer review]).

Appendix 8.3. Scores of relevance and confidence factors for Question 3: "How does the spatial extent of continuous potential habitat relate to the co-occurrence (i.e., nesting by multiple pairs) of murrelets in a forest stand and at other spatial scales?"

	Relevance			Confidence										
Study	Study objectives	Nest habitat	Continuous habitat	Study design	Sampling design	Study methods	Statistically robust	Statistical power	Study duration (years)	Study duration (season)	Sample size	Spatial coverage	Document type	Study Evaluation Score (% of maximum possible)
Bloxton and Raphael 2009	0	2	0	0	1	4	1	1	3	2	3	3	0	20 (48%)
Burger 1994	0	1	2	0	0	4	1	1	3	1	1	2	0	16 (38%)
Carter and Sealy 1987	0	2	0	0	0	0	1	1	3	1	1	1	2	12 (29%)
Hamer and Cummins 1990	0	2	2	0	1	4	1	1	0	2	1	1	0	15 (36%)
Hull et al. 2001	0	1	0	0	0	4	1	1	0	2	3	1	2	15 (36%)
Kuletz et al. 1995	0	1	0	0	1	4	1	1	0	2	1	1	2	14 (33%)
Manley 1999	2	1	2	3	1	4	1	1	3	2	5	1	2	28 (67%)
Naslund et al. 1995	2	1	3	3	1	4	1	1	1	2	3	1	2	25 (60%)
Nelson and Peck 1995	0	2	0	0	0	4	1	1	3	1	1	1	2	16 (38%)
Nelson and Wilson 2002	2	2	0	3	3	4	1	1	3	2	5	2	0	28 (67%)
Ryder et al. 2012	0	1	0	0	0	4	1	1	0	1	1	1	2	12 (29%)
Suddjian 2003	0	1	0	0	1	4	1	1	3	2	3	1	0	17 (40%)
Waterhouse et al. 2011	0	1	2	0	0	4	1	1	1	2	3	3	2	20 (48%)
Zharikov et al. 2007	2	1	2	3	0	4	5	1	3	2	5	1	2	31 (74%)
Maximum scores	2	2	3	3	4	4	5	4	3	2	5	3	2	42

Relevance Rating Factors:

Study objectives: Was the study designed to address specifically the primary review question? (Scoring: 0 = no, but study contains relevant data; 2 = Yes).

Nest habitat: How similar is the nesting habitat (i.e., forest structure and composition) to that found in Oregon? (Scoring: 0 = not similar [treeless or lacking trees with platforms]; 1 = forested habitat in Alaska, British Columbia, and/or California; 2 = forested habitat in Oregon and/or Washington).

Continuous habitat: Are blocks of continuous habitat defined in the study areas? (Scoring: 0 = no; 2 = yes, but continuity undefined; 3 = yes, with continuity defined).

Confidence Rating Factors:

Study design: Was overall nature of the study qualitative (score = 0) or quantitative (score = 3) in regard to the review question?

Sampling design: What was the sampling design as it pertains to the question of interest? (Scoring: 0 = anecdotal or peripheral observations; 1 = descriptive study without control groups, 2 = descriptive study with control/reference groups OR experimental study without replicates OR control groups; 3 = experimental study with replicates OR control groups; 4 = experimental study with replicated sampling AND control groups).

Study methods: Were the study methods (e.g., audiovisual, radar, telemetry) appropriate for the question of interest? (Scoring: 0 = no; 1 = unknown; 4 = yes).

Statistically robust: Were the statistical analyses that were conducted appropriate to address the objectives and the data collected? (Scoring: 0 = no; 1 = not applicable [i.e., for a descriptive study]; 5 = yes).

Statistical power: Did the study have adequate power to detect significant differences if they occurred? (Scoring: 0 = no [power < 0.8]; 1 = not applicable or unknown; 4 = yes [power ≥ 0.8]).

Study duration: How many years was the study conducted? (Scoring: 0 = 1 year, 1 = 2 years, 3 = ≥3 years).

Within-season study duration: Were study efforts within seasons sufficient for the question of interest? (Scoring: 0 = no, sampling insufficient for seasonal variation; 1 = unknown or not applicable; 2 = yes).

Sample size: How large was/were the sample size(s) of interest (e.g., number of nests, number of flight behaviors; number of sites)? (Scoring: 0 = single [1]; 1 = small [2–9]; 3 = medium [10-29]; 5 = large ≥30]).

Spatial coverage: What was the relative spatial extent of data collection within each study area? (Scoring: 0 = low—included <25% of focal watershed, stand, site, etc.; 1 = unknown or not applicable; 2 = medium -- included 25-75% of focal watershed, stand, site, etc.; 3 = high—included >75% of focal watershed, stand, site, etc.).

Document type: Was the study document peer-reviewed? (Scoring: 0 = no [i.e., unpublished reports, articles in non-peer-reviewed serials, or manuscripts in review]; 2 = yes [i.e., published articles, agency reports, Ph.D. or M.S. theses, or manuscripts in press that have undergone peer review]).

Appendix 8.4. Scores of relevance and confidence factors for Question 4: "How is the occurrence of Marbled Murrelet nest sites related to the number and size of potential nest platforms and platform tree density within stands of different age classes (young, mature, and old growth)?"

	Relevance			Confidence									
Study	Study objectives	Nest habitat	Study design	Sampling design	Study methods	Statistically robust	Statistical power	Study duration (years)	Study duration (season)	Sample size	Spatial coverage	Document type	Study Evaluation Score (% of maximum possible)
Baker et al. 2006	2	1	3	2	4	5	0	3	1	3	1	2	27 (75%)
Bradley and Cooke 2001	2	1	3	2	4	1	1	1	1	0	1	2	19 (53%)
Burger 1994	0	1	3	1	4	1	1	3	1	0	1	0	16 (44%)
Burger and Bahn 2001	0	1	3	2	4	5	0	3	1	1	1	0	21 (58%)
Burger et al. 2000	2	1	3	1	4	1	1	1	1	1	1	0	17 (47%)
Conroy et al. 2002	2	1	3	2	4	5	0	1	1	1	1	2	23 (64%)
Dechesne and Smith 1997	0	1	3	0	1	1	1	0	1	0	1	0	9 (25%)
Ford and Brown 1995	0	0	3	0	4	1	1	0	1	0	1	2	13 (36%)
Golightly and Schneider 2009	0	1	3	0	4	1	1	3	1	0	1	0	15 (42%)
Golightly et al. 2009	2	1	3	2	4	5	0	3	1	3	1	0	25 (69%)
Grenier and Nelson 1995	2	2	3	3	4	5	0	3	1	3	1	2	29 (81%)
Hamer and Nelson 1995	2	2	3	1	4	1	1	3	1	5	1	2	26 (72%)
Jordan et al. 1997	0	1	3	0	4	1	1	0	1	0	1	0	12 (33%)
Manley 1999	2	1	3	1	4	5	1	3	1	5	1	2	29 (81%)
Manley 2003	2	1	3	1	4	1	1	3	1	5	1	0	23 (64%)
Manley et al. 2001	2	1	3	2	4	1	1	0	1	1	1	0	17 (47%)
Meekins and Hamer 1999	2	2	3	4	4	5	0	3	1	3	1	0	28 (78%)
Naslund et al. 1995	2	1	3	4	4	5	0	1	1	3	1	2	27 (75%)
Nelson and Wilson 2002	2	2	3	4	4	5	4	3	1	5	1	0	34 (94%)
Quinlan and Hughes 1990	0	1	3	1	4	1	1	0	1	0	1	2	15 (42%)
Silvergieter and Lank 2011a	2	1	3	4	4	5	0	3	1	5	1	2	31 (86%)
Silvergieter and Lank 2011b	2	1	3	4	4	5	1	3	1	5	1	2	32 (89%)
Waterhouse et al. 2007	0	1	3	4	4	5	0	0	1	1	1	2	22 (61%)
Waterhouse et al. 2009	2	1	3	4	4	5	1	3	1	5	1	2	32 (89%)
Witt 1998	0	2	3	1	4	1	1	0	1	0	1	2	16 (44%)
Maximum scores	***2***	***2***	***3***	***4***	***4***	***5***	***4***	***3***	***1***	***5***	***1***	***2***	***36***

Relevance Rating Factors:

Study objectives: Was the study designed to address specifically the primary review question? (Scoring: 0 = no, but study contains relevant data; 2 = Yes).

Nest habitat: How similar is the nesting habitat (i.e., forest structure and composition) to that found in Oregon? (Scoring: 0 = not similar [treeless or lacking trees with platforms]; 1 = forested habitat in Alaska, British Columbia, and/or California; 2 = forested habitat in Oregon and/or Washington).

Confidence Rating Factors:

Study design: Was overall nature of the study qualitative (score = 0) or quantitative (score = 3) in regard to the review question?

Sampling design: What was the sampling design as it pertains to the question of interest? (Scoring: 0 = anecdotal or peripheral observations; 1 = descriptive study without control groups, 2 = descriptive study with control/reference groups OR experimental study without replicates OR control groups; 3 = experimental study with replicates OR control groups; 4 = experimental study with replicated sampling AND control groups).

Study methods: Were the study methods (e.g., audiovisual, radar, telemetry) appropriate for the question of interest? (Scoring: 0 = no; 1 = unknown; 4 = yes).

Statistically robust: Were the statistical analyses that were conducted appropriate to address the objectives and the data collected? (Scoring: 0 = no; 1 = not applicable [i.e., for a descriptive study]; 5 = yes).

Statistical power: Did the study have adequate power to detect significant differences if they occurred? (Scoring: 0 = no [power < 0.8]; 1 = not applicable or unknown; 4 = yes [power ≥ 0.8]).

Study duration: How many years was the study conducted? (Scoring: 0 = 1 year, 1 = 2 years, 3 = ≥3 years).

Within-season study duration: Were study efforts within seasons sufficient for the question of interest? (Scoring: 0 = no, sampling insufficient for seasonal variation; 1 = unknown or not applicable; 2 = yes). Note: not applicable for Question 4.

Sample size: How large was/were the sample size(s) of interest (e.g., number of nests, number of flight behaviors; number of sites)? (Scoring: 0 = single [1]; 1 = small [2–9]; 3 = medium [10-29]; 5 = large ≥30]).

Spatial coverage: What was the relative spatial extent of data collection within each study area? (Scoring: 0 = low—included <25% of focal watershed, stand, site, etc.; 1 = unknown or not applicable; 2 = medium—included 25-75% of focal watershed, stand, site, etc.; 3 = high -- included >75% of focal watershed, stand, site, etc.). Note: not applicable for Question 4.

Document type: Was the study document peer-reviewed? (Scoring: 0 = no [i.e., unpublished reports, articles in non-peer-reviewed serials, or manuscripts in review]; 2 = yes [i.e., published articles, agency reports, Ph.D. or M.S. theses, or manuscripts in press that have undergone peer review]).

Appendix 8.5. Scores of relevance and confidence factors for Question 5: "How is Marbled Murrelet nesting success affected by habitat characteristics?"

	Relevance			Confidence										
Study	Study objectives	Nest habitat	Nests	Study design	Sampling design	Study methods	Statistically robust	Statistical power	Study duration (years)	Study duration (season)	Sample size	Spatial coverage	Document type	Study Evaluation Score (% of maximum possible)
Barbaree et al. 2014	0	1	2	0	1	4	1	1	1	2	5	3	2	23 (55%)
Becking 1991	0	1	2	0	0	4	1	1	0	1	0	0	2	12 (29%)
Bloxton and Raphael 2009	2	2	2	3	1	4	1	1	3	1	3	1	0	24 (57%)
Bradley 2002	2	1	2	3	1	4	5	0	3	2	5	1	2	31 (74%)
Bradley and Cooke 2001	0	1	2	0	0	4	1	1	1	2	1	1	2	16 (38%)
Burger 1994	0	1	2	0	0	4	1	1	3	2	1	0	0	15 (36%)
Burger et al. 2000	0	1	2	0	0	4	1	1	1	2	1	1	0	14 (33%)
Burger et al. 2004	2	1	0	3	4	4	5	4	3	2	5	1	2	36 (86%)
Drever et al. 1998	0	1	2	0	1	4	5	1	0	2	5	1	0	22 (52%)
Ford and Brown 1995	0	1	2	0	0	4	1	1	0	1	0	1	2	13 (31%)
Golightly et al. 2009	2	1	2	3	2	4	5	0	3	1	3	1	0	27 (64%)
Hamer and Cummins 1991	0	2	2	0	0	4	1	1	1	2	1	1	0	15 (36%)
Hirsch et al. 1981	0	0	2	0	0	4	1	1	1	2	0	1	2	14 (33%)
Hull et al. 2001	2	1	2	3	1	4	5	0	0	2	3	1	2	26 (62%)
Jones 2001	0	1	2	0	0	4	1	1	3	2	1	1	0	16 (38%)
Kerns and Miller 1995	0	1	2	3	1	4	1	1	0	2	0	1	2	18 (43%)
Kuletz et al. 1994	0	0	2	0	0	4	1	1	0	1	0	1	0	10 (24%)
Luginbuhl et al. 2001	2	2	0	3	3	4	5	0	3	1	5	1	2	31 (74%)
Malt and Lank 2007	2	1	0	3	3	4	5	0	1	2	5	0	2	28 (67%)
Manley 1999	2	1	2	3	2	4	5	0	3	2	5	1	0	30 (71%)
Manley 2003	0	1	2	3	4	4	5	0	3	2	5	1	2	32 (76%)
Manley et al. 2001	2	1	2	0	1	4	1	1	0	2	1	1	0	16 (38%)
Marks and Naslund 1994	0	1	2	0	0	4	1	1	0	1	0	1	2	13 (31%)
Marzluff and Neatherlin 2006	2	2	0	3	3	4	5	0	3	1	5	1	2	31 (74%)
Marzluff et al. 1999	2	2	0	3	3	4	5	0	1	1	5	1	0	27 (64%)
Naslund et al. 1995	0	1	2	0	1	4	1	1	1	2	1	1	2	17 (40%)
Nelson 1992	0	2	2	3	1	4	1	0	0	2	1	1	0	17 (40%)

Appendix 8.5. Continued.

Study	Relevance: Study objectives	Relevance: Nest habitat	Relevance: Nests	Confidence: Study design	Confidence: Sampling design	Confidence: Study methods	Confidence: Statistically robust	Confidence: Statistical power	Confidence: Study duration (years)	Confidence: Study duration (season)	Confidence: Sample size	Confidence: Spatial coverage	Document type	Study Evaluation Score (% of maximum possible)
Nelson and Hamer 1995b	2	2	2	3	2	4	5	4	3	1	5	1	2	36 (86%)
Nelson and Hardin 1993	0	2	2	0	0	4	1	1	0	2	1	1	0	14 (33%)
Nelson and Peck 1995	0	2	2	0	1	4	1	1	3	1	1	1	2	19 (45%)
Nelson and Wilson 2002	0	2	2	0	1	4	1	1	3	2	3	1	0	20 (48%)
Raphael et al. 2002	2	2	0	3	3	4	5	0	3	1	5	1	2	31 (74%)
Silvergieter 2009	2	1	2	3	1	4	5	0	3	2	5	1	2	31 (74%)
Singer et al. 1991	0	1	2	0	0	4	1	1	0	1	1	1	2	14 (33%)
Singer et al. 1995	0	1	2	0	0	4	1	1	3	2	1	3	2	20 (48%)
Suddjian 2003	0	1	2	0	0	4	1	1	3	2	1	2	0	17 (40%)
Waterhouse et al. 2008	2	1	2	3	1	4	5	0	3	2	5	1	2	31 (74%)
Witt 1998	0	2	2	3	1	4	1	1	0	1	0	1	2	18 (43%)
Zharikov et al. 2007	2	1	2	3	1	4	5	0	3	2	5	1	2	31 (74%)
Zharikov et al. 2006	2	1	2	3	3	4	5	0	3	2	5	1	2	33 (79%)
Maximum scores	***2***	***2***	***3***	***3***	***4***	***4***	***5***	***4***	***3***	***2***	***5***	***3***	***2***	***42***

Relevance Rating Factors:

Study objectives: Was the study designed to address specifically the primary review question? (Scoring: 0 = no, but study contains relevant data; 2 = Yes).

Nest habitat: How similar is the nesting habitat (i.e., forest structure and composition) to that found in Oregon? (Scoring: 0 = not similar [treeless or lacking trees with platforms]; 1 = forested habitat in Alaska, British Columbia, and/or California; 2 = forested habitat in Oregon and/or Washington).

Nests: Does the study include data on real or artificial Marbled Murrelet nests? (Scoring: 0 = artificial murrelet nests/eggs/young only; 2 = includes real Marbled Murrelet nests).

Confidence Rating Factors:

Study design: Was overall nature of the study qualitative (score = 0) or quantitative (score = 3) in regard to the review question?

Sampling design: What was the sampling design as it pertains to the question of interest? (Scoring: 0 = anecdotal or peripheral observations; 1 = descriptive study without control groups, 2 = descriptive study with control/reference groups OR experimental study without replicates OR control groups; 3 = experimental study with replicates OR control groups; 4 = experimental study with replicated sampling AND control groups).

Study methods: Were the study methods (e.g., audiovisual, radar, telemetry) appropriate for the question of interest? (Scoring: 0 = no; 1 = unknown; 4 = yes).

Statistically robust: Were the statistical analyses that were conducted appropriate to address the objectives and the data collected? (Scoring: 0 = no; 1 = not applicable [i.e., for a descriptive study]; 5 = yes).

Statistical power: Did the study have adequate power to detect significant differences if they occurred? (Scoring: 0 = no [power <0.8]; 1 = not applicable or unknown; 4 = yes [power ≥0.8]).

Study duration: How many years was the study conducted? (Scoring: 0 = 1 year, 1 = 2 years, 3 = ≥3 years).

Within-season study duration: Were study efforts within seasons sufficient for the question of interest? (Scoring: 0 = no, sampling insufficient for seasonal variation; 1 = unknown or not applicable; 2 = yes).

Sample size: How large was/were the sample size(s) of interest (e.g., number of nests, number of flight behaviors; number of sites)? (Scoring: 0 = single [1]; 1 = small [2–9]; 3 = medium [10-29]; 5 = large ≥30]).

Spatial coverage: What was the relative spatial extent of data collection within each study area? (Scoring: 0 = low—included <25% of focal watershed, stand, site, etc.; 1 = unknown or not applicable; 2 = medium—included 25-75% of focal watershed, stand, site, etc.; 3 = high -- included >75% of focal watershed, stand, site, etc.).

Document type: Was the study document peer-reviewed? (Scoring: 0 = no [i.e., unpublished reports, articles in non-peer-reviewed serials, or manuscripts in review]; 2 = yes [i.e., published articles, agency reports, Ph.D. or M.S. theses, or manuscripts in press that have undergone peer review]).

Appendix 9
Protocol for Marbled Murrelet Systematic Review—August 2014 Final Draft

PROTOCOL FOR MARBLED MURRELET SYSTEMATIC REVIEW

FINAL

Prepared for

Oregon Department of Forestry

2600 State Street, Bldg. C
Salem, OR 97310

Prepared by

ABR, Inc. —Environmental Research & Services
P.O. Box 249
Forest Grove, Oregon 97116

August 2014

Introduction

Background

The Marbled Murrelet (*Brachyramphus marmoratus*) is a small seabird that nests in large coniferous trees of coastal forests throughout most of its range in North America (Nelson 1997). In 1992, the Washington, Oregon, and California population of the Marbled Murrelet was federally listed as a Threatened Species (USFWS 1992, 1997), requiring that landowners take measures to “avoid take” of the species or develop programmatic approaches to listed species management that may include application for “incidental take” permits. Murrelets are present in some Oregon State Forests (i.e., in the Clatsop, Tillamook, and Elliott State Forests), where they presently are managed by the Oregon Department of Forestry’s (ODF's) State Forests Division under a “take avoidance approach,” as outlined in Oregon’s Marbled Murrelet Operational Policies.

This management approach relies heavily, although not exclusively, on the Pacific Seabird Group’s (PSG’s) “Methods for surveying Marbled Murrelets in forests: a revised protocol for land management and research” (“PSG protocol;” Evans Mack et al. 2003) for designating forest stands as occupied by murrelets. The PSG protocol provides standardized techniques for detecting murrelets in forests while partially accounting for imperfect detection. The document also identifies procedures for delineating potential murrelet nesting habitat and classifying survey areas based on results of audio-visual surveys designed to detect birds in flight near nesting areas. Survey data are used to classify survey sites and areas as having “probable absence” of murrelets, “presence” of murrelets flying over the area, or “occupancy” by nesting birds, based on observed flight behaviors (p. 22 of PSG protocol). The 2003 revised protocol has undergone updates over the past several years, and plans are underway to develop a revised protocol.

The State Forests Division is sponsoring this science assessment. The project employs methods similar to those used in Systematic Evidence Reviews (also known as Systematic Review [SR]) to assess the amount, strength, and relevance of the science related to several central elements of the PSG protocol and to a question that will inform the evolution of Marbled Murrelet protection measures. The methodology for conducting this review largely will follow that established for

SR's (CEE 2013); however this review differs from standard SR's in that it will explore the amount, strength, and relevance of evidence related to several hypotheses regarding Marbled Murrelet ecology, rather than develop and address questions directly related to a management intervention.

The Division expects to use the results of the Marbled Murrelet review in the following ways:

1. to inform the ongoing development and revisions to murrelet survey protocols;
2. to inform longer term Division policies, plans and strategies for murrelet protection;
3. to develop and refine research and monitoring questions ;
4. to inform ODF interactions with other agencies, professional organizations, and other interested parties;
5. to further learn about the SR method, and if/how it may be applied to other topics.

The resulting assessment should be a transparent, objective science review. ODF expects that it will help better differentiate questions of science from value and policy questions. The final contract products will not include any policy recommendations.

Systematic Review Protocol

A Systematic Review is a rigorous, transparent, and repeatable process that differs from traditional literature reviews in that an SR focuses tightly on a specific question or small set of questions and uses pre-established, explicit protocols for finding, screening, and rating the quality and relevance of studies before using evidence from the most methodologically-sound studies to formulate answers. The process is transparent and repeatable in documenting the specific criteria used for identifying and rating studies included in the review, as well as specifying how the evidence is analyzed. Elements incorporated in an SR are outlined in Table 1. The protocol initially will be tested by the principal reviewers on a small sample of studies (one per question). The protocol may be modified following these tests or later during the review process if reviewers identify ways to improve it; however, any changes to this protocol will be approved by ODF and fully documented for transparency.

Table 1. Elements described in a protocol for conducting a systematic review (Czarnomski and Hale 2013).

Elements	Brief explanation
Question	Focused, scientifically answerable question that guides search strategy and inclusion criteria
Search strategy	Methods (e.g., search terms and databases) to find studies pertinent to the question
Inclusion criteria	Filters used to determine relevance of studies to question
Study quality and relevance assessment	Criteria used to determine strength of study methodology, and the relevance of study findings to the review question
Data extraction	Tables used for consistently recording data and meta-data from studies and associated reviewer notes
Data synthesis	Methods (quantitative, qualitative) used for synthesizing data with respect to the review question

Review partners

ODF contracted with a team of external scientists from ABR, Inc. to conduct the review. The review team includes five ABR scientists (Dr. Jonathan Plissner, Brian Cooper, Dr. Robert Day, Peter Sanzenbacher, Todd Mabee) and two additional Marbled Murrelet experts, Dr. Martin Raphael (U.S. Forest Service) and Dr. Alan Burger (University of Victoria). The quality of the review is further enhanced by the input of numerous stakeholders including university, federal, forest industry, and state scientists; other agency staff; and representatives of nongovernmental organizations with interests in Marbled Murrelets. Stakeholders provide input on both the formulation of the review questions and this protocol (see Project Timeline below). Stakeholders also will be asked to 1) assess the implementation of the inclusion criteria on considered publications and provide input on whether any additional studies should be considered for inclusion; and 2) comment on a final draft of the synthesis report. All comments submitted will be documented and addressed by the report authors and included as an appendix of the final report for transparency. ODF staff composed initial drafts of the review questions, provided guidance in development of the study protocol, and reviewed drafts of all documents before they were sent to stakeholders for review.

Review Questions

This review will address five questions on topics considered high priority for ODF. The first four questions are designed to inform discussions of the PSG murrelet inland survey protocol. The fifth question is designed to inform discussions and decisions on the evolution of Marbled Murrelet protection measures and is not directly linked to the PSG protocol.

Although Systematic Reviews often conclude with a quantitative analysis (i.e., meta-analysis) of the data extracted from appropriate studies, such an analysis often is not appropriate for ecological studies because of differences in study methods and scope (CEE 2013); we therefore anticipate providing a narrative synthesis for all questions. As noted below, our search strategies and types of studies included in the review are well-defined and include sources of primary data in both peer-reviewed literature and other documents (i.e., "gray" literature); however, we will not include undocumented data (e.g., personal communications) or sources of raw data in the review.

The context given for each question provides some background on ODF's intent behind the question and some key concepts embodied in the question. Operational definitions for many terms are included in the Glossary section of this protocol.

***Question 1*. How are individual behaviors (subcanopy flight, circling, landing, vocalizations) of Marbled Murrelets indicative of nesting in the forest stand where those behaviors occur?**

This question addresses the current information on the significance of various Marbled Murrelet behaviors as indicators of nesting, and is related to information on pages 20–21 of the Evans Mack et al. (2003) survey protocol. We acknowledge that forest habitats may also have value for murrelets beyond a direct association with nesting (e.g., prospecting for nest sites, pair-bonding, roosting), but for this question we focus only upon the measureable indicators of nesting.

***Question 2*. To what extent do Marbled Murrelets exhibit nest-site fidelity at various spatial scales (i.e., at the scale of a watershed, forest stand, tree, branch, and platform), and how does the spatial extent of continuous potential habitat affect nest-site fidelity?**

***Question 3*. How does the spatial extent of continuous potential habitat relate to the co-occurrence (i.e., nesting by multiple pairs) of murrelets in a forest stand and at other spatial scales?**

These two questions address current information used to inform “site classification” within the PSG murrelet inland survey protocol. The analysis of survey effort required to classify occupancy correctly (Appendix A of the PSG protocol) was done at the survey-site level; however, the protocol extends “site classification” beyond the survey site to the entire survey area. The protocol recommends consulting with appropriate regulatory agencies regarding habitat beyond the survey area boundary. The spatial extent to which occupancy status applies currently is based on explanations regarding the importance of “continuous habitat” for current and future nesting by one or more pairs (pages 6 and 23 of the PSG protocol). The overall question of the importance of continuous habitat is broad and includes subsidiary questions; for example: “How does the amount and extent of continuous habitat relate to murrelet breeding, occupancy, abundance, and persistence at a site?” The questions in this review focus on two aspects of Marbled Murrelet breeding ecology (site fidelity [including re-use of nest sites by the same or different individuals] and the distribution of nesting pairs at different spatial scales) that, at the level of the forest stand, are cited in the survey protocol as supportive evidence for the importance of continuous habitat beyond the survey site. The relevance of results to the extent of continuous habitat considered important and to the application of survey results will be addressed in the synthesis. Note that our use of the term “site fidelity” in this SR includes repeated use of a nest site within a year or between years by the same or different individuals.

Question 4. ***How is the occurrence of Marbled Murrelet nest sites related to the number and size of potential nest platforms and platform-tree density within stands of different age-classes (young, mature, and old growth)?***

This question is associated with the suitable habitat definitions (p. 2 of the PSG protocol) that can be used to inform decisions on which stands to survey. There currently is a brief description in the protocol of potential murrelet habitat, including a qualifying platform diameter (10cm/4inches). ODF would like to understand better the information base to inform decisions on where/what to survey and to determine whether platform characteristics of murrelet-occupied habitats vary among stands of different age-classes.

Question 5. ***How is Marbled Murrelet nesting success affected by habitat characteristics?***

This question will focus only on habitat associations with nest success and not on the much broader question of habitat associations with the presence of nests. In this question, habitat characteristics are assumed to include stand-level (and patch-level) aspects, such as habitat quality and quantity, and larger-scale features, such as habitat continuity and configuration, and corvid abundance. It also will include other abiotic factors (e.g., slope, aspect, elevation, human activity) relating to the location of the nest within the stand. This question is not centered on the survey protocol. Rather, it focuses on understanding the information available to inform management decisions in areas where occupied sites are identified.

Search Strategy

Systematic reviews use a search strategy that specifies, *a priori*, how a comprehensive and unbiased sample of the literature will be sought and obtained. For this review, a search strategy was drafted by the ABR team that will be modified following input from ODF and stakeholders. Our strategy will be to search the literature as widely as possible, then use rigorous inclusion criteria to determine which studies to include in the review. Except for results of internet searches, all publications found during each stage of the search process will be imported or entered into EndNote bibliographical software. Only the first 50 results (based on relevance) of internet searches will be reviewed for relevant publications. Results with indeterminate information (e.g., incomplete citation) or that are duplicates will be discarded. The source of each reviewed publication will be specified in the study inclusion table.

Search strategies for SR's typically start with extraction of literature from publication databases, catalogs, and web-based search engines, using pre-determined search terms. Because most of our questions address hypotheses and supporting evidence stated in the PSG survey protocol (pg. 6) and/or other review documents, and because we choose to include relevant work in unpublished and "gray" literature that may not occur in on-line databases, we instead will begin our searches by identifying and searching the bibliographies and citations of appropriate "seed" documents for each question. These documents will include the Inland Forest Survey Protocol for Marbled Murrelets (Evans Mack et al. 2003), the recent drafts of the revised protocol, the Birds of North America species account for Marbled Murrelets (Nelson 1997), and several in-depth reviews (Ralph et al. 1995, Burger 2002, Raphael et al. 2002, McShane et al. 2004, Piatt et al. 2007, Raphael et al. 2008, USFWS 2009, Raphael et al. 2011). Bibliographies and citations of literature extracted in this manner and included as review papers also will in turn be searched for additional studies to include. We anticipate that we will be able to identify a substantial proportion of the relevant literature in this manner.

We will conduct subsequent searches for additional resources via online databases, search engines, and agency and institutional websites. For these searches, we will identify sets of question-specific search terms (see below).

For every search, the following information will be documented:

- Date when search was conducted
- Database, search engine, website, or professional network that was searched
- Exact search terms used
- List of hits and outputs (first 50, sorted by relevance)

After completion of searches, members of the review team and other stakeholders will be provided an opportunity to identify additional resources (particularly unpublished works and manuscripts in press) to be considered for inclusion in the review process. For resources identified in this manner, the source, inquiry date, and rationale for failing to identify these resources during earlier searches also will be documented. To be considered for inclusion and to provide transparency of this process, all studies that are in-review or in-press must have the primary author's consent that those documents can be made available for scrutiny upon request to the authors.

For studies that meet the criteria for inclusion in the review (see section below on Study Inclusion Criteria), we will conduct citation searches on the titles via the search engines listed. The bibliographies of included studies also will be searched for additional studies to consider.

Publication Databases and Search Engines

The following publication databases will be searched:

- BioOne
- JSTOR
- World Cat
- Directory of Open Access Journals

An Internet search also will be conducted with the following search engines:

- Google Scholar (www.scholar.google.com);
- ScienceDirect (www.sciencedirect.com)

The first 50 hits (based on relevance) from each internet search (not database search) will be examined for appropriate studies that have not been identified previously.

Specialist Websites

Websites of the following organizations will be searched for links or references to relevant publications, including gray literature:

- British Columbia Ministry of Forests, Lands, and Natural Resource Operations (www.gov.bc.ca/for/)
- California Department of Fish and Wildlife (www.wildlife.ca.gov/)
- Environment Canada (www.ec.gc.ca/default.asp?lang=En&n=FD9B0E51-1)
- National Park Service (www.nps.gov/index.htm)
- Oregon Department of Forestry (www.oregon.gov/ODF/Pages/index.aspx)
- Oregon Department of Fish and Wildlife (www.dfw.state.or.us/)
- Tree Search: USDA Forest Service Research (http://www.treesearch.fs.fed.us/)
- USDA Forest Service (www.fs.fed.us/)
- U.S. Fish and Wildlife Service (www.fws.gov)
- Washington Department of Fish and Wildlife (wdfw.wa.gov/)
- Washington Department of Natural Resources (www.dnr.wa.gov/Pages/default.aspx)
- Regional Ecosystem Office (www.reo.gov/monitoring/reports/marbled-murrelet-reports-publications.shtml)
- Pacific Seabird Group (www.pacificiseabirdgroup.org)
- Universities listed in the following section

Masters and PhD Theses

To capture unpublished chapters of theses and dissertations, the search will include catalogues of electronic graduate theses from research universities in the Pacific Northwest:

- Oregon State University;
- University of Oregon;
- Portland State University;
- University of California (system);
- University of Alaska;
- University of Washington;
- Washington State University;
- Simon Fraser University;
- University of Victoria;
- University of British Columbia.

<u>Search Terms and Exclusions</u>

Search terms are divided into sets that represent a particular review question. Terms within each set will be combined via Boolean operators (e.g., AND, OR) with those of each term within the other sets. These terms were determined via consultation with ODF partners, and by looking at protocols of similar SRs (e.g., Bernes et al. 2013; Czarnomski and Hale 2013). No foreign-language searches will be conducted, because we anticipate that all pertinent literature on these topics will be published in English.

We acknowledge that, in the absence of information on Marbled Murrelets, data on similar species may be considered the "best available science." However, the extent to which studies of related species, with different breeding ecologies and geographic distributions; can be considered appropriate for inclusion as evidence for questions regarding Marbled Murrelets is uncertain. For example, tree-nesting murrelets in forested areas have different breeding habitats than most cliff- and burrow-nesting alcids in coastal or oceanic ecosystems. Studies regarding non-forested habitat characteristics, therefore, are unlikely to be relevant. Further, differences between murrelets and related species in nest-site fidelity are likely at some if not all spatial scales because documented breeding site fidelity rates of alcids, while generally high, are variable among species (e.g., Divoky and Horton 1995, Gaston and Jones 1998, Schreiber and Burger 2002). Lastly, one would expect to see some differences in flight behaviors near nests between Marbled Murrelets and other alcids because Marbled Murrelets do not nest in dense colonies (as do many alcids) and generally nest in trees (vs. treeless areas) in inland areas (vs. marine islands and cliffs). While some flight characteristics near nests are likely to be similar to those of other species (both alcids and non-alcids), there is no basis to assume similar associations with habitat or proximity to nests. Thus, for the purpose of this review, we limit our searches to studies pertaining to Marbled Murrelets.

For each question, we will apply the following search terms to database searches (* indicates wildcard search term):

<u>Search terms for question 1</u> (How are individual behaviors [subcanopy flight, circling, landing, vocalizations] of Marbled Murrelets indicative of nesting in the forest stand where those behaviors occur?):

("Marbled Murrelet" OR "*Brachyramphus marmoratus*") AND

(nest* OR breed*) AND
(“flight behavior” OR subcanopy OR circling OR “jet sound” OR arcing OR calling OR vocaliz* OR wing-beat OR “wing whir” or “occupied behavior”)

Search terms for question 2 (To what extent do Marbled Murrelets exhibit nest-site fidelity at various spatial scales [e.g., at the scale of a watershed, forest stand, tree, branch, and platform], and how does the spatial extent of continuous potential habitat affect nest-site fidelity?):

(“Marbled Murrelet” OR *“Brachyramphus marmoratus”*) AND
(nest* OR breed*) AND
(fidelity OR dispers* OR philopatry OR re-occup* OR renest* OR return OR re-use)

Search terms for question 3 (How does the spatial extent of continuous potential habitat relate to the co-occurrence [i.e., nesting by multiple pairs] of murrelets in a forest stand and at other spatial scales?):

(“Marbled Murrelet” OR *“Brachyramphus marmoratus”*) AND
(nest* OR breed*) AND
(co-occur* OR "nest density" OR "breeding density" OR colon* OR multiple)

Search terms for question 4 (How is the occurrence of Marbled Murrelet nest sites related to the number and size of potential nest platforms and platform-tree density within stands of different age-classes [young, mature, and old growth]?):

(“Marbled Murrelet” OR *“Brachyramphus marmoratus”*) AND
nest* AND
(branch OR limb OR platform)

Search terms for question 5 (How is Marbled Murrelet nesting success affected by habitat characteristics?):

(“Marbled Murrelet” OR *“Brachyramphus marmoratus”*) AND
(“breeding success” OR “reproductive success” OR “nest success” OR fledging OR “nest failure” OR predation OR depredation OR mortality) AND
(habitat OR stand OR landscape OR continu* OR fragment*)

Study inclusion criteria

Study inclusion criteria are predefined to ensure an objective selection of the relevant literature. For this review, only primary studies (i.e. studies with original data or original analyses, not reviews without original analyses) will be included since we want to base our synthesis on evidence, not authors’ interpretation of the evidence. In addition to peer-reviewed articles, we also will include “gray literature” (e.g., government reports, graduate theses) and manuscripts in review, because some of these studies are relevant to the review questions. We will not include undocumented data (e.g., personal communications), sources of raw data, or documents with insufficient information on methodology to allow assessment of the quality or relevance of the study (e.g., presentation abstracts, newsletters). A wide variety of studies is anticipated, including descriptive studies, presence/absence studies, abundance studies, audio-visual/radar/telemetry studies, habitat studies, and predation studies. We plan to include as many types as appropriate for each question.

Articles found in our searches will be evaluated for inclusion at three successive levels. In cases of uncertainty or insufficiency of information, the article will be included in the next level of assessment. Inclusion will be determined initially on viewing the titles of articles. If titles provide insufficient information, inclusion will be based on reading abstracts (or summaries). Finally, each article found to be relevant on the basis of the title or abstract will be judged for inclusion by reviewing the full text. Studies that meet all inclusion criteria will be reviewed for quality and data extraction. For transparency, a list of all studies rejected on the basis of full-text assessment will be provided in an appendix that lists the basis for that decision. If a thesis (or other unpublished document) meets all inclusion criteria and also has a peer-reviewed publication associated with it, the peer reviewed publication will be used. If there are other chapters of the thesis that contain relevant information not mentioned in the publication, those chapters also will be included in the review.

To be included as a review paper for a particular question, a study must meet each of the inclusion criteria highlighted for that question in Appendix A. A synopsis of those criteria is that each study must:

- provide data on Marbled Murrelets anywhere in their geographic range, and
- directly inform the particular question of interest.

Data-extraction strategy

We will extract the primary results of studies from literature selected for inclusion in the data synthesis. Reviewers will record this information in data-extraction tables for each question, with one table to be completed for each study (Appendix B). These tables are intended to provide objective information for the assessment and synthesis of evidence and will help identify gaps in knowledge pertaining to the questions. For two studies relating to each question, data extraction will be conducted by two reviewers to assess consistency among reviewers.

In addition to extraction tables for each study, we will include an overall summary table for each question that summarizes the key information from each study. Those tables will include information on: (1) study name; (2) study location; (3) publication type; (4) whether the study's objective or question was directly related to the review question; and (5) the Study Evaluation Score of the study (described below). In addition to those columns for all five summary tables, there will be the following question-specific information:

- Question #1 table: We will include additional columns for summaries of "occupied" behaviors observed (1) over known nesting habitat; and (2) over non-nesting habitat.
- Question #2 table: We will include additional columns for (1) a summary of information on re-use of nesting cups, limbs, trees, patches, sites, stands, or watersheds; and (2) a column for a summary of the distance between subsequent nests of a bird or pairs.
- Question #3 table: We will include additional columns for (1) a summary of information on the known number (1 or >1) or density of nesting pairs within trees, patches, survey sites, stands, or watersheds; and (2) a column indicating whether or not the paper provided information on the amount of potential habitat present.
- Question #4 table: We will include additional columns for (1) mean (± SE or SD) platform diameter; (2) mean (± SE or SD) platform density; (3) mean (± SE or SD) platform-tree density; (4) the definition of nest platforms or potential platforms; and (5) the age-class(es) of stands studied.
- Question #5 table: We will include an additional column for a summary of associations described between nesting success and nest-site habitat characteristics recorded at landscape, stand, or sub-stand scales.

Critical Appraisal of Studies

When synthesizing data from the studies, it is important to consider both how much confidence we have in the results of the study as they apply to the SR question and their relevance to the review question. For example, a study might directly addressed the review question, yet have a weak design and power so low that it provides little confidence in the study's results. Conversely, a study may have strong design and power, yet provide results that have only weak relevance to the review question. Another factor to consider in this particular SR is that many of the studies will be of a descriptive nature, so there is a need to consider additional specific factors that will help quantify the relevance/confidence of those types of studies that may be important to include yet have no statistical components *per se*.

External reviewers will apply information from the data-extraction tables (Appendix B) to score each study on relevance and confidence factors by using the following scoring system to appraise each study critically:

Relevance Rating Factors:

- Study objectives: Was the study designed to address the primary review question specifically? (Scoring: 1 = no, but study has some relevant data even though the study objectives are not directly related to the review question; 3 = yes).
- Nests: Does the study include data on real or artificial Marbled Murrelet nests? (Scoring: 1 = artificial murrelet nests/eggs/young only; 3 = includes real Marbled Murrelet nests). Note: applies to Question 5 only.
- Continuous habitat: Are blocks of continuous habitat defined within the study area? (Scoring: 0 = no; 2 = yes, but continuity not defined; 3 = yes, with continuity defined). Note: applies to Questions 2 and 3 only.
- Nest habitat: How similar is the nesting habitat (i.e., forest structure and composition) to that found in Oregon? (Scoring: 0 = not similar (treeless habitat; 1 = forested habitat in Alaska, British Columbia, and/or California; 2 = forested habitat in Oregon and/or Washington).

Confidence Rating Factors:

- Study design: Was overall nature of the study qualitative (score = 1), or quantitative (score = 4) in regard to the review question?
- Sampling design: What was the overall strength of the sampling design? (Scoring: 1 = descriptive study without control groups, 2 = descriptive study

with control groups <u>or</u> experimental study without replicates or control groups; 3 = experimental study with replicates but without control groups <u>or</u> with control groups but without replicates; 4 = experimental study with replicated sampling and control groups).

- Study methods: Was the basic study method (i.e., audiovisual, radar, telemetry, etc.) appropriate to the question being asked? (Scoring: 0 = no; 2 = yes, but better techniques [listed by reviewer] were available and not used; 4 = yes, the best technique was used).
- Study duration: How many years was the study conducted? (Scoring: 1 = 1 year, 2 = 2 years, 4 = ≥3 years).
- Within-season study duration: What was the intensity of the study within each survey season? (Scoring: 1 = low [covered <10% of season] or unknown; 2 = medium [11–50% of season] or not applicable; 3 = high [>50% of season].
- Sampling intensity: What was the intensity of data collection within each study area? (Scoring: 0 = low; 2 = medium; 4 = high [specific ranges for low, medium, and high TBD for each study question]).
- Sample size: How large was the sample size(s) of interest (e.g., number of nests, number of flight behaviors; number of sites)? (Scoring: 0 = small; 2 = medium; 4 = large [specific ranges for low, medium, and high TBD for each study question]).
- Statistically robust: Were the statistical analyses that were conducted appropriate to address the objectives and the data collected? (Scoring: -2 = no; 0 = not applicable (i.e., a descriptive study); 2 = yes).
- Statistical power: Did the study report adequate power to detect significant differences if they occurred? (Scoring: -1 = no [power < 0.8]; 0 = not applicable or unknown; 3 = yes [power ≥ 0.8]).
- Document type: Was the study document peer-reviewed? (Scoring: 1 = no [i.e., unpublished reports, non-reviewed agency reports, articles in non-peer-reviewed publications, or manuscripts in review]; 3 = yes [i.e., published articles, agency peer-reviewed reports, PhD or MS theses, or manuscripts in press that have undergone peer review]).

Scoring will be conducted after data extraction because some scoring levels (e.g., "low," "medium," "high") may be defined or revised based on the range of values obtained from the included studies. The range of values for each factor reflects the relative importance of the factor in determining overall confidence (e.g., factors with four score levels are deemed more important than those with two levels, based on a survey of factor values among reviewers). The scores of all relevance and confidence factors will be summed for a single Study Evaluation Score to help rank all review papers within each study question. Maximal Study Evaluation Scores for each question will vary because some factors and responses may be more or less relevant to certain questions than to others. For each question, scores of all included studies will be listed and tallied in tables that enable quick, objective comparisons (Appendix C).

Data Synthesis

Rating the strength of the body of evidence for each review question entails not only evaluating study quality and the relevance of each study as described above but also includes assessing the consistency of results among studies and assessing the comparability of study methodologies. Meta-analyses often are the preferred approach for evidence synthesis but will not be conducted for this review because of the nature of some of the questions and inconsistencies in study methods that result in small samples of comparable studies for many of the questions. Thus, we will provide a narrative synthesis for each question in this review.

Information from all included studies will be summarized and, whenever possible, tabulated qualitatively. Narratives then will be used to summarize that table or figure and discuss both the evidence relevant to the question and any gaps in that evidence. These tabulated study characteristics and narrative syntheses will allow for comparisons of the degree of similarity among studies and will illustrate how the reviewers arrived at an overall assessment for each review question. The narrative will document an organized, qualitative evaluation of the strength of the entire body of evidence based on the following criteria: (1) Quality: the aggregate quality of the entire body of evidence (based on an average of the Study Evaluation Scores of all the individual studies); (2) Quantity: the number of studies, sample sizes, power, and magnitudes of effect; (3) Consistency: the extent to which similar findings are reported when using similar and different study designs; and (4) Coherence: do the findings of the body of evidence make sense as a whole? The narrative also will document how our evaluation may have been impacted by study characteristics and will identify potential effects modifiers (e.g., study locations, habitat type, year effects) that may contribute to variation in study results. Finally, based on the evaluation of the evidence, gaps in knowledge will be identified.

We envision using the following types of tables or figures to begin to summarize and illustrate the strength of evidence for each question; however, we anticipate that additional tables and figures (such as scatterplots of primary quantitative results plotted against Study Evaluation Scores) will be included in the final report, based on the amount and type of data that are encountered during the review:

1) All questions:

Bar charts showing distribution of Study Evaluation Scores for all studies reviewed within a question.

x-axis = Study Evaluation Scores (e.g., in categories of 0–7, 8–14, 15–22, based on scoring criteria listed above);

y-axis = number of studies.

2) Question 1:

Bar chart depicting the proportion of visits with each type of "occupied" behavior observed over nesting habitat vs. non-nesting habitat (with sample sizes provided above each bar).

x-axis = location categories (non-nesting habitat without adjacent nesting habitat, non-nesting habitat adjacent to nesting habitat, known nesting habitat) with separate bars for each behavior;

y-axis = proportion of total visits to site when each type of behavior (e.g., circling, subcanopy flight, etc.) was observed.

3) Question 2:

Table summarizing the key elements of each observation of nest site fidelity:

Study	Scale	Within or between seasons	Identity of individuals known?	Number of occurrences	Study Evaluation Score	Additional information

Bar chart #1 depicting the proportion of cases where nest site fidelity (or nest re-use) was observed at nests, branches, trees, stands and watersheds (with sample size provided above each bar).

x-axis = scale (nest cup, branch, tree, stand, watershed);

y-axis = proportion of cases with returning birds (only for between-year analyses).

Bar chart #2 depicting the proportion of cases of murrelets returning to potential nesting areas in subsequent years, by categories of habitat area (with sample size provided above each bar). May do separate charts for stands and watersheds.

x-axis = categories of habitat area (acres);

y-axis = proportion of stands with returning birds (only for between-year analyses).

4) Question 3:

Bar chart #1 depicting number of cases of co-occurrence reported at the stand and watershed levels (depict separately for studies with low, medium, and high Study Evaluation Scores):

x-axis = "stand" and "watershed";

y-axis = number of cases with >1 nesting pairs or nests.

z-axis = three categories of Study Evaluation Scores (low, medium, and high).

Scatterplots #1a & 1b depicting the number of nests or pairs by area of potential habitat available in a stand (1a) or watershed (1b).

x-axis = total area of potential habitat;

y-axis = number of nests or nesting pairs.

5) Question 4:

Table summarizing key information on mean platform size, platform density, and platform-tree density for each study:

Study	Platform definition (size)	Scale (branch, tree, stand)	Number of platforms	Platform density (platforms/ha)	Platform-tree density (trees/ha)	Stand age	Study Evaluation Score

Box plot #1 comparing mean platform size measured at known nests by stand-age type (with sample size provided above each bar).

x-axis = stand age (young, mature, old-growth);

y-axis = mean ± SE nest platform size.

Box plot #2 comparing mean platform density by stand-age type.

x-axis = stand age (young, mature, old-growth), with separate boxes for 4" platforms and 7" platforms;

y-axis = mean ± SE density of nest platforms in stand (for stands with nesting Marbled Murrelets only).

Box plot #3 comparing mean platform tree density by stand age type.

x-axis = stand age (young, mature, old growth) with separate boxes for 4" platforms and 7" platforms;

y-axis = mean ± SE density of platform trees in stand (for stands with nesting Marbled Murrelets only).

6) Question 5:

Bar chart depicting the number of studies that discuss nesting success in relation to each of the following habitat characteristics: fragmentation (with metrics defining fragmentation), degree of predation, habitat continuity, nesting-stand size, or configuration of the nesting stand (with stacked bars depicting the proportion of studies with significant relationships between those characteristics and nesting success).

x-axis = habitat characteristics;

y-axis = number of studies with information on nesting success.

Additional figures used to summarize facts relevant to this question (e.g., scattergraphs comparing nesting success with degree of predation, density of nest predators, stand size, percentage of edge habitat, ...), will be determined based on the amount of information that we are able to obtain for each habitat variable identified during the review.

Project Timeline

Milestone	Due Date
Award of Contract	26 March 2014
ABR meeting with ODF in Salem	3 April 2014
ABR team sends draft list of refined questions to ODF for review	17 April 2014
ODF review (7 days)	17–25 April 2014
ABR team refines questions incorporating ODF comments	25 April–1 May 2014
Draft list of refined questions sent to external stakeholders for comments (2-week review period)*	**1–15 May 2014**
Draft review protocol and final list of questions to ODF	25 May 2014
ODF review of draft protocol (9 days)	25 May–3 June 2014
Draft protocol sent to external stakeholders for comments (2-week review period)	**20 June–4 July 2014**
Final review protocol and summary report of external stakeholder input to ODF	25 July 2014
ABR team search and screen literature and acquire final review documents	25 July–25 August 2014
Results of search and screening sent to ODF & external stakeholders for comments and suggested additions (2-week review period)	**25 August–10 September 2014**
Document review	25 August–10 October 2014
Data synthesis and report production	11 October–25 November 2014
Draft synthesis report to ODF	25 November 2014
ODF review of draft synthesis report (2 weeks)	25 November–10 December 2014
ABR team revises draft report incorporating initial ODF comments	11–24 December 2014
Revised draft report sent to external stakeholders for comments (3.5-week period, including holiday period)	**25 December 2014–20 January 2015**
Final synthesis report incorporating external review comments to ODF	10 February 2015
Five presentations of the report	February & March 2015
“Lessons learned” forum with ODF	April 2015

*Stakeholder review periods in **bold**.

Potential Conflicts of Interest and Sources of Support

Any studies included in our review that were authored by a member of the review team will be reviewed by a different member of the team. We have no conflicts of interest to declare. This systematic review is funded by the Oregon Department of Forestry.

Glossary

For the purposes of this protocol, the following definitions apply:

Continuous potential habitat (as defined in the inland survey protocol; Evans Mack et al. 2003): "[habitat] which contains no gaps in suitable forest cover wider than 100 m (328 ft).

Forest age-classes (functional definition for this review, based upon Franklin and Spies [1991] classification for Douglas-fir forests; not general policy definition):

- Young: coniferous forests ~35–80 years old that have platforms in young trees or in residual older trees.
- Mature: coniferous forests ~80–200 yr old with or without an old-growth component.
- Old-growth: coniferous forest stands >~200 yr old.

Forest stand: An aggregation of trees of sufficiently uniform species composition, age, and condition to be distinguished from the forest or other growth on adjoining areas and considered a homogeneous unit for many management purposes.

Habitat characteristics: biotic and abiotic factors associated with habitat quality, quantity, continuity, or configuration of forest patches/stands or watersheds.

Occupied behavior: a term used in the inland survey protocol (Evans Mack et al. 2003) to describe the following behaviors believed to indicate that the site either has or may have some importance for breeding: subcanopy flights and dives, low circling or arcing, landings, subcanopy wing-beat sounds, stationary calling, and the "jet sounds" associated with diving birds.

Patch: An area of forest consisting of a contiguous expanse of similar habitat without gaps in that habitat type.

Platform: a relatively flat surface ≥10 cm (≥4 in) in diameter and ≥10 m (≥33 ft) high in the live crown of a coniferous tree (Evans Mack et al. 2003).

Site fidelity: Refers to within-year and between-year returns of birds and re-use of nesting locations (i.e., at the nest cup, limb, tree, patch, site, stand, or watershed scale) by the same or different individuals.

Survey area: the entire area (often a timber sale and surrounding forest) that is under observation during inland surveys for murrelets, as described in Evans Mack et al. (2003).

Survey site: the designated survey unit for the murrelet survey protocol, as described in Evans Mack et al. (2003).

References

Bernes C., K. A. Bråthen, B. C. Forbes, A. Hofgaard, J. Moen, and J. D. M. Speed. 2013. What are the impacts of reindeer/caribou (*Rangifer tarandus* L.) on arctic and alpine vegetation? A systematic review protocol. Environmental Evidence 2:1–7.

Burger, A. E. 2002. Conservation assessment of Marbled Murrelets in British Columbia: review of the biology, populations, habitat associations, and conservation of this threatened species. Technical Report Series No. 387, Canadian Wildlife Service, Delta, BC.

Collaboration for Environmental Evidence (CEE). 2013. Guidelines for systematic review and evidence synthesis in environmental management. Version 4.2. Environmental evidence: www.environmentalevidence.org/Documents/Guidleines/Guidelines 4.2.pdf

Czarnomski, N., and H. Hale. 2013. Effectiveness of riparian buffers at protecting stream temperature and shade in Pacific Northwest Forests: a systematic review. Report prepared by Environmental Science Associates, Portland, OR, and Nutter and Associates, Athens, GA, for Oregon Dept. of Forestry, Salem, OR.

Divoky, J. G., and M. Horton. 1995. Breeding and natal dispersal, nest habitat loss and implications for Marbled Murrelet populations. Pp. 83–87 in C. J. Ralph, G. L. Hunt Jr., M. G. Raphael, and J.F. Piatt, eds. Ecology and conservation of the Marbled Murrelet in North America. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, General Technical Report No. PSW-GTR-152, Albany, CA.

Evans Mack, D. M., W. P. Ritchie, S. K. Nelson, E. Kuo-Harrison, P. Harrison, and T. E. Hamer. 2003. Methods for surveying Marbled Murrelets in forests: a revised protocol for land management and research. Pacific Seabird Group unpublished document.

Franklin, J. F., and T. A. Spies. 1991. Ecological definitions of old-growth Douglas-fir forests. Pp. 61–69 in L. F. Ruggiero, K. B. Aubry, A. B. Carey, and M. H. Huff, tech. eds. Wildlife and vegetation of unmanaged Douglas-fir forests. U.S. Department of Agriculture, Forest

Service, Pacific Northwest Research Station, General Technical Report no. PNW-285. Portland, OR.

Gaston, A. J., and I. L. Jones. 1998. The Auks, Alcidae. Oxford University Press, Oxford, UK. 388 pp.

McShane, C., T. Hamer, H. Carter, G. Swartzman, V. Friesen, D. Ainley, R. Tressler, K. Nelson, A. Burger, L. Spear, T. Mohagen, R. Martin, L. Henkel, K. Prindle, C. Strong, and J. Keany. 2004. Evaluation report for the 5-year status review of the Marbled Murrelet in Washington, Oregon, and California. Report prepared by EDAW, Inc., Seattle, WA, for the U.S. Fish and Wildlife Service, Region 1, Portland, OR.

Nelson, S. K. 1997. Marbled Murrelet (*Brachyramphus marmoratus*). *In* A. Poole and F. Gill (eds.). The Birds of North America, No. 276. Academy of Natural Sciences, Philadelphia, PA, and American Ornithologists' Union, Washington, D.C.

Piatt, J. F., K. J. Kuletz, A. E. Burger, S. A. Hatch, V. L. Friesen, T. P. Birt, M. L. Arimitsu, G. S. Drew, A. M. A. Harding, and K. S. Bixler. 2007. Status review of the Marbled Murrelet (*Brachyramphus marmoratus*) in Alaska and British Columbia: U.S. Geological Survey Open-File Report No. 2006-1387.

Ralph, C. J., G. L. Hunt Jr., M. G. Raphael, and J. F. Piatt (eds.). 1995. Ecology and conservation of the Marbled Murrelet in North America. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, General Technical Report No. PSW-GTR-152, Albany, CA.

Raphael, M. G., D. E. Mack, J. M. Marzluff, and J. M. Luginbuhl. 2002. Effects of forest fragmentation on populations of the Marbled Murrelet. Studies in Avian Biology 25: 221–235

Raphael, M. G., S. K. Nelson, P. Swedeen, M. Ostwald, K. Flotlin, S. Desimone, S. Horton, P. Harrison, D. Prenzlow Escene, and W. Jaross. 2008. Recommendations and supporting analysis of conservation opportunities for the Marbled Murrelet long-term conservation strategy. Washington State Department of Natural Resources, Olympia, WA.

Raphael, M. G., G. A. Falxa, K. M. Dugger, B. M. Galleher, D. Lynch, S. L. Miller, S. K. Nelson, and R. D. Young. 2011. Northwest Forest Plan—the first 15 years (1994–2008): status and trend of nesting habitat for the Marbled Murrelet. : U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR. General Technical Report No. PNW-GTR-848.

Schreiber, E. A., and J. Burger (eds.). 2002. Biology of marine birds. CRC Marine Biology Series, CRC Press, NY. 722 pp.

USFWS (U.S. Fish and Wildlife Service). 1992. Endangered and threatened wildlife and plants determination of threatened status for the Washington, Oregon, and California population of the Marbled Murrelet. Federal Register 61: 26,256–26,320.

USFWS (U.S. Fish and Wildlife Service). 1997. Recovery Plan for the Marbled Murrelet (Washington, Oregon, and California population). U.S. Fish and Wildlife Service, Portland, OR.

USFWS (U.S. Fish and Wildlife Service). 2009. Marbled Murrelet (*Brachyramphus marmoratus*): 5-year review. U.S. Fish and Wildlife Service, Lacey, WA.

Appendix A—Study Inclusion

Study citation: **Initial source of study:**	**Question**				
Inclusion criteria	**1**	**2**	**3**	**4**	**5**
Does the study specifically address Marbled Murrelets at inland sites?					
Does the paper contain primary data or novel analysis of secondary data pertaining to the questions?					
Does the paper contain sufficient information on methodology and results to assess study quality?					
Does the study include information on one or more of the following behaviors: circling/arcing flight, flight altitude relative to tree height, wing-whirring, jet sounds, wing-beats, stationary calling?					
Does the study include information on known nesting or non-nesting habitat when behaviors were observed?					
Does the study include information on either or both of the following: (1) within- or between-year re-use of nesting cup, limb, tree, patch, site, stand, or watershed; or (2) distance between subsequent nests of a bird or pair?					
Does the study include information on the known number (1 or >1) or density of nesting pairs within one or more of the following: tree, patch, survey site, stand, watershed?					
Does the study include information on one or more of the following: (1) nest-platform diameters; (2) nest-platform density (including definition of minimal platform size); (3) platform-tree density (including definition of minimal platform size)?					
Does the study include information on known nesting sites?					
Does the study include information on nest success or nest failure?					
Does the study include information on nest-site habitat characteristics?					
Will study be included in review?					

Assessed by:
Date assessed:

Appendix B—Data Extraction

Table B-1. Data to be extracted from each publication included in evaluating review question 1: "How are individual behaviors (subcanopy flight, circling, landing, vocalizations) of Marbled Murrelets indicative of nesting in the forest stand where those behaviors occur?"

Study citation	
Primary focus of study	
Focal species	
Study location (region/state or province)	
Study area habitat	
Study design[1]	
Sampling design[2]	
Study methods[3]	
Study dates and study duration (# of years, days within a year)	
Sampling intensity[4]	
Sample sizes[5]	
Statistical analysis of results[6]	
Statistical power[7]	
Document type	
Behaviors recorded[8]	
Circling behavior definition	
Distances of recorded behaviors from nest known?	
Distances of recorded behaviors from potential nesting habitat?	
How was nesting determined?	
Pertinent results, including statistical significance values and measures of variation[9]	
Location of results within article (e.g., specific tables & figures, text)	
Potential sources of bias or error	
Effects modifiers[10]	
Additional notes	

[1] Brief description of study design (e.g., qualitative, quantitative).
[2] Observational or experimental, control groups, replicates.
[3] Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
[4] How often were data collected within a season?
[5] Number of birds, nests, sites, replicates, visits.
[6] How were results analyzed? What statistical tests were conducted? Were these tests appropriate?
[7] If calculated, what was the statistical power and effect size for the question?
[8] Types and definitions of vocalizations and/or flight characteristics recorded.
[9] List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
[10] List potential factors that may have affected results and comparability relative to other studies.

Table B-2. Data to be extracted from each publication included in evaluating review question 2: "To what extent do Marbled Murrelets exhibit nest-site fidelity at various spatial scales (i.e., at the scale of a watershed, forest stand, tree, branch, and platform), and how does the spatial extent of continuous potential habitat affect nest-site fidelity?"

Study citation	
Primary focus of study	
Focal species	
Study location (region/state or province)	
Study area habitat	
Study design[1]	
Sampling design[2]	
Study methods[3]	
Study dates and study duration (# of years, days within a year)	
Sampling intensity[4]	
Sample sizes[5]	
Statistical analysis of results[6]	
Statistical power[7]	
Document type	
Spatial scale(s)[8]	
How was nesting determined?[9]	
Known individuals?[10]	
Extent of habitat (area)[11]	
Nests within same year?	
Pertinent results, including statistical significance values and measures of variation[12]	
Results: Distance(s) between nests and whether in same tree, patch, stand, watershed (if known)	
Location of results within article (e.g., specific tables & figures, text)	
Potential sources of bias or error	
Effects modifiers[13]	
Additional notes	

[1] Brief description of study design (e.g., qualitative, quantitative).
[2] Observational or experimental, control groups, replicates.
[3] Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
[4] How often were data collected within a season?
[5] Number of birds, nests, sites, replicates, visits.
[6] How were results analyzed? What statistical tests were conducted? Were these tests appropriate?
[7] If calculated, what was the statistical power and effect size for the question?
[8] Watershed, forest stand, survey site, patch, tree, branch, platform, etc.
[9] Observed nests or assumed occupancy? Basis for determination?
[10] Was multiple nesting documented for individual birds?
[11] Acreage of habitat, continuous or not, and how defined.
[12] List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
[13] List potential factors that may have affected results and comparability relative to other studies.

Table B-3. Data to be extracted from each publication included in evaluating review question 3: "How does the spatial extent of continuous potential habitat relate to the co-occurrence (i.e., nesting by multiple pairs) of murrelets in a forest stand and at other spatial scales?"

Study citation	
Primary focus of study	
Focal species	
Study location (region/state or province)	
Study area habitat	
Study design[1]	
Sampling design[2]	
Study methods[3]	
Study dates and study duration (# of years, days within a year)	
Sampling intensity[4]	
Sample sizes[5]	
Statistical analysis of results[6]	
Statistical power[7]	
Document type	
Spatial scale[8]	
How was nesting determined?	
Dependent variable[9]	
Extent of habitat (area)[10]	
Pertinent results, including statistical significance values and measures of variation[11]	
Results: Distance(s) between nests and whether in same tree, patch, stand, watershed (if known)	
Location of results within article (e.g., specific tables & figures, text)	
Potential sources of bias or error	
Effects modifiers[12]	
Additional notes	

[1] Brief description of study design (e.g., qualitative, quantitative).
[2] Observational or experimental, control groups, replicates.
[3] Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
[4] How often were data collected within a season?
[5] Number of birds, nests, sites, replicates, visits.
[6] How were results analyzed? What statistical tests were conducted? Were these tests appropriate?
[7] If calculated, what was the statistical power and effect size for the question?
[8] Watershed, forest stand, survey site, patch, tree, branch, platform, etc.
[9] Probability of multiple nests, total number of nests/pairs, nesting density, etc.
[10] Acreage of habitat, continuous or not, and how defined.
[11] List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
[12] List potential factors that may have affected results and comparability relative to other studies.

Table B-4. Data to be extracted from each publication included in evaluating review question 4: "How is the occurrence of Marbled Murrelet nest sites related to the number and size of potential nest platforms and platform tree density within stands of different age classes (young, mature, and old growth)?"

Study citation	
Primary focus of study	
Focal species	
Study location (region/state or province)	
Study area habitat	
Study design[1]	
Sampling design[2]	
Study methods[3]	
Study dates and study duration (# of years, days within a year)	
Sampling intensity[4]	
Sample sizes[5]	
Statistical analysis of results[6]	
Statistical power[7]	
Document type	
Spatial scale[8]	
Definition of nest platform	
Dependent variable[9]	
Stand age or age class (define)	
Pertinent results, including statistical significance values and measures of variation[10]	
Location of results within article (e.g., specific tables & figures, text)	
Potential sources of bias or error	
Effects modifiers[11]	
Additional notes	

[1] Brief description of study design (e.g., qualitative, quantitative).
[2] Observational or experimental, control groups, replicates.
[3] Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
[4] How often were data collected within a season?
[5] Number of birds, nests, sites, replicates, visits.
[6] How were results analyzed? What statistical tests were conducted? Were these tests appropriate?
[7] If calculated, what was the statistical power and effect size for the question?
[8] Watershed, forest stand, survey site, patch, tree, etc.
[9] Number/density of platforms or platform trees, platform size
[10] List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
[11] List potential factors that may have affected results and comparability relative to other studies.

Table B-5. Data to be extracted from each publication included in evaluating review question 5: "How is Marbled Murrelet nesting success affected by habitat characteristics?"

Study citation	
Primary focus of study	
Focal species	
Study location (region/state or province)	
Study area habitat	
Study design[1]	
Sampling design[2]	
Study methods[3]	
Study dates and study duration (# of years, days within a year)	
Sampling intensity[4]	
Sample sizes[5]	
Statistical analysis of results[6]	
Statistical power[7]	
Document type	
Spatial scale[8]	
Natural or artificial nests?	
Habitat characteristic(s) associated with nesting success	
Cause of nest failure[9]	
Pertinent results, including statistical significance values and measures of variation[10]	
Location of results within article (e.g., specific tables & figures, text)	
Potential sources of bias or error	
Effects modifiers[11]	
Additional notes	

[1] Brief description of study design (e.g., qualitative, quantitative).
[2] Observational or experimental, control groups, replicates.
[3] Audiovisual, radar, telemetry, tree-climbing, nest-cameras, etc.
[4] How often were data collected within a season?
[5] Number of birds, nests, sites, replicates, visits.
[6] How were results analyzed? What statistical tests were conducted? Were these tests appropriate?
[7] If calculated, what was the statistical power and effect size for the question?
[8] Watershed, forest stand, survey site, patch, tree, limb.
[9] Predation (list predators if known), abandonment, etc.
[10] List specific results that are most pertinent to answering the question; include *P*-values, confidence limits, range of values, standard deviations, or other measures of variation.
[11] List potential factors that may have affected results and comparability relative to other studies.

Appendix C—Relevance/Confidence

Scores of relevance and confidence factors from each study.

ID#	Study	Relevance			Confidence										Study Evaluation Score
		Study objectives	Nests	Nest habitat	Study design	Sampling design	Study methods	Statistically robust	Statistical power	Study duration (years)	Study duration (season)	Sample size	Sampling intensity	Document type	

Relevance Rating Factors:

Study objectives: Was the study designed to address specifically the primary review question? (Scoring: 1 = no, but study has some relevant data even though the study objectives are not directly related to the review question; 3 = Yes).

Nests: Does the study include data on real or artificial Marbled Murrelet nests? (Scoring: 1 = artificial murrelet nests/eggs/young only; 3 = Includes real Marbled Murrelet nests). Note: applies only to Question 5.

Nest habitat: How similar is the nesting habitat (i.e., forest structure and composition) to that found in Oregon? (Scoring: 0 = not similar (treeless habitat; 1 = forested habitat in Alaska, British Columbia, and/or California; 2 = forested habitat in Oregon and/or Washington).

Confidence Rating Factors:

Study design: Was overall nature of the study qualitative (score = 1) or quantitative (score = 4) in regard to the review question?

Sampling design: What was the overall strength of the sampling design? (Scoring: 1 = descriptive study without control groups, 2 = descriptive study with control groups or experimental study without replicates or control groups; 3 = experimental study with replicates but without control groups or with control group but without replicates; 4 = experimental study with replicated sampling and control groups).

Study methods: Was the basic study method (e.g., audiovisual, radar, telemetry) appropriate to the question being asked? (Scoring: 0 = no; 2 = yes, but better techniques were available and not used; 4 = yes, the best technique was used).

Study duration: How many years was the study conducted? (Scoring: 1 = 1 year, 2 = 2 years, 4 = ≥3 years).

Within-season study duration: What was the intensity of the study within each survey season? (Scoring: 1 = low [<10% of season] or unknown; 2 = medium [11–50% of season]; 3 = high [>50% of season] or not applicable).

Sampling intensity: What was the intensity of data collection within each study area? (Scoring: 0 = low; 2 = medium; 4 = high [specific ranges for low, medium, and high TBD for each study question]).

Sample size: How large was the sample size(s) of interest (e.g., number of nests, number of flight behaviors; number of sites)? (Scoring: 0 = small; 2 = medium; 4 = large [specific ranges for small, medium, and large TBD for each study question]).

Statistically robust: Were the statistical analyses that were conducted appropriate to address the objectives and the data collected? (Scoring: -1 = no; 0 = not applicable (i.e., for a descriptive study); 4 = yes,).

Statistical power: Did the study have adequate power to detect significant differences if they occurred? (Scoring: -1 = no [power < 0.8]; 0 = not applicable or unknown; 3 = yes [power ≥ 0.8]).

Document type: Was the study document peer-reviewed? (Scoring: 1 = no [i.e., unpublished reports, articles in non-peer-reviewed serials, or manuscripts in review]; 3 = yes [i.e., published articles, agency reports, Ph.D. or M.S. theses, or manuscripts in press that have undergone peer review]).