Focused Investment Partnership Proposal from North Coast Watershed Association

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1) Proposed priority description

a. What is the native fish or wildlife habitat to be conserved or another natural resource issue to be addressed?

b. What are the expected ecological outcome(s) to be achieved after this priority is addressed?

c. What is the defined geographic location within which this proposed priority can be successfully addressed?

We propose the Oregon portion of the lower Columbia River chum salmon *Oncorhynchus keta* ESU to be conserved through a focused investment partnership (FIP). Chum salmon were historically the most broadly distributed and potentially abundant species of Pacific salmon. Within the Columbia River, chum salmon historically migrated upstream to Celilo Falls (river km [RKM] 309; Nehlsen et al. 1991) and anecdotal reports indicate chum salmon may have entered the Walla Walla River (RKM ~470; Nehlsen et al. 1991; Johnson et al. 1997). From observation data at lower Snake River dams (Fish Passage Center), it also appears that some chum salmon migrated above Little Goose Dam, 638 RKM from the mouth of the Columbia River.

Beginning in the early 1800s, settlement along the lower Columbia River (LCR) and tributaries resulted in changes to land use and harvest of chum salmon that ultimately led to the extirpation of 90% of chum salmon populations in the LCR. In particular, removal of large woody debris from streams, channelization and diking of tributaries and the LCR, logging in headwaters and along stream banks, over harvest, and construction and operation of large dams dramatically decreased the availability and quality of habitat. Through the 1940s, chum salmon populations precipitously decreased in distribution and abundance, and by the 1950s, returns to the lower Columbia River numbered in the thousands.

In response to these dramatic declines, all populations of Columbia River chum salmon were listed as "threatened" under the Endangered Species Act in 1999 (USFWS 1999) as a single evolutionary significant unit (ESU). At the time of listing, 17 historic populations were recognized (Myers et al. 2003, USFWS 1999) and all but two of them (the Grays River and lower gorge populations) were considered extirpated (Kostow 1995). The Grays River population is located in Washington and the Lower Gorge population is located below Bonneville Dam on both sides of the Columbia River in tributaries and the mainstem. Following listing, Oregon Department of Fish and Wildlife (ODFW) developed a Chum Recovery Strategy (ODFW 2010) and a Chum Salmon Reintroduction Plan (Homel 2014) to detail the specific actions that need to be accomplished to recover chum salmon.

The objective of this proposed FIP would be to reestablish self-sustaining wild populations of chum salmon. This would occur through further research into limiting factors, restoration to address limiting factors, and in support of continued effort by ODFW to actively supplement or reintroduce chum salmon throughout the historic range.

These efforts would be focused in the mainstem and Oregon tributaries to the Columbia River from the upper extent of the Upper Gorge population to the mouth of the river (Figure 1).

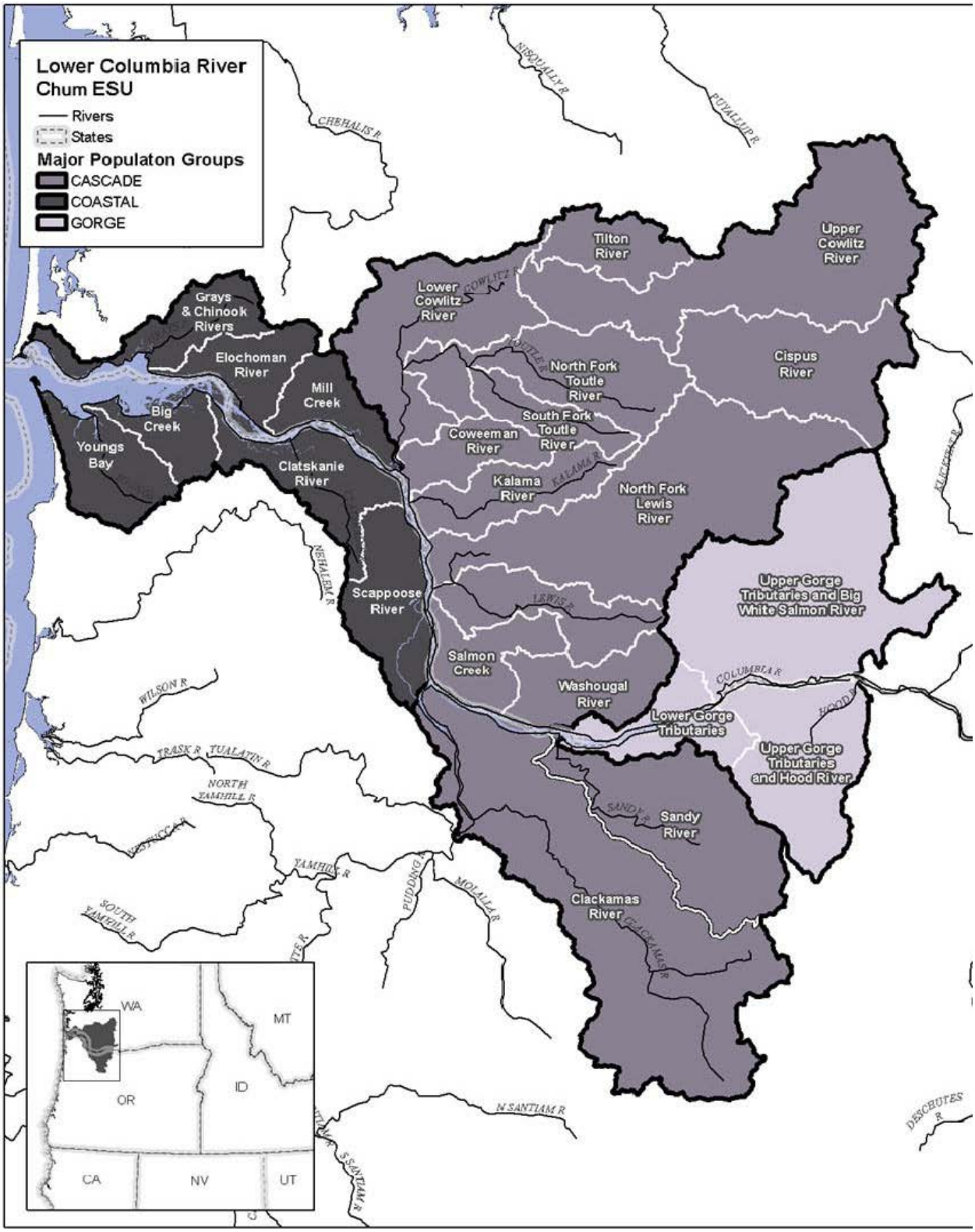


Figure 1. Designated recovery populations for chum salmon Oncorhynchus keta in the lower Columbia River ESU. This focused investment partnership targets all Oregon populations.

2) Significance to the state

a. Why is this proposed priority of ecological significance to the state, even though it may not be present everywhere in the state?

b. Are there any social and/or economic considerations that the Board should understand regarding this proposed priority?

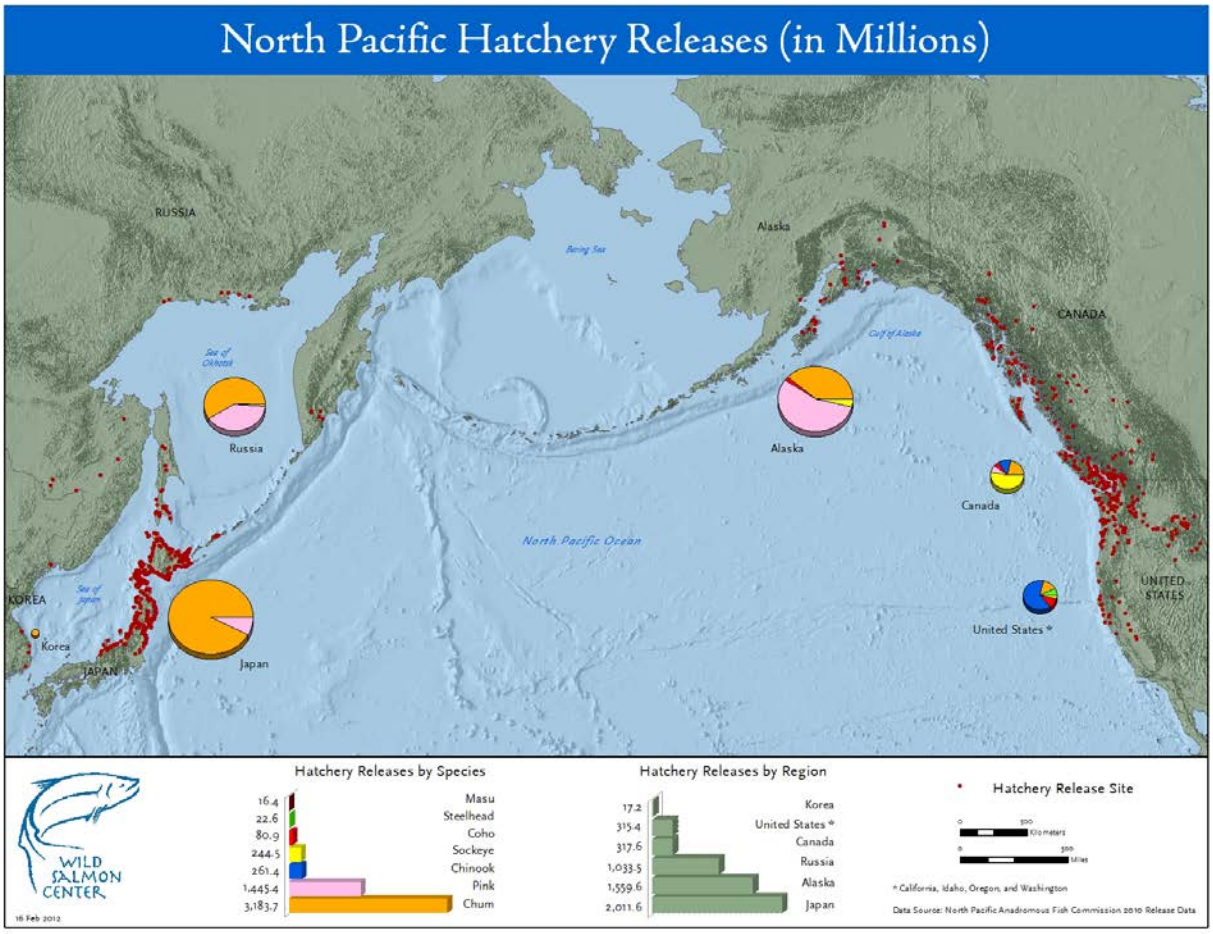
c. *In addition to its significance to the state, identify how the proposed priority fits within regional and local ecological priorities.*

Historically, chum salmon represented a significant portion of the annual returns of salmon and steelhead to the lower Columbia River; it is thought that 10-15 million salmon and steelhead returned annually (Gresh et al. 2000), of which chum may have comprised 7 – 10% of the return (NPPC 1986). The earliest estimate of abundance of chum salmon comes from commercial catch data; in 1928, over 700,000 chum salmon were captured (Smith 1979), which may have represented a population of over a million chum salmon (NPPC 1986). At an average of 8-15 pounds each (Salo 1991), those chum salmon returns represented a significant input of nutrients (Minakawa and Gara 1999) into the Columbia River basin (Gresh et al. 2000).

The loss of chum salmon has affected ecosystem function throughout the lower Columbia River. Chum salmon function as a keystone species in salmon ecosystems because of the habitats used for spawning, their ocean-type life history, and their spawning behavior. In particular, chum salmon spawn low down in tributaries and along banks in the mainstem Columbia River. As aggregates of chum salmon excavate redds, they flush excess fine sediments from the system and leave cleaner gravels that are suitable habitat for other species. After spawning, the adults die and provide nutrients to the stream, but because chum salmon are fry migrants, most of those nutrients remain in the stream and are available to fuel productivity for other species. Consequently, systems with chum salmon become more suitable for other fish species, in particular, listed salmon and steelhead. The level of marine derived nutrients to the ecosystem would be high. This level of nutrients would fuel productivity from forest health to the food chain from macro-invertebrates to juvenile fish to large carnivores. Additionally, the benefits of ecosystem restoration in chum habitat would extend to other native fish species particularly chinook in addition to coho, steelhead and lamprey.

The loss of chum salmon has also had economic impacts regionally and to the state of Oregon. Historically, 70-80% of chum salmon returns were harvested in the ocean both for flesh and for roe. Although not as valuable per pound as Chinook, the sheer volume of chum returns were economically valuable. Currently, chum salmon are more economically valuable than all other species of salmon except pink salmon. Globally, chum salmon have an estimated market value > 1 billion dollars (Wild Salmon Center, estimates for 2005-2007), and in the U.S., that value is > 187 million dollars. For reference, the U.S. commercial value of Chinook and coho salmon *combined* is 101 million dollars (Wild Salmon Center). *Although immediate goals to recover chum salmon are not focused on providing harvest opportunities,* if Columbia River chum salmon were recovered to the point of federal delisting, there could be significant economic benefit to the region. For these ecological and economic reasons, recovery of chum salmon through an FIP is of benefit to the state of Oregon at large, and to the lower Columbia River region.

Below is a map that shows evidence of the economic value of viable chum salmon populations elsewhere in the world.



3) Limiting Factors

a. Reference any framework(s) that exist (Recovery Plans, Implementation plans, etc.).

ODFW developed the Chum Recovery Strategy in 2010 to outline the overall approach towards restoring chum populations. In preparing that recovery strategy, it was determined that very little historic data existed on chum salmon distribution and abundance within the lower Columbia River. Moreover, it was unclear which specific limiting factors (historically) existed within each historic population and whether those limiting factors had been addressed. As such, the Chum Recovery Strategy was designed as a framework to guide recovery planning based on the information available at the time it was prepared and it outlined the specific critical uncertainties that need to be addressed to proceed with rebuilding chum populations. This plan was cited as the Oregon strategy for chum salmon recovery in the federal salmon recovery plan (NOAA 2013).

The Chum Recovery Strategy focused on recovery efforts in the Coastal Stratum in the Clatskanie River and Scappoose Creek Populations. It was thought that opportunities for recovery in those populations might be greater than in the Youngs Bay or Big Creek Populations given the large hatchery programs associated with the Select Area Fishery Enhancement Program (SAFE; ODFW 2010). The Chum Recovery Strategy suggested that specific re-establishment techniques could be tested in the Coastal Stratum and then refined and applied in the Cascade and Gorge Strata, once chum salmon became more numerous in the Coastal Stratum.

The Chum Salmon Reintroduction Plan (Homel 2014) summarized additional historic data on chum salmon in the LCR, identified target streams and abundance goals (consistent with the federal salmon recovery plan; NOAA 2013), and outlined the specific techniques, monitoring, and adaptive management to be employed during the re-establishment of chum salmon. The reintroduction plan focused on the entire lower Columbia ESU on the Oregon side of the LCR.

4. Threats and Benefits a) *What overall threats exist to the proposed priority identified?*

Each Columbia River Chum population experiences threats, but there are some common threats experienced by all populations. However, Diet composition data from DCCO nesting on East Sand Island indicate that chum salmon are rarely consumed (Lyons et al. 2014), indicating that something in their life history or behavioral patterns make them more resistant to avian predation in the Columbia River estuary.

Past or current land use practices: Physical habitat quality, including habitat complexity/diversity and loss of access to off-channel habitats, has been degraded through past and current land use practices. (*All juvenile populations*)

Hydrologic processes have been altered, and/or water quantity has been reduced due to land use practices on upland slopes. (*All juvenile and adult populations*)

Spawning habitat has been impaired due to fine sediment from forest and rural roads, land uses, as well as all roads built on unstable slopes. As a result, excessive amounts of fine sediments have entered the stream, reducing the quality of spawning gravels, incubation habitat and egg development and survival. (*All juvenile and adult populations*)

Water Quality is degraded by poor riparian conditions, which contribute to elevated water temperatures, and run-off from agricultural, rural and urban sources. (*All juvenile and adult populations*)

Columbia Basin hydropower dams and operations: Operations have altered the food web by reducing the macrodetrital input and increasing the microdetrital input. The substitution of the estuary's current microdetrital-based food web, made up of decaying phytoplankton delivered from upstream reservoirs, for the historical macrodetrital-based web has reduced productivity in the estuary. Operations have also altered the hydrograph/water quantity. Alteration of the Columbia River hydrograph changes the timing and magnitude of spring freshets, and impairs estuarine habitat quality and access. Artificial regulation of flow can stimulate or delay juvenile emigration, thereby affecting the timing of juvenile arrival in the estuary and ocean. Water regulation affects habitat-forming processes thereby impairing physical habitat quality by altering the sediment and sand routing processes. (*All juvenile populations*)

Bonneville Reservoir impacts access to and from habitats in the upper Gorge population. (*adult and juvenile*)

I-84 transportation corridor: Highway and rail development have degraded habitat quality and connectivity in the lower and upper Gorge populations. (*Adult and juvenile*)

b) *What will happen if threats are not addressed?*

Recovery of Oregon's chum salmon populations will be in jeopardy. The goals of the Lower Columbia River Recovery Plan, the Chum Recovery Strategy and the Chum Re-Introduction plan will be in danger of failure and significant resources put on the ground from 2010 to present will, at best, have a highly reduced return for the investment in terms of chum productivity.

c) *Describe the economic, social, iconic and cultural benefits of addressing the outcome and impacts of not addressing it.*

The economic and social impacts of addressing this proposed priority would play a role if the species is delisted from the federal ESA and achievement of broad sense recovery is realized. All Pacific salmon species are considered iconic and the return of chum salmon would be heralded as the first salmon species to be removed from the federal ESA. Chum salmon were mostly extirpated from the Columbia Basin prior to detailed abundance records being kept. According to the Northwest Power and Planning Council the earliest catch records in 1928 indicated a total of 700,000 chum harvested which equated to nearly 1,000,000 returning chum. This return level is estimated at approximately 10% of total salmon and steelhead returns to the Columbia River basin in comparison to 1% of the total returns which occurs now at two State of Washington locations. The amounts of nutrients provided by this size of chum salmon run would equal a 10-100X increase in what volunteers are able to place in stream from spawned and excess hatchery fish combined for all species. All salmon species are culturally significant to Native American tribes and can be seen as a symbol on totem poles and other art work representing instinct, persistence and determination.

The impacts of not addressing the priority will not truly be known. The work needed will proceed, but the pace remains unknown. The Oregon Department of Fish and Wildlife began implementing the Chum Recovery Strategy in 2010 and has invested in broodstock collections and releases, conducted habitat and estuary investigations and has been conducting baseline studies for 2 years. Chum spawners from the largest age class (4 yo) return in 2014 and will continue into the foreseeable future. The time is right to begin habitat restoration in the spawning grounds and estuary. Hydropower operations to benefit chum were negotiated during the Federal Hydropower System biological opinion.

d) *Briefly summarize how much has been done already, how much is remaining.*

The Chum Recovery Strategy was approved by the Oregon Fish and Wildlife Commission in 2010, which was a part of the Lower Columbia River Conservation and Recovery Plan. The strategy directed the department to work with the State of Washington to collect brood stock for hatchery purposes starting in 2010. Every year since that time ODFW has collected broodstock and released over 100,000 chum fry into Big Creek in Oregon. Beginning in 2012 habitat surveys commenced within the coastal stratum to assess and map potential spawning areas. In 2012 to present, baseline surveys were conducted to assess natural spawning and reproduction. In 2013 estuary investigations occurred to assess spatial distribution, movement and potential predation. Additionally, a small return of age 3 hatchery chum returned to Big Creek and 20 pairs were out-planted into to Clatskanie drainages. Juvenile traps were constructed and some natural production was observed in both drainages in the spring of 2014.

In 2014 the draft Chum Reintroduction Plan was developed and it is anticipated that a much larger adult return to Big Creek Hatchery from Age 4 fish will occur. In combination from these adult returns and from Washington State broodstock, ODFW should have double to triple the hatchery production for 2015 fry releases. Increased releases into Big Creek and from out planted eyed-eggs into the Clatskanie River should allow Oregon to eventually eliminate the need for Washington State broodstock.

For 2016 and beyond, spawn, screw trap and habitat surveys throughout the ESU will allow ODFW to assess the success of these efforts and potentially move to other basins such as Youngs Bay, Clackamas and the Sandy basins.

What remains at this time is to use the results of the habitat surveys which identify suitable spawning sites and implement identified enhancement actions that intend to improve chum productivity, while the hydropower threats are being dealt with through the Federal Hydropower System BiOp.

e) *What is your best estimate of cost to address the priority, and as a result, how economically feasible do you believe it is to address this priority over time*?

Best estimate to restore conditions within an independent population is approximately 15 million dollars. These estimates are based on the Lower Columbia River Recovery Plan cost estimates for approximately 15 miles of spawning are rearing habitat. These actions include easements, breaching dikes, LWD enhancements, off-channel habitat, riparian planting and storm proofing or vacating roads in high risk landslide areas. The feasibility of to address this priority over time is moderate to high within the Coastal stratum. With the Lower Columbia Estuary prioritization process that indicates certain populations in this stratum are a high priority brings BPA dollars to the table as can be seen in the Louisiana Swamp project and interests from the Columbia Land Trust and the Cowlitz Tribe.

5. Opportunities *What are the measures of ecological success? What's the likelihood of ecological success in the short, medium and long-term*?

The ultimate success would be to meet the goals of the Lower Columbia River Conservation and Recovery Plan and the draft Chum Recovery Strategy (in progress) of Federal delisting from the ESA and broad sense recovery. Success will not be met in the short term (6 years). A self-sustaining hatchery return to Big Creek Hatchery (non-reliance on Washington chum broodstock), the return of natural spawners in the Clatskanie population and 10 miles of stream restoration would be appropriate short term goals and should be attainable with a FIP. In the medium-term (15 years), it is unlikely to achieve the delisting goal. Having two self-sustaining populations within the ESU and an additional 10 miles of stream restoration would be appropriate goals. Long-term (30 years) success is likely if the short term goals are achieved and the public becomes aware of this success story. Population goals (and thus delisting) will be considered achieved when the minimum population goals are met for 15 consecutive years by spawners that were all naturally produced within the population, and all target streams are occupied, with stable or positive population growth rates.

What types of voluntary conservation actions could be undertaken to address the proposed priority?

Table 1. Prescribed habitat restoration actions for lower Columbia River chum salmon spawning habitat and estuary rearing habitat. (Draft Chum Re-introduction Plan)

Population	Stream	Action
Young's Bay	Skipanon R.	Improved connectivity, construct spawning channel
Young's Bay	Lewis and Clark R.	Removal of fill in tributaries, bank stabilization, gravel additions, large woody debris, improved connectivity, dike breaching
Big Creek	Big Cr.	Large wood additions, bank stabilization, address excess fine sediment, increase riparian vegetation, gravel additions
Big Creek	Bear Cr.	Secure water rights, gravel additions, large wood additions, increased habitat complexity, address excess fine sediment
Big Creek	Little Cr.	Large wood additions, channel stabilization, potentially create spawning channel if Little

		Creek remains bisected by Big Creek, improved riparian vegetation
Clatskanie	Graham Cr.	Replace culverts with box culvert, increase channel complexity, increase riparian vegetation, set back levees on both sides to double active channel width, add large woody debris, address excess fine sediment, gravel additions, address land use practices that may cause landslides or debris torrents (logging on over-steep slopes in headwaters)
Clatskanie	Clatskanie R.	Reconnect off channel habitat, large woody debris additions, address excess fine sediment, stabilize and re-grade banks, remove culverts
Clatskanie	Stewart Cr.	Replace culverts with box culvert, increase channel complexity, grade back banks and replant, large woody debris additions, gravel augmentation, address excess fine sediment
Clatskanie	Beaver Cr.	Large woody debris additions, address excess fine sediment, increase channel complexity
Scappoose	Milton Cr.	Add large woody debris, gravel augmentation, address excess fine sediment, re-grade stream bed where splash damming has caused significant erosion, replant stream banks, re-grade stream banks and replant, notch or remove low-head dams on mainstem, replace culvert barriers on tributaries, address sediment source in Cox Creek (a tributary)
Scappoose	Scappoose Cr.	Create off-channel habitat, add large woody debris, add gravel, lay back banks, re-vegetate banks, address agricultural runoff into stream, stabilize banks

Should the priority be divided into geographic areas that are appropriate for partners to address? Yes, spawning and rearing use by chum salmon will limit the geographic area by independent populations, but chum distribution throughout the ESU spans from the Upper Gorge to Youngs Bay. Some actions for the Cascade and Gorge strata are identified but additional actions will be forthcoming in the future as the habitat is further assessed during ensuing years.

Do partnerships exist to address the proposed priority? Yes, the Lower Columbia Estuary Partnership provides one full time employee to provide assistance in the Clatskanie and Scappoose basins and oversees projects in all tide water portions of the Lower Columbia River on behalf of Bonneville Power Association. Watershed councils and SWCDs also provide valuable partnerships. The NCWA (a group of four watershed councils) and the Clatsop and Columbia Counties SWCDs operate in the Coast Stratum and Multnomah and Clackamas County SWCDs operate within the Cascade and Gorge Strata and provide assistance. The USFWS is an ongoing partner for many projects in the Coast Stratum. ODOT is a supporter of chum re-introduction and has allowed trapping to occur within the ROW to assess natural reproduction in various watersheds. Many state and federal representatives on the chum work group assist with these efforts. The National Park Service has invested in chum recovery efforts through funding spawning surveys and reconnecting off-channel habitats to the Lewis and Clark River.

What social opportunities exist to address the proposed priority? Is there momentum built? Momentum has been built with outreach from watershed councils. A project has been designed and scheduled for implementation in the Clatskanie drainage with assistance from OWEB, the local watershed council, Columbia SWCD, the local NRCS and the Lower Columbia Estuary Partnership. Other potential sources for social opportunities area: Lewis and Clark National Historic Park, NCWA, ODFW on Facebook, Astoria's Nature Matters series and other outreach, SWCD outreach to the agricultural community and LCEP outreach to the tidal floodplain community.

Describe educational benefits. Since chum populations have been extirpated on the Oregon side of the river their life history and contributions to watershed health are not well understood by the public. Chum salmon are returning to Big Creek in 2014 in numbers that we have not seen in many decades. The

offspring will be released in the Clatskanie population and should return by 2017/18. Educating the public about their life history and their return should create quite an attraction in the coming years.

Summarize the social, community, political, regulatory or other factors that will help lead to the success of this proposed priority. The community will play a large role in the success of this priority. A majority of the actions needed to address this priority will rest in the hands of the agriculture and industrial timber communities. Regulatory factors will most likely not change due to the proposed FIP and voluntary measures are proposed in association with this project. Regulatory factors may come into play in regards to levee setback but are currently on-going. Political considerations may be needed at the county planning level to ease the process of potentially removing portions of agricultural land out of production to accommodate off channel and side channel voluntary restoration. Chum recovery has the potential to catalyze and unite fractured interests such as the gillnetting industry and environmentalists around a common cause – working together to recover a listed species, while continuing to support a heritage fishery, with the vision of abundance that will be win-win for all. (Note: recent research shows that chum could be more resistant to avian predation.)

What can be leveraged to address the proposed priority? Partnership funding, permitting assistance, materials donations, volunteer assistance, and technical assistance can all be leverage to address the priority.

Describe the economic benefits of addressing the ecological proposed priority? The economic benefits of meeting the long term goal of broad sense recovery pertain to having an abundant supply of fish to meet all societal needs. From a commercial standpoint if we had 500,000 fish return and harvested at 30% with a market price at $5 a fish this would equate to $750,000. The value of sport fishing is nearly ten times that of commercial fishing when factoring in license, snacks, travel, gear, etcetera and is currently limited to the Tillamook basin. (Also important to think about for the future is that Chum (aka keta) roe (caviar) currently has a worth of $95.00 per kilogram. Eventually, this region could produce its own high end keta.)

6. Assess the proposed priority by locating the proposed priority in one of the quadrants. Describe why the proposed priority falls in this quadrant.

We would describe the proposed priority as well understood but complex. The Chum Re-introduction Plan lays out the process that needs to occur to move toward recovery status and contains an adaptive management section that allows deviation from the process if monitoring does not indicate recovery is trending in right direction. The plan is well thought out and vetted through the Chum Workgroup with representatives who have the most experience in Oregon and Washington in chum recovery. The plan was based upon the Chum Recovery Strategy which was part of the Lower Columbia River Conservation and Recovery Plan. This plan was developed over a few years and had input from both a planning and stakeholder teams. While the process to restore the population is well understood there are many parts of recovery that make the process complex. This proposal is to restore habitat while other parts of the plan deal with hatchery management, chum re-introduction techniques, biological viability criteria, monitoring and adaptive management.

7) Is there any other information the Board should know regarding this priority?

The recovery of chum salmon populations has begun in earnest in Oregon, but funding for evaluation of limiting factors or for restoration projects has been limited. Despite this funding limitation, ODFW has already completed several important steps in the recovery of chum salmon. Beginning in 2010, Oregon

established an interagency Chum Recovery Workgroup focused on rebuilding historic populations. One of the first accomplishments of this workgroup was the identification of a hatchery where a broodstock could be started and creation of a memorandum of understanding with Washington Department of Fish and Wildlife to detail the collection, spawning, and transport of eggs from a healthy population in the Grays River, WA, to Big Creek Hatchery, OR. The first releases of fry from this broodstock (n = ~100,000) occurred in April, 2011.

From 2012-2014, annual efforts have been underway to identify whether any remnant spawning populations existed in Oregon through juvenile trapping and adult spawning surveys. In addition, coarse habitat surveys have been conducted to identify what spawning habitat currently exists and to begin identifying potential restoration sites in target populations. These studies culminated in 2013 with the first experimental outplanting of chum salmon in the Clatskanie Population. Other research has been conducted by ODFW with partners at WDFW, NOAA, and the watershed councils.

Ultimately, investing in chum salmon recovery provides an opportunity to recover an iconic species to the historic range. In fact, because chum salmon have limited freshwater rearing, this may be the easiest salmon species to recover in the Columbia River Basin. For lack of a better term, chum are the low hanging fruit of salmon recovery. Chum deserve as much attention as other listed species. *Moreover, because chum salmon are not yet harvested, this recovery effort provides an opportunity to test the effectiveness of reintroduction and restoration strategies without impacting commercial and recreational fisheries.*

8. List of Partners

ODFW, North Coast Watershed Association, Lewis and Clark National Historic Park, NOAA, area landowners, Lower Columbia Watershed Council, Astoria High School, Clatsop and Columbia SWCDs and USFWS. Potential partners are the Cowlitz Tribe and CREST.

References

Gresh, T., J. Lichatowich, and P. Schoonmaker. 2000. An Estimation of Historic and Current Levels of Salmon Production in the Northeast Pacific Ecosystem: Evidence of a Nutrient Deficit in the Freshwater Systems of the Pacific Northwest. Fisheries 25: 15-21.

Homel, K. 2014. Chum Salmon Reintroduction Plan. *Draft*. Oregon Department of Fish and Wildlife, Clackamas, OR, 200 pps.

Johnson, O. W., W. S. Grant, R. G. Kope, K. Neely, F. W. Waknitz, and R. S. Waples. 1997. Status review of chum salmon from Washington, Oregon, and California. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-NWFSC No. 32.

Lyons, D.E.,D.D. Roby, A.F. Evans, N.J. Hostetter, and K. Collis. 2014. Benefits to the Columbia River anadromous salmonids from potential reductions in predation by double-crested cormorants nesting at the East Sand Island colony: A report to the U.S. Army Corps of Engineers Portland District. Bird Research Northwest. Available on-line at www.birdresearchnw.org

Minakawa N. and R. I. Gara. 1999. Ecological effects of a chum salmon (*Oncorhynchus keta*) spawning run in a small stream of the Pacific Northwest Journal of Freshwater Ecology 14: 327‑335.

Myers, J., C. Busack, D. Rawding, and A. Marshall. 2003. Historical population structure of Willamette and lower Columbia River basin Pacific salmonids. 92 Willamette/Lower Columbia River Technical Recovery Team report. (October 2003). (Available at http://www.nwfsc.noaa.gov/trt/popid_report.htm)

Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington. Fisheries (Bethesda) 16: 4-21.

NOAA 2013. Lower Columbia River plan for salmon and steelhead. Available at: http://www.westcoast.fisheries.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/lower_columbia_river/lower_columbia_river_recovery_plan_for_salmon_steelhead.html. (Accessed May 14, 2014).

Northwest Power Planning Council (NPPC). 1986. Appendix D of the 1987 Columbia River Basin Fish and Wildlife Program. Compilation of information on salmon and steelhead losses in the Columbia River Basin. March 1986. Portland, Oregon.

ODFW 2010. Lower Columbia River conservation and recovery plan for Oregon populations of salmon and steelhead. Appendix I: Oregon's Columbia River chum salmon recovery strategy. Available at: http://www.dfw.state.or.us/fish/CRP/docs/lower-columbia/OR_LCR_Plan_Appendices%20-%20Aug_6_2010_Final.pdf (Accessed May 14, 2014).

Salo, E.O. 1991. Life history of chum salmon, *Oncorhynchus keta*. *In* Pacific salmon life histories. *Edited by* C. Groot and L. Margolis. UBC Press, Vancouver. pp. 231-309.

U.S. Fish and Wildlife Service. 1999. Endangered and Threatened Wildlife and Plants; Listing of Nine Evolutionary Significant Units of Chinook Salmon, Chum Salmon, Sockeye Salmon, and Steelhead. Final Rule, 50 CFR Part 17, RIN 1018-AF70. Federal Register 64(147): 41835- 41839.

Wild Salmon Center: http://www.wildsalmoncenter.org/pdf/Salmon_Economic_Valuation.pdf