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Endangered Species Act Recovery Plan for the Southern Distinct Population Segment of Eulachon (*Thaleichthys pacificus*)

Prepared by: National Marine Fisheries Service, West Coast Region

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Recovery Plan for Southern Distinct Population Segment of Eulachon

Thaleichthys pacificus

Approved: Chris Oliver

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Assistant Administrator for Fisheries,
National Oceanic and Atmospheric Administration

Date: 9/6/17

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Acknowledgements

Eulachon Recovery Team

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Eulachon Stakeholder Group

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Recovery Plan Development

This recovery plan is the product of a collaborative process initiated by NMFS and strengthened through regional and local participation. The goal was to produce a Recovery Plan that would meet NMFS' ESA requirements for recovery plans as well as broader needs. Throughout the recovery planning process, NMFS collaborated with the states of California, Oregon, and Washington, the Department of Fisheries and Oceans Canada, as well as with other Federal agencies, tribal and local governments, representatives of industry and environmental groups, other stakeholders, and the public.

The collaborative process reflects NMFS' belief that ESA recovery plans should be based on state, regional, tribal, local, and private conservation efforts already underway throughout the region. Local support of recovery plans by those whose activities directly affect the listed species, and whose actions will be most affected by recovery efforts, is essential to recovery plan implementation.

NMFS developed this Recovery Plan by synthesizing the best available scientific and commercial data available with input from (1) the Eulachon Recovery Team, and (2) the Eulachon Stakeholder Group. On October 20, 2016, we released the *Proposed ESA Recovery Plan for the southern DPS of Eulachon* (Draft Recovery Plan), and published a notice of availability in the *Federal Register* (81 FR 72572) requesting comments. Four comment submissions were received during the 60-day public comments period on the Draft Recovery Plan. We considered all of the public comments received on the Draft Recovery Plan in developing the final version of the Recovery Plan.

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Abbreviations and Acronyms

Biological Review Team	BRT
Department of Fisheries and Oceans Canada	DFO
Distinct Population Segments	DPS
Environmental Species Act	ESA
National Oceanic and Atmospheric Administration	NOAA
Northwest Fisheries Science Center	NWFSC
National Marine Fisheries Service	NMFS
Oregon Department of Fish and Wildlife	ODFW
United States Fish and Wildlife Service	USFWS
Washington Department of Fish and Wildlife	WDFW

Terms and Definitions

Adaptive Management	The process of adjusting management actions and/or directions based on new information.
Endangered Species	A species in danger of extinction throughout all or a significant portion of its range.
ESA Recovery Plan	A plan to recover a species listed as threatened or endangered under the U.S. Endangered Species Act (ESA). The ESA requires that recovery plans, to the extent practicable, incorporate (1) objective, measurable criteria that, when met, would result in a determination that the species is no longer threatened or endangered; (2) site-specific management actions that may be necessary to achieve the plan's goals; and (3) estimates of the time required and costs to implement recovery actions.
Delisting Criteria	Criteria incorporated into ESA recovery plans that define both biological viability (biological criteria) and alleviation of the causes for decline (threats criteria based on the five listing factors in ESA section 4[a][1]), and that, when met, would result in a determination that a species is no longer threatened or endangered and can be proposed for removal from the Federal list of threatened and endangered species.
Diversity	All the genetic and phenotypic (life history, behavioral, and morphological) variation within a population. Variations could include fecundity, run timing, spawn timing, behavior, age at maturity, egg size, developmental rate, ocean distribution patterns, male and female spawning behavior, physiology, molecular genetic characteristics, etc.
Escapement	The amount of fish in a given population that does not get caught by commercial or recreational fisheries and return to their freshwater spawning habitat.
Factors for Decline	Five general categories of causes for decline of a species, listed in the Endangered Species Act section 4(a)(1)(b): (A) the present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the

	inadequacy of existing regulatory mechanisms; or (E) other natural or human-made factors affecting its continued existence.
Goal	The end toward which effort is directed.
Limiting Factors	Impaired physical, biological, or chemical features (e.g., inadequate spawning habitat, high water temperature, insufficient prey resources) that result in reductions in population parameters (abundance, productivity, spatial structure, and diversity). Key limiting factors are those with the greatest impacts on a population's (or major population group's or species') ability to reach its desired status.
Monitoring	Implementation monitoring to determine whether an activity was performed and/or completed as planned.
Objectives	The parameters which, when taken together, characterize the conditions under Persistence Probability
Persistence Probability	The complement of a population's extinction risk (i.e., persistence probability = 1 – extinction risk).
Phenotypic Trait	A phenotypic trait is an obvious, observable, and measurable trait; it is the expression of genes in an observable way.
Productivity	The average number of surviving offspring per parent. Productivity is used as an indicator of a population's ability to sustain itself or its ability to rebound from low numbers. The terms "population growth rate" and "population productivity" are interchangeable when referring to measures of population production over an entire life cycle.
Recovery Strategy	A statement that identifies the assumptions and logic—the rationale—for the species' recovery program.
Self-sustaining	A self-sustaining viable population has a negligible risk of extinction due to reasonably foreseeable changes in circumstances affecting its abundance, productivity, spatial structure, and diversity characteristics over a 100- year period and achieves these characteristics without dependence upon artificial propagation. Artificial propagation may be used to benefit threatened and endangered species and a self-sustaining population may include artificially propagated fish, but a self-sustaining population must not be dependent upon propagation measures to achieve its viable

	characteristics. Artificial propagation may contribute to but is not a substitute for addressing the underlying factors (threats) causing or contributing to a species' decline.
Threatened Species	A species likely to become endangered within the foreseeable future throughout all or a significant portion of its range.
Threats	Human activities or natural events (e.g., dams, road building, floodplain development, fish harvest, hatchery influences, and volcanoes) that cause or contribute to limiting factors. Threats may exist in the present or be likely to occur in the future.

EULACHON RECOVERY PLAN—EXECUTIVE SUMMARY

Introduction

This Recovery Plan serves as a blueprint for the protection and recovery of the southern Distinct Population Segment (DPS) of eulachon (*Thaleichthys pacificus*) using the best available science per the requirements of the Endangered Species Act (ESA). The Recovery Plan links threats and management actions to an active research program to fill data gaps, and a monitoring program to assess these actions' effectiveness. Research and monitoring results will provide information to refine ongoing actions and prioritize new actions to achieve the Plan's goal: to restore the listed species to the point where it no longer requires the protections of the ESA.

Current Status of the DPS

Eulachon are endemic to the northeastern Pacific Ocean; they range from northern California to southwest and south-central Alaska and into the southeastern Bering Sea. The southern DPS of eulachon is comprised of fish that spawn in rivers south of the Nass River in British Columbia to, and including, the Mad River in California (Gustafson et al. 2010), and was listed as a threatened species[1] under the ESA on March 18, 2010 (75 FR 13012). NMFS' 2016 ESA five-year review concluded that the DPS's threatened designation remained appropriate. Critical habitat was designated under the ESA for eulachon on October 20, 2011 (76 FR 65324).

The Biological Review Team (BRT) concluded that, starting in 1994, the southern DPS of eulachon experienced an abrupt decline in abundance throughout its range (Gustafson et al. 2010). Although eulachon abundance in monitored rivers improved in the 2013–2015 return years, recent conditions in the northeast Pacific Ocean are likely linked to the sharp declines in eulachon abundance in monitored rivers in 2016 and 2017. The likelihood that these poor ocean conditions will persist into the near future suggest that subpopulation declines may again be widespread in the upcoming return years.

Abundance and Productivity

There are no reliable fishery-independent, historical abundance estimates for eulachon. Spawning stock biomass estimations of eulachon in the Columbia River for the years 2000 through 2017 have ranged from a low of 783,400 fish in 2005 to a high of 185,965,200 fish in 2013, with an estimated 18,307,100 fish in 2017[2]. Spawning stock biomass estimations of eulachon in the Fraser River for the years 1995 through 2017 have ranged from a low of 109,129

[1] In this document, "the species" and "eulachon" refers to the southern DPS of eulachon.

[2] Annual Columbia River eulachon run size 2000-2017; pounds converted to numbers of fish at 11.16 fish/pound (WDFW 2017). The estimates were calculated based on methods developed by Parker (1985), Jackson and Cheng (2001), and Hay et al. (2002) to estimate spawning biomass of pelagic fishes. For 2000 through 2010 estimates were back-calculated using historical larval density data.

to 146,606 fish in 2010 to a high of 41,709,035 to 56,033,332 fish in 1996, with an estimated 763,330 to 1,026,251 fish in 2017[3].

Threats and Limiting Factors

The BRT categorized climate change impacts on ocean conditions as the most serious threat to the persistence of eulachon in all four subpopulations of the DPS: Klamath River, Columbia River, Fraser River, and British Columbia coastal rivers south of the Nass River. Climate change impacts on freshwater habitat and eulachon bycatch in offshore shrimp fisheries were also ranked in the top four threats in all subpopulations of the DPS. Dams and water diversions in the Klamath and Columbia rivers and predation in the Fraser and British Columbia coastal rivers filled out the last of the top four threats (Gustafson et al. 2010). These threats, together with large declines in abundance, indicated to the BRT that eulachon were at moderate risk of extinction throughout all of its range (Gustafson et al. 2010). Table ES-1 is the BRT's qualitative threats assessment based on the modal score for each threat in each subpopulation. The BRT did not identify any limiting factors for eulachon.

Table ES-1. Eulachon Level of Threat Severity in each Subpopulation.

	Subpopulation			
Threats	**Klamath**	**Columbia**	**Fraser**	**BC**
	Severity			
Climate change impacts on ocean conditions	high	high	high	high
Dams /water diversions	moderate	moderate	very low	very low
Eulachon bycatch	moderate	high	moderate	high
Climate change impacts on freshwater habitat	moderate	moderate	moderate	moderate
Predation	moderate	moderate	moderate	moderate
Water quality	moderate	moderate	moderate	low
Catastrophic events	very low	low	very low	low
Disease	very low	very low	very low	very low
Competition	low	low	low	low
Shoreline construction	very low	moderate	moderate	low
Tribal/First Nations fisheries	very low	very low	very low	low
Non-indigenous species	very low	very low	very low	very low
Recreational harvest	very low	low	very low	very low
Commercial harvest	very low	low	low	very low
Scientific monitoring	very low	very low	very low	very low
Dredging	very low	moderate	low	very low

[3] The estimates were calculated based on methods developed by (Parker 1985), Jackson and Cheng (2001), and Hay et al. (2002) to estimate spawning biomass of pelagic fishes. Spawning stock biomass estimates for the Fraser River subpopulation were based on 9.9 fish/pound and 13.3 fish/pound, respectively.

Eulachon Recovery—what does recovery look like, and how will we know when we are there?

There is more that is not known about eulachon (e.g., their distribution and abundance in the marine environment, or how the species responds to condition-shifts in the marine and freshwater environments), than is known. These uncertainties present a challenge in developing quantifiable parameters (e.g., abundance—numbers of spawners averaged over a time period sufficient to account for year-to-year fluctuations that are due to natural environmental variation) that would indicate when eulachon are viable, self-sufficient, and no longer in danger of extinction or likely to become endangered in the foreseeable future. Therefore, what is provided here is a recovery concept which describes a set of qualitative conditions that if met, would indicate that the species is likely no longer in danger of extinction.

What we don't know—historically, eulachon have been a relatively poorly monitored species—compared to other commercial and recreational fisheries. As such, the data necessary to develop quantitative-based (e.g., life-cycle models, population viability analysis) recovery criteria for abundance and productivity does not exist. Likewise, the data to develop genetic, life history, and spatial diversity criteria for eulachon is too fragmented to develop subpopulation-specific recovery criteria. As such, and at this time, this Recovery Plan does not provide quantitative viability criteria for each biological parameter—abundance, productivity, spatial structure and temporal distribution, and genetic and life history diversity—for each subpopulation, but instead provides general recovery criteria based on the limited data we have and the principals of conservation biology.

What we do know—the historical accounts of eulachon portray a species with sustained runs sufficient to provide a century-plus of unrestrained harvest opportunities throughout the range of the species.

The historical landings data for the Columbia River subpopulation goes back as far as 1888[4] with newspaper reports as far back as 1866[5], and the sport dip net fishery was first reported in 1865[6]. As there are no historical fishery-independent abundance estimates for eulachon, the historical landings data can be considered a minimum measure of fish abundance[7]. Based on the landings

[4] Ceremonial and subsistence fishery for Washington and Oregon Indian Tribes in the Columbia River Basin has taken place for thousands of years. However, there are no reliable records for landings.
[5] The Oregonian, 24 February, 1866.
[6] Huntington 1963.
[7] There are no reliable landings data available for the sport dip net fishery other than an exploratory sampling program conducted by the Washington Department of Fish and Wildlife (WDFW) in 1978 on the Cowlitz River. Based on the information collected from this exploratory sampling program, WDFW estimated that the sport dip net fishery was comparable to the commercial harvest. WDFW memorandum—Cowlitz River smelt sport dip net fishery total catch estimate.

data[8], we estimated that in order to maintain harvest rates of 12,000,000 to 128,000,000[9] fish per year, the total run size would have to have been substantially higher than the estimated range of adult eulachon harvested per year.

The historical landings data for the Fraser River subpopulation goes back as far as 1881. As there are no historical fishery-independent abundance estimates for eulachon, the historical landings data can be considered a minimum measure of fish abundance. Based on the landings data[10], we estimated that in order to maintain harvest rates of 90,000 to 8,000,000[11] fish per year, the total run size would have to have had to have been substantially higher than the estimated range of eulachon harvested per year.

The historical landings data for the BC subpopulation goes back as far as 1877. As there are no historical fishery-independent abundance estimates for eulachon, the historical landings data can be considered a minimum measure of fish abundance. Based on the landings data[12], we estimated that in order to maintain harvest rates of 9,000 to 5,000,000[13] fish per year, the total run size would have to have had to have been substantially higher than the estimated range eulachon harvested per year.

The historical landings data for the Klamath River subpopulation is extremely limited. The only reliable landings data is for 1963[14], when a total of 650,000 fish were reported to have been landed. Based on the limited nature of the data we cannot estimate the fraction of the harvest relative to the total run (escapement[15]). Nonetheless, what is known is that harvest of eulachon in the Klamath River has been documented for more than 100 years, albeit intermittently, as far back as 1879, and in the years 1919, 1963, 1968, 1969, 1976, 1978, 1979, and 1980[16].

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[8] Commercial harvest data is available from 1888 – 2017 for the whole Columbia River system (most years, a few missing) and broken down by state (early years) and/or tributaries (mostly after 1935). Harvest is reported as pounds landed (converted to numbers of fish). We restrict the data to the period 1936 – 1992 so that we have a consistent set of tributary data, and because earlier data may be more unreliable. The geometric mean of the commercial landings data for the years 1936 through 1992 (range) was 6,000,000 to 64,000,000 fish. All landings estimates were rounded.
[9] Combined estimate – commercial and sport dip net fishery.
[10] Commercial harvest data is available from 1881 – 2004 for the Fraser River. Harvest is reported as metric tons landed (converted to numbers of fish). We restrict the data to the period 1936 – 1992 so that we have a consistent set of data with the Columbia River, and because earlier data may be more unreliable.
[11] The geometric mean of the commercial landings data for the years 1936 through 1992 (range) was 90,000 to 8,000,000 fish.
[12] Harvest data is available from 1887 – 2009 for the BC subpopulation (multiple rivers). Harvest is reported as metric tons landed (converted to numbers of fish). We restrict the data to the period 1936 – 1992 so that we have a consistent set of data with the Columbia and Fraser River, and because earlier data may be more unreliable.
[13] The geometric mean of the commercial landings data for the years 1936 through 1992 (range) was 9,000 to 5,000,000 fish. In 2001 DFO conducted a spawning stock biomass estimation for the Skeena River with a median estimate of 10,733,968 fish, Lewis et al. 2009.
[14] Gustafson et al. 2010.
[15] The amount of fish in a given population that does not get caught by commercial or recreational fisheries and return to their freshwater spawning habitat.
[16] Gustafson et al. 2010.

Therefore, one way to answer "*what does recovery look like, and how will we know when we are there?*" is to have sustained eulachon runs that provide harvest opportunities in-line with the historical landings data described herein for each subpopulation—plus an escapement multiplier to sustain each of the four subpopulations across multiple generations.

Recovery Strategy

There is much uncertainty in our knowledge regarding how threats (Table ES-1) influence eulachon. Nonetheless, we propose to work on what we can to advance the conservation of eulachon by working with our stakeholders to continue to implement actions that further reduce the severity of threats to eulachon, as well as develop a comprehensive research program to collect the data to enable a greater understanding of eulachon population abundance and demographics, and improve our understanding of the impact that large-scale threats like climate change impacts on ocean conditions have on eulachon productivity, recruitment, and persistence.

Therefore, we have developed an approach that includes a set of priority actions and near-term research priorities to be implemented in years 1 through 5 to expedite funding and implementation of recovery actions that will reduce the severity of threats, and to kick-start the research necessary to answer some of the questions needed to improve our understanding of the species and the linkages between threats, marine and freshwater environments, and the species. Although we have identified a set of priority recovery actions and near-term research priorities, this in no way implies that all recovery actions identified in this Recovery Plan should wait to be implemented. Based on these initial results, we will then make adjustments, via adaptive management, to this Recovery Plan to implement recovery action in years 5 through 25.

Priority Actions

- Establish a eulachon technical recovery and implementation team to develop an overall framework for funding, prioritization, implementation, and reporting of recovery actions.
- Develop outreach and education strategies regarding the ecological, economic, and cultural values of eulachon; foster stewardship of the marine ecosystem; expand funding and research partnerships; and increase involvement of existing regional and international organizations.
- Continue to work with the ocean shrimp trawl fisheries and the states of California, Oregon, and Washington to implement actions, e.g., fleet-wide implementation of light emitting diode lights, rigid grate bycatch reduction devices, and additional gear-type or operational modifications, to further reduce bycatch of eulachon in the ocean shrimp trawl fisheries.
- Continue to work with the states to implement a limited-opportunity eulachon fishery to: (1) provide essential context for interpreting historical harvest data to better understand trends and variability in eulachon abundance; (2) filling critical information gaps such as

the length and age structure of spawning eulachon, as well as the temporal and spatial distribution of the run; (3) supporting the cultural traditions of Northwest tribes who rely on eulachon as a seasonally important food source; and (4) providing a limited public and commercial opportunity for eulachon harvest to maintain a connection between people and the eulachon resource. This connection is important to sustaining public engagement in eulachon conservation and recovery.

- Continue to work with Federal and non-Federal entities that maintain and operate dams and channel-spanning water control structures to develop and implement actions to reduce the ecological effects caused by water management operations on riverine and estuarine habitats to support the full-range of biological requirements for eulachon.
- Continue to work with the U.S. Army Corps of Engineers to develop and implement actions to reduce impacts from dredging, e.g., entrainment, on eulachon.
- Continue to work with the states of California, Oregon, and Washington to implement programs that improve water quality for temperature.
- Continue to work with Federal agencies and the states of California, Oregon, and Washington to implement programs, e.g., revetment breaching and removal, to reduce the impacts of shoreline construction on eulachon and their habitats.

Near-Term Research Priorities

Abundance and Productivity

- Conduct annual in-river spawning stock biomass surveys in spawning areas with a high-to-moderate spawning frequency to develop long-term, high resolution abundance estimations for each subpopulation of eulachon.
- Conduct a gap analysis to identify the data needs to develop an at-sea survey method to create a reliable index of eulachon abundance in the marine environment.
    - Develop and implement an at-sea survey method to create a reliable index of eulachon abundance in the marine environment.

Spawning Habitat

- Conduct a gap analysis to identify the data needs to develop a survey method to map eulachon spawning areas, with an emphasis on identifying high density spawning areas, for each subpopulation.
    - Implement a high resolution mapping survey to identify high density eulachon spawning areas for each subpopulation.

Subpopulation Structure

- Conduct a gap analysis to identify the data needs to develop a genetic mixed stock baseline analysis of eulachon spawning subpopulations.
    - Conduct a genetic baseline analysis of eulachon spawning subpopulations to determine subpopulation-population structure of eulachon throughout the range of the DPS.

- Conduct a gap analysis to identify the data needs to develop a genetic mixed stock baseline analysis of eulachon in the marine environment.
    - Conduct a genetic mixed stock baseline analysis of eulachon in the marine environment.
- Conduct a gap analysis to identify the data needs to develop a method to correlate in-river and marine abundance estimations of eulachon.
    - Conduct an analysis that correlates in-river and marine abundance estimations of eulachon.

Species-Ecosystem Interactions

- Conduct a gap analysis to identify the data needs to develop an ocean ecosystem indicators model of eulachon marine survival in the California Current Ecosystem.
    - Develop an ocean ecosystem indicators model of eulachon marine survival in the California Current Ecosystem to determine how short-term and long-term variability in ocean conditions affect eulachon abundance and productivity for each subpopulation.

Subpopulation Viability Criteria

- Conduct a gap analysis to identify the data needs, e.g., age composition, length-weight relationship, intrinsic mortality rates, sex ratios, fecundity; necessary to parameterize a population viability analysis and develop abundance and productivity criteria for each subpopulation of eulachon.
    - Develop abundance and productivity criteria for each subpopulation of eulachon.

In addition to the actions directed at eulachon and their habitats, there are hundreds of habitat restoration projects each year that are implemented in California, Oregon, and Washington aimed at improving riverine and estuarine habitats. Some of these habitat restoration actions, e.g., actions that improve water quality, are likely to improve riverine and estuarine habitats for eulachon as well, resulting in direct and indirect benefits to eulachon.

Recovery Goal, Objectives, and Delisting Criteria

Recovery Goal

The goal of this Recovery Plan is to:

1. Increase the abundance and productivity of eulachon.

2. Protect and enhance the genetic, life history, and spatial diversity of eulachon throughout its geographical range; and

3. Reduce existing threats to warrant delisting of the species.

Figure ES-1 is a conceptual model that illustrates the linkages of the recovery strategy with the goal, objectives, delisting criteria, and actions.

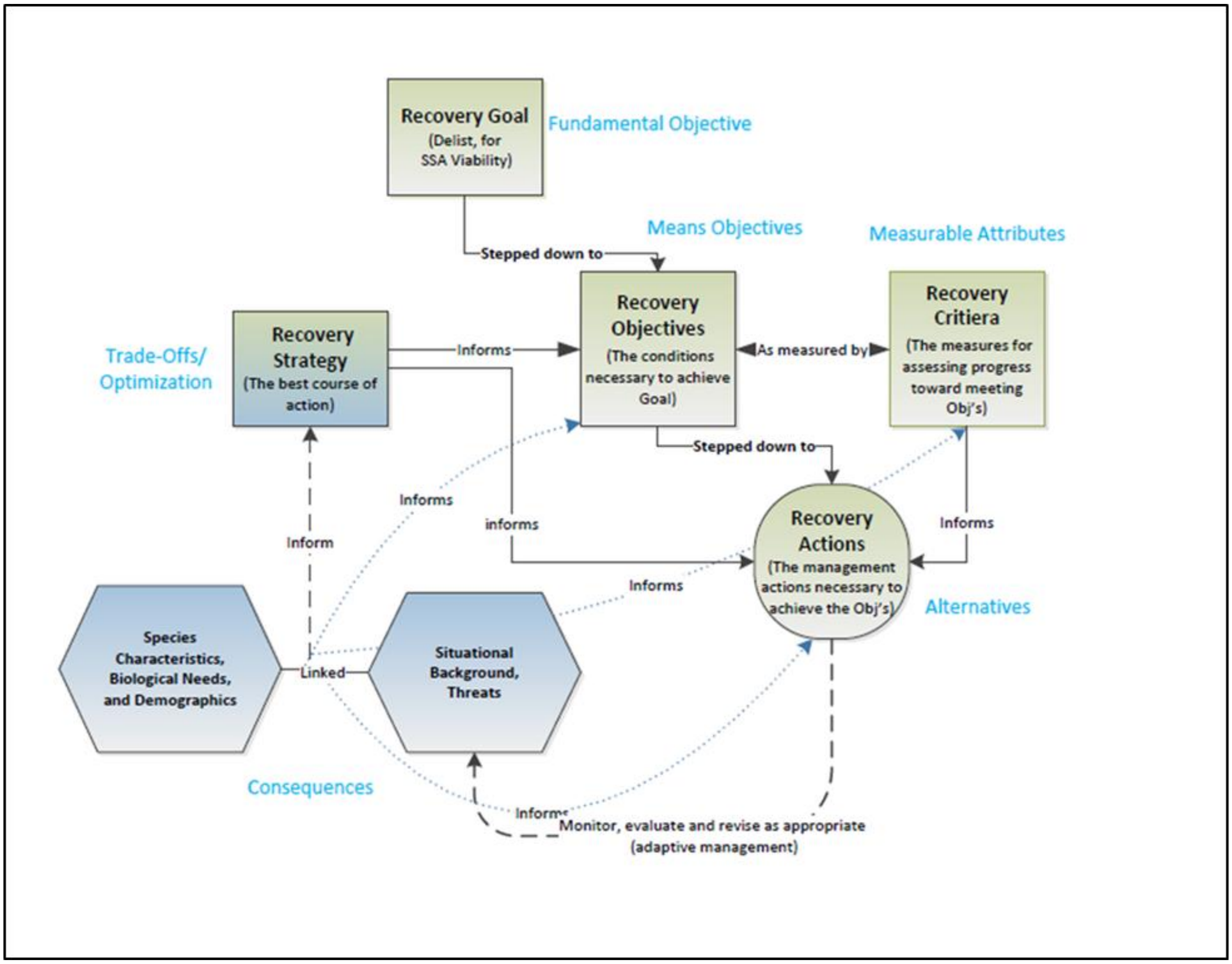

Figure ES-1. Recovery strategy conceptual model.

Recovery Objectives

The recovery goal can be subdivided into discrete component objectives that, collectively, describe the conditions necessary for achieving the recovery goal. The Eulachon Recovery Team identified four recovery objectives:

1. Ensure subpopulation viability.

2. Conserve spatial structure and temporal distribution patterns.

3. Conserve existing genetic and life history diversity and provide opportunities for interchange of genetic material between and within subpopulations.

4. Eliminate or sufficiently reduce the severity of threats.

Delisting Criteria

The Eulachon Recovery Team determined that meeting the following measurable criteria will indicate when the recovery objectives have been sufficiently achieved to propose removal of eulachon from the Federal list of threatened and endangered species.

1. Abundance: Each of the four subpopulations is self-sustaining, i.e., each subpopulation has less than 5% probability of extinction in 100 years.

2. Productivity: Each subpopulation has a stable or increasing growth rate greater than 1 across multiple generations.

3. Spatial Structure and Temporal Distribution: Eulachon subpopulations are distributed in a manner that insulates against loss from local catastrophic events and provides for re-colonization of a subpopulation that is affected by such an event.

4. Genetic and Life History Diversity: Eulachon subpopulations exhibit high certainty that genetic and life history diversity is sufficient to sustain natural production across a range of conditions, and eulachon subpopulations exhibit high certainty that changes in phenotypical traits represent positive natural adaptations to prevailing environmental conditions.

5. Threats: For each subpopulation, the threats listed in Table ES-1 have been diminished such that they do not limit attainment of the desired biological status of the DPS, and all the factors in section 4(a)(l) of the ESA have been addressed.

This Recovery Plan covers the status, threats, recovery goals, objectives, and delisting criteria for eulachon at the species' scale. However, for the most part[17], the recovery actions in this document are specific to eulachon subpopulations within the jurisdiction of the U.S. For the Fraser River and British Columbia Coast subpopulations, NMFS will, to the extent feasible, collaborate with the Department of Fisheries and Oceans Canada (DFO) and First Nations in Canada to develop recovery actions to address threats to eulachon for the Fraser River and BC subpopulations.

[17] Due to the nature of the threats eulachon face, e.g., climate impacts on ocean conditions, as well as the distribution of eulachon in the marine environment, actions to address the species' and the threats it faces will cross political jurisdictions.

Adaptive Management

In conjunction with a research, monitoring, and evaluation plan, adaptive management plays a critical role in recovery planning. The long-term success of recovery efforts will depend on the effectiveness of incremental steps taken to move eulachon from its current status to a viable level, and to restore self-sustaining eulachon subpopulations in the U.S. and Canada. Adjustments will be needed if actions do not achieve desired goals, and to take advantage of new information and changing opportunities. Adaptive management provides the mechanism to facilitate these adjustments.

Adaptive management works by binding decision making with data collection and evaluation. Most importantly, it offers an explicit process through which alternative approaches and actions can be proposed, prioritized, implemented, and evaluated. Successful adaptive management requires that monitoring and evaluation plans be incorporated into overall implementation plans for recovery actions. These plans should link monitoring and evaluation results explicitly to feedback on the design and implementation of actions.

Figure ES-2. The adaptive management process.

Time and Cost Estimates

It is important to consider the unique challenges of estimating time and cost for eulachon recovery given the complex relationship of these fish to the environment and to human activities on land and water. NMFS estimates that it will take approximately 25 to 100 years for the southern DPS of eulachon to achieve recovery. The recovery plan contains an extensive list of actions to recover the subpopulations; however, it recognizes that there are many uncertainties involved in predicting the course of recovery and in estimating total costs over such a long recovery period. Such uncertainties include biological and ecosystem responses to recovery actions.

NMFS has developed a set of recovery actions and cost estimates based on the best information currently available. With the many uncertainties involved in predicting the course of recovery and in estimating total costs, we focused on the first five years of implementation and in five-year intervals thereafter to coincide with our 5-year status reviews, with the understanding that before the end of each five-year implementation period, specific actions and costs will be estimated for subsequent years. Based on recovery actions for which we have cost estimates, the cost of implementation in the U.S. jurisdiction over the first 5 fiscal years is $12,205,000. A gross estimate for the total cost of recovery actions to be implemented in the U.S jurisdiction is between $21,358,750 (25 years) to $32,038,125 (100 years). After the first 5 years, we will reevaluate the status of eulachon based on the information gathered over this period. It should be possible to make better informed projections about the time for and expense of recovery as more information is obtained.

Chapter 1. Introduction: Biology and Life History of Eulachon

Overview: The southern DPS of eulachon is comprised of fish that spawn in rivers south of the Nass River in British Columbia to, and including, the Mad River in California (Figure 1-1), and were listed as a threatened species[18] under the ESA on March 18, 2012 (52 FR 13012). NMFS' 2016 ESA five-year review concluded that the DPS's threatened designation remained appropriate.

The Biological Review Team (BRT) concluded that, starting in 1994, the southern DPS of eulachon experienced an abrupt decline in abundance throughout its range (Gustafson et al. 2010). Although eulachon abundance in monitored rivers improved in the 2013–2015 return years, recent conditions in the North East Pacific Ocean are likely linked to the sharp declines in eulachon abundance in monitored rivers in 2016 and 2017. The likelihood that these poor ocean conditions will persist into the near future suggest that subpopulation declines may again be widespread in the upcoming return years.

There are many "populations" of eulachon within the range of the species. For their threats analysis, the BRT did not include all known or possible eulachon spawning areas (Table A-1, Gustafson et al. 2010). As such, the BRT partitioned the southern DPS of eulachon into geographic areas, i.e., subareas/subpopulations, for their threats assessment. As such, the subpopulation structure used by the BRT leaves out some "populations" within the DPS, e.g., Elwha River, Naselle River, Umpqua River, Smith River, that we now know may have (or had) some important contribution to the overall productivity, spatial distribution, and genetic and life history diversity of the species. As such, it is impossible to know, whether or not, the DPS is one large metapopulation, where local spawning populations come and go and some areas are sinks and some are sources, or whether the DPS is comprised of multiple demographically independent populations. Therefore, until we have the data necessary to determine whether eulachon are one large metapopulation or comprised of multiple demographically independent populations, we will consider the four subpopulations identified by the BRT—the Klamath River, the Columbia River, the Fraser River, and the British Columbia coastal rivers—as the minimum set of "populations" that need to meet biologically-based (abundance, productivity, spatial distribution, and genetic and life history diversity) and threats-based delisting criteria in this Recovery Plan.

A. Species Description

Eulachon are an anadromous smelt in the family Osmeridae. The genus *Thaleichthys* has only one species and valid subspecies have not been described (McAllister 1963). The binomial species name is derived from Greek roots; *thaleia* meaning rich, *ichthys* meaning fish, and *pacificus* meaning of the Pacific (Hart 1973). McAllister (1963) provides a taxonomic synonymy

[18] In this document, "the species" and "eulachon" refers to the Southern DPS of eulachon.

for the species, which was originally described from the Columbia River as *Salmo (Mallotus) pacificus* by Richardson (1836).

Eulachon have been classified previously in various other ways and placed in different genera (Scott and Crossman 1973), but the present systematic classification follows Mecklenburg et al. (2002):

Phylum: Chordata

Subphylum: Vertebrata

Superclass: Gnathostomata

Grade: Teleostomi

Class: Actinopterygii

Subclass: Neopterygii

Division: Teleostei

Subdivision: Euteleostei

Superorder: Protacanthopterygii

Order: Osmeriformes

Suborder: Osmeroidei

Superfamily: Osmeroidea

Family: Osmeridae (smelts)

Genus and species: *Thaleichthys pacificus* (Richardson, 1836)

Common Names

English

Eulachon: derived from the Chinook jargon (Tsinuk Wawa), a synthetic trading language derived from French, English, and various First Nations languages (Hay and McCarter 2000); candlefish; less commonly salvation fish, saviour fish, fathom fish.

Native Languages

Many variants of eulachon, including hoolakan, hooligan, hoolikan, olachan, ollachan, oolachan, oolichan, oulachan, oulachon, ulchen, ulichan, uthlecan; also yshuch, swavie, chucka, juk'wan or za'xwen meaning 'jittery fish' in Haisla language, saak in Tlingit.

B. Distribution

Freshwater Distribution

Eulachon, an anadromous smelt in the northeast Pacific Ocean, is composed of numerous populations that spawn in rivers from northern California to southwestern Alaska (Figure 1-1).

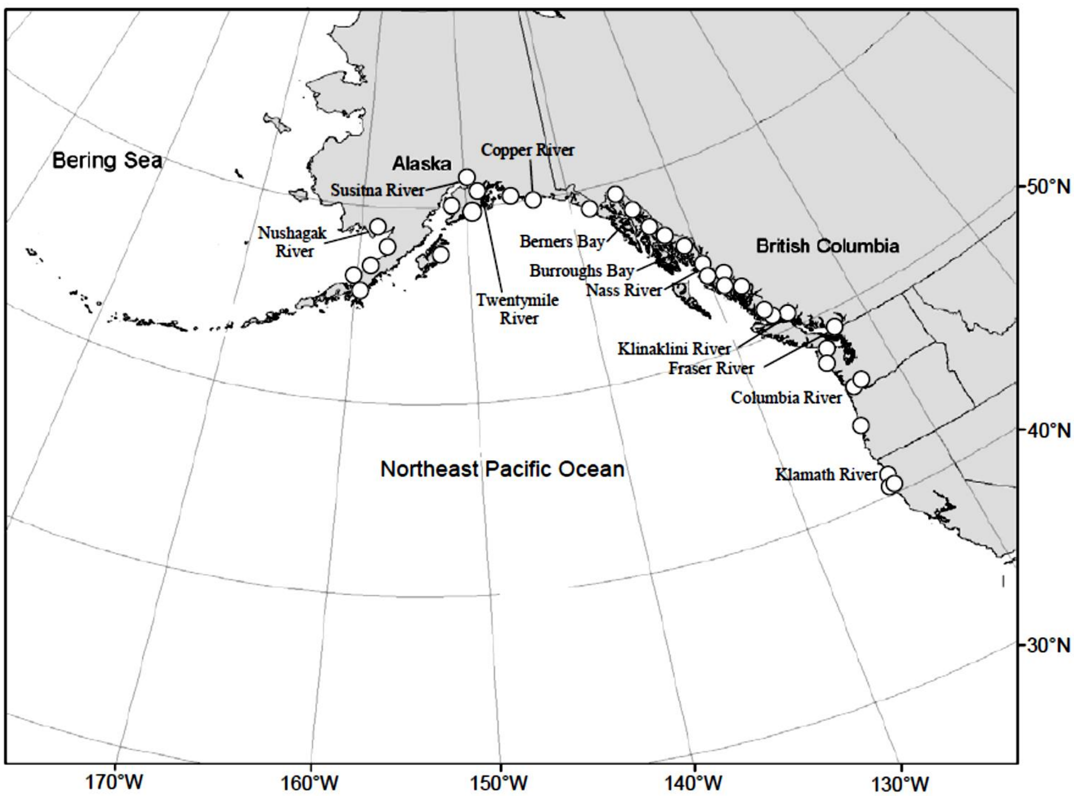

Figure 1-1. Distribution of eulachon spawning rivers (open circles) in the northeast Pacific Ocean (Gustafson et al. 2010).

In the portion of the species' range that lies south of the U.S.–Canada border, most eulachon production originates in the Columbia River Basin, including the Columbia River, the Cowlitz River the Grays River, the Kalama River, the Lewis River, and the Sandy River (Gustafson et al. 2010).

Smith and Saalfeld (1955) stated that eulachon were occasionally reported to spawn up to the Hood River on the Oregon side of the Columbia River prior to the construction of Bonneville

Dam in the 1930s. In times of great abundance (e.g., 1945, 1953), eulachon have been known to migrate as far upstream as Bonneville Dam (Smith and Saalfeld 1955, WDFW and ODFW 2008; as cited in Gustafson et al 2010) and may extend above Bonneville Dam by passing through the ship locks (Smith and Saalfeld 1955). Eulachon likely reached the Klickitat River on the Washington side of the Columbia River in 1945 via this route (Smith and Saalfeld 1955).

Williams (2009, as cited in Gustafson et al. 2010) also reported on the onetime observation by an ODFW stream surveyor in February 1991 of eulachon in Conyers Creek, a tributary of the Clatskanie River, which is in turn a tributary of the lower Columbia River on the Oregon side of the river. The stream surveyor reported that eulachon were seen holding in pools within the lower 0.8 km (0.5 mile) of Conyers Creek during a daytime flood tide, but none were observed in the main stem of the Clatskanie River.

Historically, the only other large river basins in the contiguous United States where large, consistent spawning runs of eulachon have been documented are the Klamath River in northern California and the Umpqua River in Oregon. However, eulachon have been found both frequently and infrequently in several, but not all, coastal rivers in northern California (including the Mad River, Redwood Creek, and Humboldt Bay in California (Monaco et al. 1990, Willson et al. 2006; as cited in Gustafson et al 2010); Oregon (including Tenmile Creek the Siuslaw River, the Winchuck River, the Chetco River, the Pistol River, the Rogue River, the Elk River, the Sixes River, the Coquille River, the Coos River, the Yaquina River, Hunter Creek, and Euchre Creek (Willison et al. 2006, as cited in Gustafson et al. 2010); Washington (including the Elochoman River, the Washougal River, Germany Creek, Mill Creek, Willapa Bay (North, Naselle, Nemah, Bear, and Willapa Rivers), Grays Harbor (Humptulips, Chehalis, and Wynoochee Rivers), the Copalis, Moclips, Quinault, Queets, and Bogachiel Rivers, the Elwha River, as well as Puget Sound (Monaco et al. 1990, Willson et al. 2006; as cited in Gustafson et al. 2010).

Eulachon may have historically occurred in the Sacramento River system and even farther south along the California and Baja California coast, in areas where they may have been extirpated (Minckley et al. 1986, as cited in Willson et al 2006). Although Minckley et al. (1986, their Table 15.1, p. 541; as cited in Willson et al 2006) indicate that eulachon were native to the Sacramento River and drainages within the south California Coastal to Baja California region, no verifying references for these assertions were given. In 2007 Vincik and Titus (California Department of Fish and Game) reported on the capture of a single mature male eulachon in a screw trap at RKM 228 (RM 142) on the Sacramento River (Gustafson et al. 2010).

In the portion of the species' range that lies north of the U.S.–Canada border, a large portion of eulachon production originates in the Fraser River. Early reference to eulachon being caught by First Nations groups on the Fraser River in 1827–1830 appear in the journals of the Hudson's Bay Company post Fort Langley, located on the south bank of the lower Fraser River near the Salmon River (MacLachlan 1998, as cited in Gustafson et al. 2010).

In British Columbia, north of the Fraser River, eulachon production originates in the Kingcome River (Berry and Jacob 1998, as cited in Gustafson et al. 2010), Wannock River (Berry and Jacob 1998, Moody 2008, as cited in Gustafson et al. 2010), Bella Coola River (Moody 2008), Kemano River (Lewis et al. 2002, Ecometrix 2006; as cited in Gustafson et al. 2010), Kitimat River (Pedersen et al. 1995, Kelson 1997, Ecometrix 2006; as cited in Gustafson et al. 2010), Skeena River (Lewis, 1997, Stoffels 2001; as cited in Gustafson et al. 2010), and the Nass River (Langer et al. 1977, as cited in Gustafson et al. 2010)

In Alaska, Moffitt et al. (2002, as cited in Gustafson et al. 2010) indicated that at least 35 rivers have spawning runs of eulachon, including one in a glacial stream on Unimak Island, the first island in the Aleutian Island chain off the western end of the Alaska Peninsula. Aspects of the biology of eulachon have been studied in the Stikine River (Franzel and Nelson 1981, as cited in Gustafson et al. 2010), the Taku River (Flory 2008b, as cited in Gustafson et al. 2010), the Chilkoot River (Betts 1994, as cited in Gustafson et al. 2010), the Chilkat River (Mills 1982, Betts 1994; as cited in Gustafson et al. 2010), the Copper River (Moffitt et al. 2002, as cited in Gustafson et al. 2010), the Eyak River, the Alaganik River (Moffitt et al. 2002, Joyce et al. 2004; as cited in Gustafson et al. 2010), Twentymile River (Kubik and Wadman 1977, 1978, Spangler 2002, Spangler et al. 2003; as cited in Gustafson et al. 2010), and the Susitna River (Barrett et al. 1984, Vincent-Lang and Queral 1984; as cited in Gustafson et al. 2010).

Oceanic Distribution

Although they spend 95–98% of their lives at sea (Hay and McCarter 2000), little is known concerning the saltwater existence of eulachon. They are reported to be present in the “food rich” and “echo scattering layer” of coastal waters (Barraclough 1964, p. 1,337; as cited in Gustafson et al, 2010), and “in near-benthic habitats in open marine waters” of the continental shelf between 20 and 150 m depth (Hay and McCarter 2000, p. 14). Hay and McCarter (2000, their Figure 5) illustrated the offshore distribution of eulachon in British Columbia as determined in research trawl surveys, which indicate that most eulachon were taken at around 100 m depth, although some were taken as deep as 500 m and some at less than 10 m. Schweigert et al. (2007, p. 11, as cited in Gustafson et al. 2010) stated that “the marine distribution of adults in British Columbia includes the deeper portions of the continental shelf around Dixon Entrance, Hecate Strait, Queen Charlotte Sound, and the west coast of Vancouver Island, generally at depths of 80–200 m.” Mueter and Norcross (2002, as cited in Gustafson et al. 2010) reported eulachon were present in 32% of triennial bottom trawl surveys on the upper slope and continental slope in the Gulf of Alaska between 1984 and 1996 and were caught at depths down to 500 m in the Kodiak, Yakutat, and southeast areas of Alaska. Armstrong and Hermans (2007, as cited in Gustafson et al. 2010) indicated that eulachon are commonly caught in trawls in the coastal fjords of southeast Alaska.

Smith and Saalfeld (1955, p. 12, as cited in Gustafson et al. 2010) reported the occasional capture of eulachon in the offshore “otter trawl fishery,” particularly in November to January near the mouth of the Columbia River "as the mature smelt approach the Columbia River." Emmett et al. (2001) reported the capture of small numbers of eulachon by nighttime surface trawls targeted on pelagic fishes off the Columbia River in April to July of 1998 and 1999. About 10% of hauls in 1999 contained from one to a maximum of eight eulachon (Emmett et al. 2001). Eulachon also occur as bycatch in some U.S.-based groundfish fisheries (Bellman et al. 2008) off the U.S. West Coast and more commonly in the California and Oregon ocean shrimp (*Pandalus jordani*) fisheries (NWFSC 2008, as cited in Gustafson et al. 2010). The Pacific Fishery Management Council has prohibited at-sea directed harvest of eulachon in U.S. West Coast waters and eulachon are not an actively managed or monitored species (PFMC 2008, as cited in Gustafson et al. 2010); therefore there is a paucity of data on at-sea distribution of eulachon off the U.S. West Coast.

C. Morphology

Eulachon are a slender-bodied fish with an average weight of 40 grams (g) and typically reach 150 to 200 millimeters (mm) standard length, although a few may reach 250 mm standard length. Eulachon have compressed, elongated bodies and large mouths, the maxilla usually extending just past the middle of the eye (Moyle 1976). The operculum possess strong concentric striations and the pectoral fins, when pressed against the body, reach about two-thirds of the way to the bases of the pelvic fins. The lateral line is complete, with 7 to 78 scales. There are 8 to 11 pyloric ceca, 18 to 23 dorsal rays, 8 pelvic rays, 10 to 12 pectoral rays, 18 to 23 anal rays, 17 to 23 slender gill rakers on the first arch, and 7 to 8 branchiostegal rays (Moyle 1976). The jaws have small, pointed teeth which may be missing from spawning fish, especially males. The lining of the gut cavity is pale with dark speckles. Live fish are dark brown to dark blue on the back and head with a silvery white belly and unmarked fins. Spawning males develop a distinct midlateral ridge and numerous distinct tubercles on the head, body, and fins. Females may also have tubercles but they are poorly developed (Moyle 1976).

Sexual Dimorphism

Spawning male eulachon can be told readily from females by the rougher skin produced by tubercles on the scales, especially near the lateral line and on the head, by a more rigid body and less cylindrical cross section caused by a raised lateral ridge, and by slightly larger paired fins (Hart and McHugh 1944, Hay and McCarter 2000, as cited in Willson et al 2006). Lewis et al. (2002, as cited in Willson et al. 2006) note that in another species of smelt, the lateral ridges of the males are used to press females down to the substrate, perhaps encouraging extrusion of eggs. Females also have more abdominal vertebrae (Hart and McHugh 1944, as cited in Willson et al. 2006). Males often tend to be slightly larger than females, even when controlling for age (Willson et al. 2006), but are not always larger (Warner and Shafford 1979, Langer et al 1977; as cited in Willson et al. 2006). Morphological hermaphrodites are sometimes reported (Lewis et al 2002, as cited in Willson et al. 2006).

D. Genetic Differentiation

The BRT reviewed four published genetic studies of genetic population structure in eulachon. One of these studies (McLean et al. 1999) used RFLP analysis to examine variation in mitochondrial deoxyribonucleic acid (mtDNA). The other studies (McLean and Taylor 2001, Kaukinen et al. 2004, Beacham et al. 2005) analyzed microsatellite loci.

McLean et al. (1999) examined mtDNA variation in two fragments (each containing two genes NADH-5/NADH-6 and 12S/16S rRNA) in 285 eulachon samples collected at 11 freshwater sites ranging from the Columbia River to Cook Inlet, Alaska, and also in 29 ocean-caught fish captured in the Bering Sea. Samples were taken at two sites (Columbia and Cowlitz Rivers) in two years and all other locations were sampled in single years. Overall, 37 mtDNA composite haplotypes were observed in the study. Two haplotypes were found in all sampling locations and together accounted for approximately 67% of the samples in the study. Eight additional haplotypes were present at multiple sites and the remaining 27 haplotypes were "private" (found only in one location).

An analysis of the nucleotide substitutions separating the 37 haplotypes revealed that the haplotypes were all closely related, with the number of substitutions ranging between 1 and 13. The mtDNA haplotypes clustered into two major groups and the frequencies of the two haplotype groups differed among sampling sites, particularly in the Alaska and Bering Sea collections compared to samples from further south, although these differences were not statistically significant. Approximately 97% of mtDNA variation occurs within populations and about 2% is found among regions (F_{ST} = 0.023). McLean et al. (1999) also found that genetic distance among sampling locations was correlated with geographic distance (r2 = 0.22, P = 0.0001). Based on these results, McLean et al. (1999) concluded that there was little genetic differentiation among distinct freshwater locations throughout the eulachon range. However, McLean et al. (1999) noted that association of geographic distance and genetic differentiation among eulachon populations suggested an emerging population subdivision throughout the range of the species.

In a later study, McLean and Taylor (2001) used five microsatellite loci to examine variation in the same set of populations as McLean et al. (1999). The populations in the Columbia and Cowlitz rivers were represented by 2 years of samples with a total sample size of 60 fish from each river. However, several populations were represented by very few samples including just 5 fish from the 3 rivers in Gardner Canal and just 10 fish from the Fraser River. Results from a hierarchical analysis of molecular variance test were similar to that of the McLean et al. (1999) mtDNA study, with 0.85% of variation occurring among large regions and 3.75% among populations within regions.

Tests of differentiation were significant among several pairs of populations in the microsatellite study (27% of tests after correction for multiple comparisons), particularly comparisons that included populations in the Columbia and Cowlitz rivers and those with the Nass River sample and samples taken further south. F_{ST} (a commonly used metric to evaluate population subdivision) was estimated as 0.047 when sample sites were considered separately, and was significantly different from zero. In contrast to the mtDNA analysis, genetic distances among populations using these five microsatellite loci were not correlated with geographic distances. Overall, however, McLean and Taylor (2001) concluded that their microsatellite results were mostly consistent with the mtDNA findings of McLean et al. (1999) and that both studies indicated that eulachon have some degree of population structure.

The most extensive study of eulachon, in terms of sample size and number of loci examined, is that of Beacham et al. (2005). Beacham et al. (2005) examined microsatellite DNA variation in eulachon collected at 9 sites ranging from the Columbia River to Cook Inlet, Alaska, using the 14 loci developed by Kaukinen et al. (2004). Sample sizes per site ranged from 74 fish in the Columbia River to 421 from the Fraser River. Samples collected in multiple years were analyzed from populations in the Bella Coola and Kemano rivers (2 years of sampling) and also in the Nass River (3 years of sampling).

Beacham et al. (2005) observed much greater microsatellite diversity within populations than that reported by McLean and Taylor (2001) and all loci were highly polymorphic in all of the sampled populations. Significant genetic differentiation was observed among all comparisons of the nine populations in the study and F_{ST} values for pairs of populations ranged from 0.0014 to 0.0130. A cluster analysis of genetic distances showed genetic affinities among the populations in the Fraser, Columbia, and Cowlitz rivers and also among the Kemano, Klinaklini, and Bella Coola rivers along the central British Columbia coast. In particular, there was evidence of a genetic discontinuity north of the Fraser River, with Fraser and Columbia/Cowlitz samples being approximately 3–6 times more divergent from samples further to the north than they were to each other. Similar to the mtDNA study of McLean et al. (1999), Beacham et al. (2005) also found that genetic differentiation among populations (F_{ST}) was correlated with geographic distances ($r = 0.34$, $P < 0.05$).

Beacham et al. (2005) found stronger evidence of population structure than the earlier genetic studies, and concluded that their results indicated that management of eulachon would be appropriately based at the level of the river drainage. In particular, the microsatellite analysis showed that populations of eulachon in different rivers are genetically differentiated from each other at statistically significant levels. The authors suggested that the pattern of eulachon differentiation was similar to that typically found in studies of marine fish, but less than that observed in most salmon species.

Although Beacham et al. (2005) found clear evidence of genetic structure among eulachon populations; the authors also noted that important questions remained unresolved. The most important one in terms of identifying a DPS or DPSs for eulachon is the relationship between temporal and geographic patterns of genetic variation. In particular, Beacham et al. (2005) found that year-to-year genetic variation within three British Columbia coastal river systems was similar to the level of variation among the rivers, which suggests that patterns among rivers may not be temporally stable. However, in the comparisons involving the Columbia River samples, the variation between the Columbia samples and one north-of-Fraser sample from the same year was approximately five times greater than a comparison within the Columbia from two different years. Taken together, there appears to be little doubt that there is some genetic structure within eulachon and that the most obvious genetic break appears to occur in southern British Columbia north of the Fraser River.

Two genetic studies have been published since the 2010 status review (Gustafson et al. 2010) was released, one utilizing microsatellite DNA differentiation to study population structure among samples of eulachon in Alaska (Flannery et al. 2009, 2013; as cited in Gustafson 2016) and another utilizing newly developed putatively neutral and adaptive single nucleotide-polymorphisms (SNPs) (Candy et al. 2015; as cited in Gustafson 2016).

Flannery et al. (2009, 2013; as cited in Gustafson 2016) examined eulachon population structure among 26 rivers in Alaska by analyzing variation at the same 14 microsatellite DNA loci used by Beacham et al. (2005) to analyze population structure in British Columbia and the Columbia River. All collections occurred in either 2003 or 2004, and there was no temporal sampling at any of the 26 locations (Flannery et al. 2013; as cited in Gustafson 2016). Eulachon in Alaska exhibited a low degree of genetic divergence, with a broad scale regional level of population structure. Samples from the northern region (Yakutat Forelands, Cook Inlet, and Prince William Sound) were significantly different from samples obtained from the southern region (Behm and Lynn canals, Stikine Strait, and Berners Bay) (Flannery et al. 2013; as cited in Gustafson 2016); however, there was little inter-regional differentiation. According to Flannery et al. (2013, p. 1040; as cited in Gustafson 2016), “The level of genetic divergence between regions was four times as great as that within regions.” The fine scale genetic population structure that Beacham et al. (2005) described, based on samples of eulachon from British Columbia and the Columbia River, was absent in Alaskan eulachon (Flannery et al. 2013; as cited in Gustafson 2016.

Candy et al. (2015; as cited in Gustafson 2016) examined eulachon population structure among 12 sampling locations ranging from Washington (Columbia and Cowlitz rivers) to south-central Alaska (Twenty-mile and Kenai rivers in Cook Inlet) by analyzing genetic variation among a panel of 3,911 putatively neutral SNPs and a panel of 193 putatively adaptive SNPs. There was no temporal sampling at any of the 12 locations included in the study by Candy et al. (2015; as cited in Gustafson 2016).

According to Candy et al. (2015), the neutral and adaptive eulachon SNP panels showed a regional population structure that was similar to that observed by Beacham et al. (2005) using microsatellite DNA markers. Candy et al. (2015; as cited in Gustafson 2016) interpreted their results as indicating that:

> … there is a three-population southern Columbia-Fraser group (Cowlitz, Columbia, and Fraser rivers), a seven-population British Columbia (BC) – SE Alaska group (Stikine, Nass, Skeena, Klinaklini, Kingcome, Kemano and Bella Coola rivers) and a two-population northern Gulf of Alaska (GOA) group (Twenty Mile and Kenai rivers)

Surprisingly, pairwise F_{ST} comparisons for the neutral SNPs showed that Columbia River eulachon were not significantly differentiated from any other population (all pairwise $F_{ST} \leq 0.0000$) (Candy et al. 2015, their table 2; as cited in Gustafson 2016). However, the adaptive SNPs displayed statistically significant pairwise F_{ST} values for the Columbia River sample compared to all other rivers, with the exception of the Cowlitz River. The Columbia River sample consisted of larval eulachon collected downstream of the Cowlitz River, so these larvae may have originated from the Cowlitz River (Candy et al. 2015; as cited in Gustafson 2016).

Small et al. (2015; as cited in Gustafson 2016) described preliminary results of a study using microsatellite DNA variation to examine potential temporal differences in genetic population structure of eulachon in the Columbia River Basin. Samples examined included: 1) 95 larval samples from the putative "pilot run" in the Cowlitz River; 2) a mainstem Columbia River collection of 95 larval eulachon near the end of the larval outmigration period; and 3) 95 tissue samples from Sandy River eulachon. Additional eulachon samples were also analyzed from samples collected near Ucluelet and Pachena Bay, offshore of the west coast of Vancouver Island (WCVI) (Small et al. 2015; as cited in Gustafson 2016). The pilot run samples proved not to be eulachon, and the mainstem larval Columbia River samples and Sandy River sample were genetically indistinguishable. The pilot run samples were most likely longfin smelt (*Spirinchus thaleichthys*), another closely related anadromous osmerid, and not eulachon. Considering that Sandy River eulachon are the latest spawning population in the Columbia River Basin it is not surprising that they would be genetically similar to larvae collected downstream of the Sandy River at the end of the larval outmigration period in the Columbia River mainstem. Small et al. (2015; as cited in Gustafson 2016) also stated that samples collected off of WCVI showed no detectable genetic differences with Columbia River eulachon. Earlier studies (Schweigert et al. 2012; as cited in Gustafson 2016) had determined that about 56% of eulachon collected off of WCVI could be genetically assigned as originating in the Columbia River. More recent estimates indicate that about two-thirds of the eulachon collected off WCVI could be genetically assigned back to the Columbia River[19].

E. Body Composition

Eulachon have a high energy density, averaging 7.7 kcal/g ash-free dry mass, markedly higher than herring (*Clupea pallasi*) and capelin (*Mallotus villosus*) (6.8 and 6.6 kcal/g, respectively) or

[19] Sean MacConnachie, Fisheries and Oceans Canada, Nanaimo, BC, Canada. Powerpoint presentation at Eulachon State of the Science and Science to Policy Forum, Portland, OR., August 21, 2015.

cod, pollock, and arrowtooth flounder (5.5-5.8 kcal/g) (Perez 1994, as cited in Willson et al. 2006). Specimens from the Gulf of Alaska had significantly higher caloric content in March (7.8 kcal/g; before spawning, for most populations) than in August (7.5 kcal/g) (Willson et al. 2006).

Eulachon are notable for the high concentration of oils (mostly mono-unsaturated fatty acids, particularly oleic acid (Kuhnlein et al. 1982, as cited in Willson et al. 2006) in the body. Among the lipids occurring in eulachon is squalene, which is typical of elasmobranchs rather than teleosts (Ackman et al. 1968, as cited in Willson et al. 2006). The fatty-acid 'signature' of eulachon is quite distinct from that of other species of forage fishes (Iverson et al. 2002, as cited in Willson et al. 2006). Samples collected in March and April contained 18% lipids (wet mass; Willson et al. 2006). There was a slight but significant increase in body lipids of Gulf of Alaska eulachon from February-March to June-September (Payne et al. 1999, as cited in Willson et al. 2006).

Samples obtained from February to June in the Gulf of Alaska contained 18-20% oil (wet mass), a value higher than that for other common forage fishes, such as sand lance (*Ammodytes hexapterus*; 3-6%) or capelin (2-10%) during the same time frame (Payne et al. 1999, Ref. 35 Willson et al. 20060). Iverson et al. 2002, as cited in Willson et al. 2006 reported similar average values for spring samples from Prince William Sound (eulachon 19% lipid [wet mass], capelin 3%, but sand lance 1.5%). "Large" (>100 mm standard length) eulachon from the northern Gulf of Alaska, collected from May to September, contained 50% lipid (by dry mass; (approximately equivalent to 14.5% lipid by wet mass), similar to the lipid content of northern lampfish (*Stenobrachius leucopsarus*) but higher than lipid content from capelin, sand lance, or herring (Anthony et al. 2000, as cited in Willson et al. 2006).

Protein content was slightly lower for eulachon (12-13%) than for the other species (13-15% for capelin, 16-18% for sand lance) (Payne et al. 1999, as cited in Willson et al. 2006). When samples from the Gulf of Alaska and the eastern Bering Sea were matched for body size and month, there were no differences in protein and lipid content (Payne et al. 1999, as cited in Willson et al. 2006). Eulachon from the Columbia River were reported to have about 13-15% protein and 5-9% oil in muscle tissue (Stansby 1976, as cited in Willson et al. 2006). Eulachon also contain high levels of vitamins A and E (Kuhnlein et al. 1996, as cited in Willson et al. 2006) and are good sources of calcium, iron, and zinc (Kuhnlein et al. 1996, as cited in Willson et al. 2006).

Eulachon can take up and store pollutants from their spawning rivers, despite the fact that they do not feed in fresh water and remain there only a few weeks (Rodgers et al. 1990, WDFW/ODFW 2001; as cited in Willson et al. 2006); eulachon avoid polluted waters when possible (Smith and Saalfeld 1955). Specimens from the Cowlitz River in Washington contained phenolics derived from the eruption of Mount St. Helens (Campbell et al. 1982, as cited in Willson et al. 2006). Eulachon returning to the lower Fraser River contained contaminants from wood-treatment processes (Rodgers et al. 1990, as cited in Willson et al. 2006), apparently acquired after river entry (Birtwell et al. 1988, Rodgers et al. 1990; as cited in Willson et al. 2006). Concentrations of some contaminants differed between males and females and increased with increasing distance upstream (Rodgers et al. 1990, as cited in Willson et al. 2006). Industrial effluent into the Kitimat River after 1972 has tainted eulachon flesh and made it unpalatable (Mikkelson et al. 1996, as cited in Willson et al. 2006). Nass River eulachon acquired detectable levels of metals derived from mine tailings (Futer and Nassichuk 1983, as cited in Willson et al. 2006). However, contaminant levels in eulachon (the edible portion only) from the Nass, Kitimat, Bella Coola, Kingcome, and Knights Inlet rivers were judged to be below the limits set by health regulations, although they increased from north to south (Futer and Nassichuk 1983, Chan et al. 1996, Kuhnlein et al. 1996; as cited in Willson et al. 2006).

F. Age, Growth, and Maturation

Age determination of eulachon is reported to be difficult, because both otoliths and scales may yield inaccurate assessments, and age estimates from otoliths are commonly 1-3 years higher than estimates from scales (Ricker et al. 1954, as cited in Willson et al. 2006). This discrepancy occurred for Fraser River fish, but there was much better correspondence of age estimates from the two methods in eulachon from the Nass River (Langer et al. 1977, as cited in Willson et al. 2006). Methodological differences may account for some of the differences among reports in the age of eulachon at spawning.

Age at Spawning

Most studies conclude that eulachon commonly spawn at age 3 or 4, but some fish spawn at age 2 or age 5 (Barrett et al. 1984, as cited in Willson et al. 2006); some 9-year old adults are recorded from the Columbia River system (Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife 2001). The mean age of fish in the Meshik River was 3.1 years, with a few fish of ages 2, 4, and 5 years (based on otoliths, Warner and Shafford 1979, as cited in Willson et al. 2006), and the dominant age class on the Susitna River was 3 years (Willson et al. 2006). Biologists on the Kalsin River in Kodiak, Alaska reported, on the basis of otolith analysis, that most fish were 2 years old, some were 3 years old, and a few were 4 years old (Blackburn et al. 1981, as cited in Willson et al. 2006). On the Twentymile River, spawners ranged from age 2 to age 5 (and a few age-1 females in one year), but most spawners were age 3, with a broader distribution of ages in 2000 than in 2001 (Spangler 2002, as cited in Willson et al. 2006). In the Copper River, spawning eulachon ranged from 2 to 6 years old, with age-4 fish predominant in one year and age-5 fish in another (Moffitt et al. 2002, as cited in Willson et al. 2006). On the Stikine River, incoming fish were 2-4 years old; 3-year-olds were most common, and the frequency of 2- and 4-year-olds differed between sample years (based on otolith analysis; Franzel and Nelson 1981, as cited in Willson et al. 2006).

There was annual variation in the dominant year class of spawners in the Nass River also, with 3-year-olds dominant in one year and 4-year-olds in another Willson et al. 2006). Kitimat River female eulachon, aged by otoliths, were mostly age 3, with some age 4, 5, and 6 years (Willson et al. 2006), but the dominant age class in the Kemano River was 4 years (range 2-7 years, Lewis et al. 2002; Triton 1990 (in Pedersen et al. 1995); as cited in Willson et al. 2006). By scale and otolith analysis, most Fraser River fish spawned at age 2 and a few at age 3 according to Hart and McHugh (1944, as cited in Willson et al. 2006), but most spawned at age 4-5 (and a few up to age 7) according to other researchers (otolith analysis; Higgins et al. 1987, Ref. 215; Rogers et al. 1990, Ref. 375). Most fish in the Columbia River were age 3-4, with some fish age 5 (based on otoliths: Smith and Saalfeld 1955; WDFW/ODFW 2001). Judging from research to date, the age distribution of eulachon in a spawning run probably varies among rivers. It also varies between sexes in some years and among years in the same river system (in the Kemano River, Lewis et al. 2002, as cited in Willson et al. 2006).

Age and Length

It is difficult to compare body lengths among reports because different length measures (standard, fork, total) have been used. We lack the data to convert one measurement to another, and reports sometimes may not state which measurements were used, so here we merely summarize the findings. As expected, both length and body mass increase with age (Willson et al. 2006). Eulachon on the Twentymile River averaged about 180-200 mm and 40-58 g at age 2, to 220-225 mm and 80-90 g at age 5; at age 3, the most common age of spawners, fork length averaged about 200-215 mm and body mass averaged about 60-65 g (estimated from graph, Spangler 2002, as cited in Willson et al. 2006). For the Fraser River population, fork-length distribution was as follows: age 0+ fish were about 20-50 mm, age 1+ about 50-80 mm, age 2+ about 75-105 mm, age 3+ about 105-135 mm, and age 4+ about 135-160 mm (estimated from graph; Barraclough 1964, as cited in Willson et al. 2006). Eulachon in the Kemano, Kitimat, Nass, Stikine, and Columbia rivers reportedly have similar distributions of size-at-age, but the increase of size-at-age is small for both sexes (10 mm and 7.2 g from age 3 to 4, 4 mm and 3.1 g from age 4 to 5; Lewis et al. 2002, as cited in Willson et al. 2006).

Despite the assorted measurements reported regarding body size, it is clear that body size differs among river systems. Some reports indicate annual variation as well, so some of the apparent variation among river systems might also reflect differences among years. As noted by Spangler (2002, as cited in Willson et al. 2006), body size of eulachon at the northern and western end of their geographic range seems to be greater than in the south and east. Average body length in the Twentymile, Susitna, and Meshik rivers all exceed 200 m, whereas small samples from the Oregon coast indicate much smaller body lengths there.

Fecundity

Hart and McHugh (1944, as cited in Willson et al. 2006) noted that fecundity in the Fraser River ranged about 17,300–39,600 eggs in female eulachon measuring 145–188 mm SL. Average fecundity was about 25,000 eggs per female (Willson et al. 2006). Smith and Saalfeld (1955, p.

22) report a fecundity of 20,000–60,000 for female eulachon ranging 140–195 mm length from the Columbia River. Both Clemens and Wilby (1967) and McPhail and Lindsey (1970, as cited in Willson et al. 2006) report fecundity to be about 25,000 eggs in an average size female. Hay and McCarter (2000, as cited in Willson et al. 2006) reported total fecundity range of 20,000–40,000 eggs, the number generally increasing with fish size. Depending on fish size, fecundity can range 7,000–31,000 eggs on the Columbia River (Willson et al. 2006).

Cowlitz River—during the run year (2014-2015), the Cowlitz Tribe carried out systematic plankton tows in the Cowlitz River with the intent to develop an SSB estimate for that tributary of the Columbia River (Langness et al. 2015, as cited in Gustafson 2016). The Cowlitz River SSB estimation can be compared to the mainstem Columbia River eulachon SSB estimation (being done by WDFW), to see how much of the Columbia River eulachon production during 2014-2015 is attributable to the Cowlitz River (Langness et al. 2015, as cited in Gustafson 2016).

Preliminary estimates of the mean cumulative plankton flux of eulachon eggs and larvae in the Cowlitz River in 2015 was on the order of about 690 billion[20], which is about 34% of the calculated total eulachon plankton flux for the Columbia River Basin, above the Grays River, of about 2 trillion, as calculated by Langness (2015, as cited in Gustafson 2016). Using a sex ratio of 4.33 males to females and an estimated fecundity of 35,155 eggs per female (derived from sampling in the Cowlitz River) an SSB of approximately 4,400 mt for the Cowlitz River in 2015 was calculated.[21] This equates to approximately 108 million spawning eulachon in the Cowlitz River in 2015[22].

Naselle River—in 2015, WDFW began plankton tows in the Naselle River, a tributary of Willapa Bay, in order to produce a eulachon SSB estimate (Langness 2015, as cited in Gustafson 2016). Using the same methods described above for estimating the Columbia River SSB, WDFW estimated that mean eulachon egg and larval production was over 592 million in 2015. Mean egg and larval density was ~12 per cubic meter over the 17 days of sampling, and mean estimated SSB amounted to 1.5 mt for the period between 11 January and 23 May 2015 (Table 5, Langness 2015; as cited in Gustafson 2016). An estimated 36,400 eulachon spawned in the Naselle River in 2015 (Table 5, Langness 2015; as cited in Gustafson 2016).

Chehalis River—the Quinault Indian Tribe (QIN 2014, as cited in Gustafson 2016) sampled for eulachon larvae during 2013 and 2014 in the Chehalis River, a tributary of Grays Harbor, Washington. In 2013 and 2014, 29 and 66 larval eulachon were captured, respectively. Putative eulachon larvae were captured in 5% of samples (19/360) in 2013 and in 9% of samples

[20] Nathan Reynolds, Cowlitz Indian Tribe. Powerpoint presentation at Eulachon State of the Science and Science to Policy Forum, Portland, OR., August 21, 2015.
[21] Nathan Reynolds, Cowlitz Indian Tribe. Powerpoint presentation at Eulachon State of the Science and Science to Policy Forum, Portland, OR., August 21, 2015.
[22] Nathan Reynolds, Cowlitz Indian Tribe. Powerpoint presentation at Eulachon State of the Science and Science to Policy Forum, Portland, OR., August 21, 2015.

(34/377) in 2014 (QIN 2014, as cited in Gustafson 2016). After normalization of data, (QIN 2014, p. 24, as cited in Gustafson 2016) stated that: … eulachon were present in similar numbers in 2013 and 2014. The mean density of all daytime samples in 2013 was 0.021 larvae/m^3 and in 2014 it was 0.023 larvae/m^3.

WDFW produced a mean eulachon SSB estimate for the Chehalis River in 2015 of 11 mt, which at 11.2 fish per pound equates to a mean estimate of about 272,000 adult spawners (Table 6, Langness 2015, as cited in Gustafson 2016). This estimate was developed using methods similar to those outlined above for the Columbia River (Langness 2015, as cited in Gustafson 2016). The mean eulachon egg and larval outflow from the Chehalis River was estimated at 4.4 billion (Table 6, Langness 2015; as cited in Gustafson 2016).

Fraser River—mean total fecundity in Fraser River eulachon ranged from a low of about 31,200 to a high of about 34,100 when estimated between 1995 and 1998 (Hay et al. 2002). Mean relative fecundity (total fecundity divided by female body weight) of Fraser River eulachon ranged from a low of 683 eggs/g in 1995 to a high of 898 eggs/g in 1997 (Hay et al. 2002). There are significant differences in fecundity among years in Fraser River eulachon, which are likely related to "significant interannual differences in mean size (length and weight)" (Hay et al. 2002, p. 11).

British Columbia Coastal Rivers—mean fecundity of 58 eulachon from the Kitimat River, British Columbia, in 1993 was about 22,900 eggs with a range of 3,242 to 47,798 (Pedersen et al. 1995, as cited in Willson et al. 2006). Relative fecundity in the Kitimat River was calculated at 504 eggs/g female body weight (Pedersen et al. 1995, as cited in Willson et al. 2006). Based on 5 years of data, mean eulachon fecundity in Kemano River, British Columbia, was about 27,000 and ranged 6,744–57,260 eggs. Mean relative fecundity of Kemano River eulachon over this 5-year data set was 544 eggs/g female body weight (Lewis et al. 2002, as cited in Willson et al. 2006).

Alaska—mean fecundity of eulachon in the Copper River, Alaska, was estimated at about 35,520 (range: 12,202–52,722) in 2000 and 36,200 (range: 18,645–62,855) in 2001 (Moffitt et al. 2002, as cited in Willson et al. 2006). From these data, Moffitt et al. (2002) estimated relative fecundity of eulachon from the Copper River in 2000 and 2001 as 790 and 792 eggs/g female body weight, respectively. Fecundity in the Twentymile River, Alaska, ranged from as low as 8,530 to as high as 67,510 and reportedly increased with increasing length, weight, and age (as determined by otolith increment analysis) (Spangler 2002, Spangler et al. 2003; as cited in Willson et al. 2006).

G. Sex Ratio

Many studies have reported that sex ratios in eulachon are either biased in favor of males (Smith and Saalfeld 1955, Kubik and Wadman 1977, 1978, Franzel and Nelson 1981, Higgins et al. 1987, Lewis 1997, Lewis et al. 2002, Moffitt et al. 2002, Spangler 2002, Spangler et al. 2003; as cited in Gustafson et al. 2010) or are highly variable depending on time and location of sampling (McHugh 1939, Hart and McHugh 1944, Langer et al. 1977, Pedersen et al. 1995; as cited in Gustafson et al. 2010). On the other hand, Hay and McCarter (2000, as cited in Gustafson et al. 2010) and Hay et al. (2002, as cited in Gustafson et al. 2010) report that the ratio of spawning male to female eulachon in their gill net samples from the Fraser River in 1995–2002 was approximately 1 to 1, with the exception of 1998 when the sex ratio was 1.7 to 1.

All reports of eulachon sex ratio should be viewed with caution, as proportions of male to female eulachon have been reported to vary with fishing gear type, distance upriver, distance from the river shoreline, time of the day, and migration time (McHugh 1939, Langer et al. 1977, Moffit et al. 2002, Lewis et al. 2002, Spangler 2002, Spangler et al. 2003; as cited in Gustafson et al. 2010). Langer et al. (1977, p. 33; as cited in Gustafson et al. 2010) reported that “sex ratios varied with location, within the duration of the run, and between years in the Nass River.” Lewis (1997, as cited in Gustafson et al. 2010) suggested that sex ratios skewed in favor of males may be due to longer residence time of male eulachon in freshwater compared to females. Moffit et al. (2002, as cited in Gustafson et al. 2010) postulated that as spawning commences, females may avoid the riverbank and disperse to the center of the river, thus skewing sex ratios calculated from dip net sampling along riverbanks. Spangler (2002, as cited in Gustafson et al. 2010) and Spangler et al. (2003, as cited in Gustafson et al. 2010) reported that sampling with different gear types (gill nets versus dip nets) resulted in different sex ratios in the Twentymile River, Alaska. However, Franzel and Nelson (1981, as cited in Gustafson et al. 2010) reported that fishing gear did not significantly change the sex ratio of eulachon captured in the Stikine River, Alaska.

Mc Hugh (1939, as cited in Gustafson et al. 2010) and Hart and McHugh (1944, as cited in Gustafson et al. 2010) reported that the sex ratio varied during the fishing season in 1939 and 1941 in the Fraser River; males predominated in the early part of the eulachon run, but in the latter part females came to predominate. A similar situation may obtain in the Columbia River basin, where WDFW and ODFW (2001, p. 15, as cited in Gustafson et al. 2010) stated that analysis of sex ratios indicated that “female return timing is skewed later than that of males,” although females never appear to dominate. Pedersen et al. (1995, p. 16, as cited in Gustafson et al. 2010) reported that earlier studies in the Nass River had found “a changing sex ratio during the spawning season,” whereas another study based on daily monitoring had found 55% males and 45% females. Lewis et al. (2002, as cited in Gustafson et al. 2010) also reported changing sex ratios over the duration of the eulachon run in the Kemano River, British Columbia; however, there appeared to be two pulses of female returns, and males rather than females appeared to dominate the later part of the run. The proportion of males was also found to increase as the run progressed in 1971 on the Nass River (Langer et al. 1977, as cited in Gustafson et al. 2010) and at Flag Point Channel on the Copper River in 1998 and 2000–2002 (Moffit et al. 2002, as cited in Gustafson et al. 2010).

The overall sex ratio reported by Smith and Saalfeld (1955, as cited in Gustafson et al. 2010) for the Columbia River basin was 4.5 males to 1 female. Similarly, Higgins et al. (1987, as cited in Gustafson et al. 2010) and Rogers et al. (1990, as cited in Gustafson et al. 2010) found a sex ratio of 3.4 males to 1 female in Fraser River samples collected in April 1986 and Rogers et al. (1990, as cited in Gustafson et al. 2010) reported the ratio to be 5.9 to 1 in 1988. Sex ratios in the early 1930s in Cowlitz River dip net, Lewis River dip net, and Columbia River gill net samples were 3.2 to 1, 12.3 to 1, and 6.8 to 1, respectively (Smith and Saalfeld 1955, as cited in Gustafson et al. 2010). In 1946 sex ratios in commercial fisheries were 10.5 to 1 in the Cowlitz River and 2.8 to 1 in the Sandy River, which may reflect the bias in the fishery for the more marketable male eulachon (Smith and Saalfeld 1955, as cited in Gustafson et al. 2010). Since males dominate the early part of the run in the Columbia River, they are more prevalent in both the sport and commercial fisheries, which preferentially target the first fish to return (WDFW and ODFW 2001, as cited in Gustafson et al. 2010).

Sex ratio of male to female eulachon in the Kemano River, British Columbia, ranged from 1.1 to 1 to 10.7 to 1 with a mean of 4.4 to 1 between 1989 and 1997; however, when weighted by fish abundance over the duration of the run, the true sex ratio was estimated at 1.6 to 1 (Lewis et al. 2002, p. 72; as cited in Gustafson et al. 2010). Males predominated in upriver locations in both 1970 and 1971 in the Nass River (Langer et al. 1977, as cited in Gustafson et al. 2010). However, in the Fraser River the proportion of male to female eulachon was independent of the distance of upriver capture (along a 31 km gradient) among April 1986 (Higgins et al. 1987, Rogers et al. 1990; as cited in Gustafson et al. 2010) and April/May 1988 (Rogers et al. 1990, as cited in Gustafson et al. 2010) samples.

Franzel and Nelson (1981, as cited in Gustafson et al. 2010) found that gill net–sampled eulachon in the Stikine River, Alaska, over two years had a sex ratio of males to females of 17.5 to 1. Eulachon sex ratios on the Copper River, Alaska, and nearby systems were also dominated by males in all samples (Moffitt et al. 2002, as cited in Gustafson et al. 2010). The percentages of males at Flag Point Channel on the Copper River in 1998, 2000, 2001, and 2002 were 78%, 60%, 72%, and 69%, respectively. At 60-km Channel on the Copper River in 2002, males represented 61%–85% of the captured eulachon (Moffit et al. 2002, as cited in Gustafson et al. 2010). On the Copper River delta, the percentages of males in 1998 and 2000 were 91% and 66%, respectively, in Alaganik Slough and ranged from 82% to 98% in January to February 2001 in Ibeck Creek (Moffit et al. 2002, as cited in Gustafson et al. 2010). Eulachon collected in Twentymile River, Alaska, from May 15 to June 2, 1976, and from April 29 to June 5, 1977, had a cumulative sex ratio of 5 males to 1 female (n = 204) (Kubik and Wadman 1977, as cited in Gustafson et al. 2010) and 7.4 males to 1 female (n = 408) (Kubik and Wadman 1978, as cited in Gustafson et al. 2010), respectively. Sampling by dip net in the Twentymile River resulted in male to female ratios of 6.7 to 1 in 2000 (n = 394) and 2.1 to 1 in 2001 (n = 2,711) (Spangler 2002, Spangler et al. 2003; as cited in Gustafson et al. 2010). Barrett et al. (1984, as cited in Gustafson et al. 2010) reported average male to female sex ratios of prespawning eulachon of 1.6 to 1 in late May 1982, 1.3 to 1 in early June 1982, 1.2 to 1 in mid-May 1983, and 0.6 to 1 in mid-May and early June 1983. Spawning and postspawning ratios were higher due to the shorter stream residence time of female eulachon (Barrett et al. 1984, as cited in Gustafson et al. 2010).

Smith and Saalfeld (1955, p. 22, as cited in Gustafson et al. 2010) first hypothesized "that the type of spawning of smelt may necessitate an excess of males." Moffitt et al. (2002, p. 26; as cited in Gustafson et al. 2010) postulated that in the case of eulachon, which broadcast-spawn eggs and sperm in fast moving rivers, "a large number of males upstream may increase the probability of egg fertilization." Spangler et al. (2003, p. 46; as cited in Gustafson et al. 2010) also postulated that a sex ratio skewed in favor of males "may be a key element to successful spawning" and that "fertilization would increase with more available milt in the water increasing the probability of eggs being fertilized." Hay and McCarter (2000, p. 23; as cited in Gustafson et al. 2010) stated that spawning involves groups of fish and eulachons must closely synchronize the timing of spawning between sexes, because the duration of sperm viability in freshwater is short, perhaps only minutes.

H. Spawning

Eulachon are fundamentally semelparous, although some individuals may spawn twice in a lifetime. The frequency of iteroparity might vary among populations—an issue still not completely resolved (Hay and McCarter 2000, Lewis et al. 2002, Barraclough 1964, Blackburn et al. 1981, Hart and McHugh 1944; as cited in Willson et al. 2006).

Spawning appears to occur at night (Hay and McCarter 2000, Parente and Snyder 1970, Prince Rupert Forest Region 1998, Lewis et al. 2002; as cited in Willson et al. 2006) or possibly afternoon (Langer et al. (1977), as cited in Willson et al. 2006). Spawning can occur at various depths: up to 25 ft in the Fraser River (Hart and McHugh 1944, as cited in Willson et al. 2006), but much less in the Kemano River (0.2-4 m, Lewis et al. 2002, as cited in Willson et al. 2006), the Susitna River (1-5 ft, Vincent-Lang and Queral 1984, as cited in Willson et al. 2006). Smith and Saalfeld (1955) recovered eggs from depths ranging from 3 in to greater than 20 ft and suspected that eggs were present at much greater depths. Egg deposition in the Nass River was greater at depths around 3.7-5.2 m than at shallower depths; deeper waters were not sampled (Langer et al. 1977, as cited in Willson et al. 2006). The sexes must synchronize their activities closely, unlike some other group spawners such as herring, because eulachon sperm are said to remain viable for only a short time, perhaps only minutes (Hay and McCarter 2000). Males are reported to lie next to females, either beside or on top of them, in riffles (Lewis et al. 2002). This description differs markedly from that in Langer et al. (1977, as cited in Willson et al. 2006), in which males were said to congregate upstream of groups of females, releasing milt simultaneously, and females laid eggs as the milt drifted over them; the spent fish then drifted downstream.

Spawning substrates can range from silt, sand, or gravel to cobble and detritus (Barrett et al. 1984, Vincent-Lang and Queral 1984; as cited in Willson et al. 2006, and Smith and Saalfeld 1955), but sand appears to be most common (Langer et al. (1977), Lewis et al. 2002; as cited in Willson et al. 2006). It is possible that the substrate favored for the spawning events themselves may be different from those where the eggs accumulate (Langer et al. 1977, as cited in Willson et al. 2006). Egg mortality was higher on silt or organic debris than on sand or gravel (Langer et al. 1977, as cited in Willson et al. 2006).

Spawning rivers may be turbid or clear, but all are thought to have spring freshets, characteristic of rivers draining large snow packs or glaciers (Hay and McCarter 2000). Many, but not all, of the reported spawning rivers in Alaska are glacial in origin, whereas the more southerly ones are not. In general, eulachon would spawn at low water levels before spring freshets (Lewis et al. 2002, as cited in Willson et al. 2006), although runs in the Fraser River appear to occur at mid-levels of river discharge (Langer et al. 1977, as cited in Willson et al. 2006). Most spawning in the Susitna River occurred at water velocities of 0.5-2.5 ft/s (Vincent-Lang and Queral 1984, as cited in Willson et al. 2006). Spawning sites may vary among years within the same river system (Hay and McCarter 2000, Pedersen et al. 1995, Moffitt et al. 2002; as cited in Willson et al. 2006), and the age distribution of spawners may vary among sites within the same system (Moffitt et al. 2002, as cited in Willson et al. 2006). Some small rivers near large runs may have occasional spawning populations (Prince Rupert Forest Region 1998, McCarter and Hay 1999; as cited in Willson et al. 2006).

In many rivers, the spawning reach is more or less limited to the part of the river that is influenced by tides (Lewis et al. 2002, as cited in Willson et al. 2006). In the Berners Bay system, the greatest abundance of eulachon was observed in tidally-influenced reaches, but some fish ascended well beyond the tidal influence (Willson et al. 2006). Eulachon are reported to go as far as 80 km up the Susitna River (Barrett et al. 1984, Vincent-Lang and Queral 1984; as cited in Willson et al. 2006), possibly because of a low gradient (Lewis et al. 2002, Ref. 269). Eulachon once ascended more than 160 km in the Columbia River system. There is some evidence that water velocity greater than 0.4 m/s begins to limit upstream movements, at least for a segment of the eulachon population (Lewis et al. 2002, as cited in Willson et al. 2006).

Run Timing

Entry into the spawning rivers appears to be related to water temperature and the occurrence of high tides (Ricker et al. 1954, Eulachon Research Council 2000, Prince Rupert Forest Region 1998, Bishop et al. 1989b, Lewis et al. 2002, WDFW/ODFW 2001, Spangler 2002; as cited in Willson et al. 2006). In the Berners Bay rivers in 1996-98, runs appeared to begin during a period of higher tides, but not necessarily at the highest tide (>16 ft; M. F. Willson et al. 2006). Low levels of river discharge may also contribute to the timing of in-migration (Spangler 2002, as cited in Willson et al. 2006).

Spawning is reported to occur at temperatures from 4° to 10°C; colder temperatures may stop migration (WDFW/ODFW 2001), at least in some rivers. Run timing (as estimated from harvest rates) in the Fraser River tended to be earlier in years with somewhat warmer temperatures ($r = -0.47$; Ricker et al. 1954, as cited in Willson et al. 2006). In the Nass River, peak eulachon in-migration occurred at temperatures between 0° and 2°C, noticeably colder than in most other rivers, and this run is earlier than the eulachon run that occurs at warmer temperatures in the Fraser River (Langer et al. 1977, as cited in Willson et al. 2006). In the Stikine River, the eulachon run began at temperatures lower than about 2°C, corresponding to the breakup of ice, and peaked at about 2 - 3.5°C; some fish were still present at about 8°C (Franzel and Nelson 1981, as cited in Willson et al. 2006). In the Kemano River, mean water temperature was 3.1°C (range 1.1 - 6.5°C) during spawning, 4.1°C (range 2.2 - 5.4°C) during incubation, but 5.9 - 6.0°C (range 0.0 - 8.2°C) during larval outmigration (Lewis et al. 2002, as cited in Willson et al. 2006).

Presumably as a result of temperature dependence and perhaps other factors, eulachon run timing does not show a simple latitudinal trend from early in the south to later in the north (Hay and McCarter 2000). In the Columbia River, spawning runs typically occur in January, February, and March (Hay and McCarter 2000, Eulachon Research Council 2000, WDFW/ODFW 2001; as cited in Willson et al. 2006), but small runs (often referred to as “pilot runs,”) can occur as early as November or December. The Fraser River runs occur in April (Northcote 1974, in Rogers et al. 1990; as cited in Willson et al. 2006) or May, and the nearby Klinaklini River runs occur earlier than runs in the Fraser River (Hay and McCarter 2000). Eulachon runs in central and northern British Columbia typically occur in late February or March (Hay and McCarter 2000; Pedersen et al. 1995, Lewis and O’Connor 2002; as cited in Willson et al. 2006) or late March-early April (Eulachon Research Council 2000, Langer et al. 1977, Lewis et al. 2002, Lewis and O’Connor 2002; as cited in Willson et al. 2006). Stikine River runs occur in early to mid-April (Franzel and Nelson 1981, as cited in Willson et al. 2006). Eulachon runs in rivers on the Yakutat forelands occur in late February to early April, or even January (Catterson and Lucey 2002, Lucey 2001; as cited in Willson et al. 2006), markedly earlier than runs in Berners Bay rivers (mid-April to early May). The principal run in the Copper River occurred from mid-May to late May over four sampling years, with peaks from 23 to 28 May, but timing sometimes differed in other streams on the Copper River Delta (Moffitt et al. 2002, as cited in Willson et al. 2006). Susitna River runs occur in May and June (Vincent-Lang and Queral 1984, as cited in Willson et al. 2006), and runs on the Alaska Peninsula occur in June and early July (Warner and Shafford 1979, as cited in Willson et al. 2006).

Some eulachon runs are very reliable from year to year; others occur more sporadically (Stacey 1995, Hinrichsen 1998, Hay and McCarter 2000, Eulachon Research Council 2000, Smith and Saalfeld 1955, as cited in Willson et al. 2006). Some rivers have two eulachon runs per year. For example, the Chilkat River has a regular run in May and possibly a smaller, more sporadic one in February (Bishop et al. 1989b, Betts 1994; as cited in Willson et al. 2006). The Nass River has (or had) a run in March and a smaller one in June (Langer et al. 1977, as cited in Willson et al.

2006), and the Dean and Susitna rivers also have two runs (Eulachon Research Council 2000, Vincent-Lang and Queral 1984, Barrett et al. 1984; as cited in Willson et al. 2006). The Twentymile River has pulses of eulachon spawners in May and June (Eulachon Research Council 2000, as cited in Willson et al. 2006), and a run duration longer than most others reported (Spangler 2002, as cited in Willson et al. 2006). The Copper River system has a small but prolonged winter run and a substantial run in May and June; run timing tends to differ among the sloughs and river outlets in this area (Moffitt et al. 2002, as cited in Willson et al. 2006).

Eggs and Larvae

Eggs are greater than 1 mm in diameter (Hay and McCarter 2000). Eggs are enclosed in a double membrane; the outer membrane breaks and turns inside out, making a sticky stalk by which the egg adheres to sand grains and small gravels (Hay and McCarter 2000, Hart and McHugh 1944; as cited in Willson et al. 2006). Eggs do not adhere to sand immediately but drift downstream for a short time; even after adherence, water velocity can move the sand grains farther downstream (Lewis et al. 2002, as cited in Willson et al. 2006). Incubation is temperature-dependent, and so incubation times can differ among rivers and years.

Eggs can accumulate on the substrate at densities of several to many thousand per square meter (Lewis et al. 2002, as cited in Willson et al. 2006). Very large masses of eggs (up to 500 eggs/ml) sometimes accumulate in areas of low water velocity and may cover many square meters (Lewis et al. 2002, as cited in Willson et al. 2006). Survival of eggs during the first 10 days of incubation in these masses is very low (< 1%). In contrast, early survival of "drifting eggs" averaged from 69% to 82% in some years, with as much as 97% survival in some locations; however, in another year, average survival was only 9% (up to 23% in some locations; Lewis et al. 2002, as cited in Willson et al. 2006). Overall egg-to-larva survival was estimated as 2.9 - 4.8% in the Kemano River, but less than 1% in the adjacent Wahoo River (Lewis et al. 2002, as cited in Willson et al. 2006). Egg survival is greatly influenced by salinity: exposure to salt water, especially salinity greater than 16 ppt, can be lethal (Farara 1996 cited in Lewis et al. 2002, as cited as cited in Willson et al. 2006). Major temperature changes also affect survival (e.g., a change from 5° to 11°C; Lewis et al. 2002, as cited in Willson et al. 2006).

Hatching and early development are described briefly by Parente and Snyder 1970, as cited in Willson et al. 2006) and DeLacy and Batts (1963), as cited in Willson et al. 2006). The "diaphanous" (Smith and Saalfeld 1955) larvae, 4-8 mm long, are immediately carried by currents to the sea and may rear in estuaries (Hay and McCarter 2000; Lewis et al. 2002, as cited in Willson et al. 2006). Peaks in larval outmigration are thought to occur during periods of relatively stable water temperatures and at low light intensities (Spangler 2002, as cited in Willson et al. 2006). Out-migrating larvae may be damaged by dredging operations (Dutta 1976, as cited in Willson et al. 2006).

Young eulachon appear to occupy a variety of depths in the water column. Yolk-sac fry captured at the mouth of the Cowlitz River were found near the bottom or at intermediate depths (Smith and Saalfeld 1955), but larval eulachon were distributed through the water column in the Fraser River estuary (Levings 1980, as cited in Willson et al. 2006). Larvae and young juveniles become widely distributed in coastal waters, mostly at depths up to 15 m (Hay and McCarter 2000) but sometimes as deep as 182 m (Barraclough 1964, as cited in Willson et al. 2006). Larvae from southern British Columbia Rivers reach the west coast of Vancouver Island by midsummer (Hay et al. 1992). Young eulachon may occur in extensive mixed-species schools with young herring and anchovy (Hay et al. 1992). Larvae turn up in ichthyoplankton surveys in rivers and bays even when few or no adults have been observed. Thus, larvae found near a spawning river may not have originated from that river (Hay and McCarter 2000); larvae might originate from undocumented spawning streams or be brought in by oceanic currents.

Chapter 2. Listing Factors

1. Threats Assessment

As part of the recovery planning process, threats comprising the listing factors leading to the species' threatened status have been assessed with regard to their geographic extent, severity, life stage affected, and responsiveness to management. A threats assessment includes consideration of both natural and human threats, which can result from either intentional or unintentional actions. The current or potential severity of each threat on the species is affected by a variety of characteristics of that threat including the immediate or long-term impact on the species, the geographic extent of the threat and the consideration of the specific life stage(s) affected by that threat.

An assessment of an individual threat not only includes consideration of its severity, but also the responsiveness of that threat to potential management actions and the feasibility of implementing those actions. While there may be concern with a particular threat to a species, if there are no effective measures that can be implemented to minimize or mitigate that threat, then abatement of this threat may not be a high priority recovery action. The ability to implement management actions to address a threat and the likelihood that those actions will be effective are critical considerations when formulating a strategy for the recovery of a listed species.

An assessment of threats must also recognize the interrelationship among various threats. There may be synergistic effects that must be taken into consideration. Evaluation of the individual threats in isolation may lead to an underestimate of their impact on eulachon. Attention needs to be paid to cumulative impacts of threats or interrelationships between threats in order to ensure an accurate assessment.

Threats include human activities or natural events (e.g., fish harvest, volcanoes) that alter key physical, biological and/or chemical features and reduce a species' viability. It is imperative that these physical/biological/chemical factors limiting eulachon viability are evaluated, and that the causal threats are identified in order to successfully document and implement actions that will lead to the recovery of eulachon. In this Recovery Plan, both natural and human-related threats are addressed as they relate to section 4(a)(1)(b) of the ESA: A) destruction or modification of habitat; B) overutilization for commercial, recreational, scientific, or educational purposes; C) disease or predation; D) inadequacy of existing regulatory mechanisms; or E) other natural or human factors. Table 2-1 is the BRT's qualitative threats rankings, and Table 2-2 is the BRT's qualitative threats assessment based on the modal score for each threat in each subpopulation. Based on the BRT's qualitative threats assessment, priority threats (those threats with a qualitative threats level of high) facing eulachon are climate change impacts on ocean conditions and bycatch in the offshore shrimp trawl fisheries.

Since the listing of eulachon in 2010, no new significant information, with the possible exception of measures to reduce bycatch in the ocean shrimp fisheries, has been discovered or brought to our attention regarding the 16 threats identified by the BRT to suggest that these threats have changed in an appreciable manner, especially the most pressing threats: climate change impacts on ocean conditions, dams/water diversions, eulachon bycatch, climate change impacts on freshwater habitats, and predation. In addition, we are not aware of any new data that suggests that there are any new threats that have emerged since the 2010 listing that will reduce the species' viability. In 2015 we published a Federal Register notice (80 FR 6695) regarding the initiation of a 5-year status review for eulachon; we received no new information or data on eulachon.

Table 2-1. Eulachon qualitative threats rankings by subpopulation[23], and ESA Section 4(a)(1)(b) Factors.

	Subpopulation				
Threats	**Klamath**	**Columbia**	**Fraser**	**BC**	**§4 Factor**
	Ranking				
Climate change impacts on ocean conditions	1	1	1	1	A
Dams/water diversions	2	4	8	11	A
Eulachon bycatch	3	2	2	2	E
Climate change impacts on freshwater habitats	4	3	4	4	A
Predation	5	7	3	3	C
Water quality	6	5	5	8	A
Catastrophic events	7	8	10	5	A
Disease	8	11	11	7	C
Competition	9	12	12	9	E
Shoreline construction	10	10	9	6	A
Tribal/First Nations fisheries	11	14	13	10	B
Nonindigenous species	12	15	15	13	E
Recreational harvest	13	13	14	14	B
Scientific monitoring	-	16	16	15	B
Commercial harvest	-	9	6	-	B
Dredging	-	6	7	12	A

(-) no ranking due to insufficient data.

[23] For a description of the qualitative threats assessment see Gustafson et al. 2010, p. 166-170.

Table 2-2. Eulachon Level of Threat Severity in each Subpopulation.

	Subpopulation			
Threats	**Klamath**	**Columbia**	**Fraser**	**BC**
	Severity			
Climate change impacts on ocean conditions	high	high	high	high
Dams /water diversions	moderate	moderate	very low	very low
Eulachon bycatch	moderate	high	moderate	high
Climate change impacts on freshwater habitat	moderate	moderate	moderate	moderate
Predation	moderate	moderate	moderate	moderate
Water quality	moderate	moderate	moderate	low
Catastrophic events	very low	low	very low	low
Disease	very low	very low	very low	very low
Competition	low	low	low	low
Shoreline construction	very low	moderate	moderate	low
Tribal/First Nations fisheries	very low	very low	very low	low
Non-indigenous species	very low	very low	very low	very low
Recreational harvest	very low	low	very low	very low
Commercial harvest	very low	low	low	very low
Scientific monitoring	very low	very low	very low	very low
Dredging	very low	moderate	low	very low

Threats

The following sections provide a summary on the threats to eulachon with respect to the five ESA section 4(a)(1)(b) factors, and an assessment of the threat from a recovery perspective. The BRT Rankings are from Gustafson et al. 2010; the BRT Threats Severity assessment is the level of threat severity based on the BRTs modal score for each threat in each subpopulation, threat levels are rated as Very Low, Low, Moderate, High, or Very High (Gustafson et al. 2010).

A. Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

Threat—Climate Change Impacts on Ocean Conditions				
Subpopulation	**Klamath**	**Columbia**	**Fraser**	**BC**
BRT Ranking	1	1	1	1
BRT Threat Severity	High	High	High	High
Listing Factor	A	A	A	A

Threat—Climate Change Impacts on Freshwater Habitats				
Subpopulation	**Klamath**	**Columbia**	**Fraser**	**BC**
BRT Ranking	4	3	4	4
BRT Threat Severity	Moderate	Moderate	Moderate	Moderate
Listing Factor	A	A	A	A

Environmental conditions in both marine and fresh waters inhabited by eulachon are influenced, in large part, by two ocean-basin scale drivers, the Pacific Decadal Oscillation (PDO) (Mantua et al. 1997) and the El Niño Southern Oscillation Index (ENSO).

Climate change impacts on ocean conditions, i.e., as measured by large-scale spatial and temporal shifts in oceanic-atmospheric patterns in the northeast Pacific Ocean associated with both natural climate variability and anthropogenic-forced climate change, is likely the principal threat to eulachon, as it is the one phenomenon that correlates with the recent species-wide declines in abundance. While the specific characteristics that provide favorable marine conditions for eulachon in the northeast Pacific Ocean are unknown, the available information suggests that there is a link between the (PDO) (Gustafson et al. 2010), as well as other marine indices such as the ENSO, the Oceanic Niño Index (ONI), and the Northern Oscillation Index (NOI), and eulachon survival, abundance, and recruitment potential. One hypothesis is that cool-phase PDO cycles are associated with greater primary and secondary productivity in the northern California Current (Figure 2-1) that provide abundant food resources for multiple age classes, especially larval eulachon entering the marine environment.

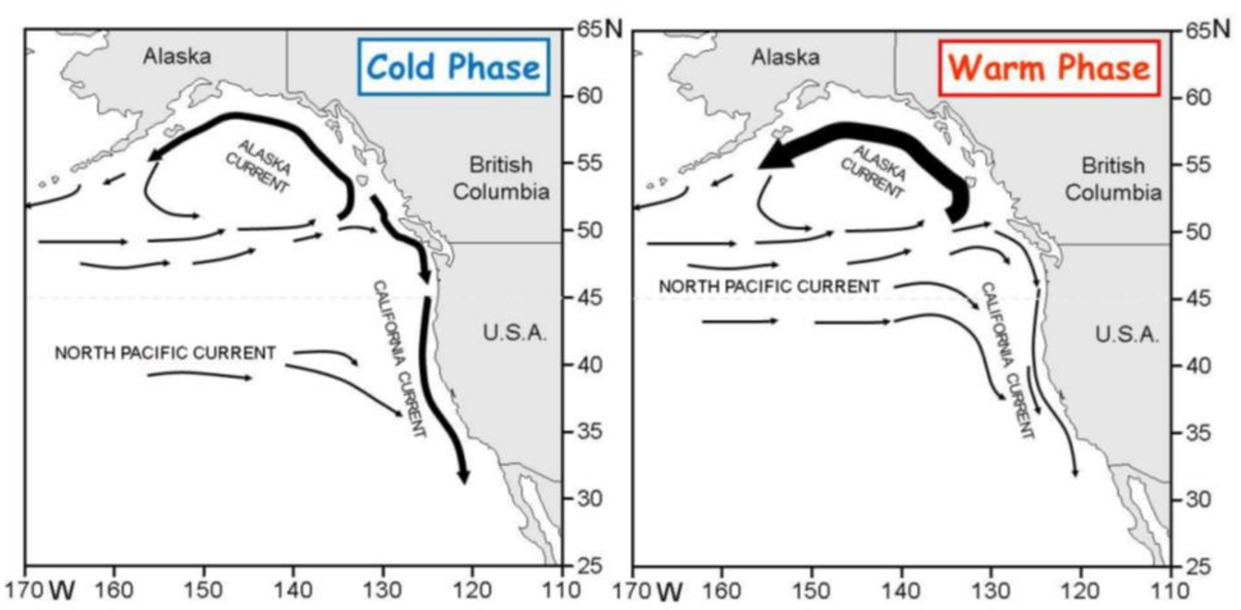

Figure 2-1. A working hypothesis on how changes in the Pacific Decadal Oscillation affect productivity in the northern California Current Peterson et al. (2013).

Likely changes in temperature, precipitation, wind patterns, and sea level height have profound implications for survival of eulachon, in both their freshwater and marine habitats. Recent descriptions of expected changes in Pacific Northwest climate that are relevant to eulachon include Elsner et al. (2009), Mantua et al. (2009), Mote and Salathe (2009), Salathe et al. (2009), and Gustafson et al. (2010). Reviews of the effects of climate change in the Columbia River basin include ISAB (2007), Hixon et al. (2010), Dalton et al. (2013), and NMFS (2014).

The following is a summary of expected climate change-related effects on eulachon and their habitats derived from the above sources.

Freshwater Environments

Climate records show that the Pacific Northwest has warmed about .07°C since 1900, or about 50% more than the global average warming over the same period (Dalton et al. 2013). The warming rate for the Pacific Northwest over the next century is projected to be in the range of 0.1°C to 0.6°C per decade. While total precipitation changes are predicted to be minor (+1% to 2%), increasing air temperature will alter the snow pack, stream flow timing and volume, and water temperature in the Columbia Basin. Climate scientists predict the following physical changes to rivers and streams in the Columbia River Basin:

- Warmer temperatures will result in more precipitation falling as rain rather than snow.
- Snow pack will diminish, water temperatures will increase, and stream flow volume and timing will be altered.

Estuarine and Plume Environments

Climate change will also affect eulachon in the estuarine and plume environments. In the estuary, eulachon would be primarily affected by increased in water temperatures, flow-related changes, altered phytoplankton and zooplankton prey, and increased predation. Eulachon may be affected by habitat changes in the plume environment due to flow- or sediment-related changes; however, use of plume habitat by eulachon remains poorly understood. Effects of climate change on eulachon in the estuary and plume may include the following:

- Higher winter freshwater flows and higher sea levels may increase sediment deposition in the plume, possibly reducing the quality of rearing habitat.
- Lower freshwater flows in late spring and summer may lead to upstream extension of the salt wedge, possibly influencing the distribution of eulachon prey and predators.
- Increased temperature of freshwater inflows and seasonal expansion of freshwater habitats may extend the range of non-native, warm-water species that are normally found only in freshwater.

In all of these cases, the specific effects on eulachon abundance, productivity, spatial distribution and diversity are poorly understood.

Marine Environments

Effects of climate change in marine environments include: increased ocean temperature, increased stratification of the water column, changes in intensity and timing of coastal upwelling, and ocean acidification. Hypotheses differ regarding whether coastal upwelling will decrease or intensify, but even if it intensifies, the increased stratification of the water column may reduce the ability of upwelling to bring nutrient-rich water to the surface. There are also indications in climate models that future conditions in the North Pacific region will trend toward conditions that are typical of the warm phases of the PDO, but the models in general do not reliably reproduce the oscillation patterns. Hypoxic conditions observed along the continental shelf in recent years appear to be related to shifts in upwelling and wind patterns that may be related to climate change.

Climate-related changes in the marine environment are expected to alter primary and secondary productivity, the structure of marine communities, and in turn, the growth, productivity, and survival of eulachon, although the degree of impact on eulachon is currently poorly understood. A mismatch between larval survival (because of earlier peak spring freshwater flows and decreased incubation period) and altered upwelling may reduce marine survival rates.

Ocean warming also may change migration patterns, increasing distances to feeding areas. Rising atmospheric carbon dioxide concentrations drive changes in seawater chemistry, increasing the acidification of seawater and thus reducing the availability of carbonate for shell-forming invertebrates. This process of acidification is under way, has been well documented along the Pacific coast of the United States, and is predicted to accelerate with increasing greenhouse gas emissions.

Ocean acidification has the potential to reduce survival of many marine organisms, including eulachon. However, because there is currently a paucity of research directly related to the effects of ocean acidification on salmon and their prey, potential effects are uncertain. Laboratory studies on prey taxa have generally indicated negative effects of increased acidification, but how this translates to the population dynamics of eulachon prey and the survival of eulachon is uncertain. Modeling studies that explore the ecological impacts of ocean acidification and other impacts of climate change concluded that salmon landings in the Pacific Northwest and Alaska are likely to be reduced.

Conclusion

Based on this information, the threat occurs at a high severity and there is a high level of uncertainty. Thus, the relative impact to recovery is ranked high.

Threat—Water Quality				
Subpopulation	**Klamath**	**Columbia**	**Fraser**	**BC**
BRT Ranking	8	5	5	8
BRT Threat Severity	Moderate	Moderate	Moderate	Low
Listing Factor	A	A	A	A

Water quality is divided here into two groups: (1) as the chemical, physical, biological, and radiological characteristics largely determined by climatic, geomorphological and geochemical conditions; and (2) anthropogenic, largely affected by man, directly or indirectly, via the introduction of substances, natural or synthetic, or energy which result in detrimental effects on aquatic ecosystems from industrial activities, such as the manufacture of computer, electrical, and optical products; manufacture of automobiles, trucks, trains, ships; dam construction; urbanization; and agricultural activities, such as crop and animal production, mining and quarrying, and forestry.

The following is a summary of expected water quality-related effects on eulachon based on Gustafson et al. (2010).

General Contaminants— Contaminants enter fresh and marine waters and sediments from numerous sources such as atmospheric transport and deposition, ocean current transport, and terrestrial runoff, but are typically concentrated near populated areas of high human activity and industrialization. The high lipid content of eulachon suggests they are susceptible to absorption of lipophilic organic contaminants (Higgins et al. 1987, Pickard and Marmorek 2007; as cited in Gustafson et al. 2010). Contaminants considered of most concern include: 1) synthetic chlorinated organic chemicals, such as hexachlorobenzene, DDTs, and the polychlorinated biphenyls (PCBs); 2) polycyclic aromatic hydrocarbons (PAHs) from petroleum and creosoted pilings; 3) dioxins and a host of other organic compounds; 4) metals such as mercury, arsenic, and lead; and 5) endocrine-disrupting compounds and new toxics like PBDE (polybrominated diphenyl ether).

The Environmental Protection Agency (EPA 2002; as cited in Gustafson et al. 2010) examined contaminants in fish, including whole eulachon, from the Columbia River in 1996–1998. In general, these eulachon had some of the lowest levels of organic chemicals of all the fishes tested but had the highest average concentrations of arsenic (0.89 µg/g whole body weight) and lead (0.50 µg/g).

Hall (1976, p. 45; as cited in Gustafson et al. 2010) reviewed water quality and sources of pollution in the lower Fraser River and stated that:

> There appear to be two main water quality problems in the lower Fraser, both apparently attributable to the urban-industrial complex of metropolitan Vancouver, namely pathogens and trace metals. … Potential problems are apparent regarding toxic substances such as trace metals. Concentrations are not high enough to be acutely toxic to

> fish but the sporadic occurrence of higher concentrations of trace metals such as lead, mercury, and zinc in the lower reaches of the river and accumulations in sediments give some cause for concern, especially since these substances are not biodegradable and bioamplification through food chain concentration or direct absorption by the organism cannot be ignored in the sensitive estuarine areas of the lower Fraser.

Types and sources of contaminants in the lower Fraser River consist of insecticides and herbicides used in agricultural production; wood preservatives associated with the lumber industry (e.g., chromium, copper, arsenic, chlorinated phenols, dioxins, polynuclear aromatic hydrocarbons, phenolics, and creosote); leachates from landfills; a wide range of contaminants in stormwater discharge; industrial effluents associated with metal, cement, forest products, and food industries; and municipal effluents (Birtwell et al. 1988, as cited in Gustafson et al. 2010).

Temperature—Smith and Saalfeld (1955) reported that eulachon are present in the Columbia River when water temperatures are between 2°C and 10°C and delay migration into spawning tributaries until temperatures are above about 4.4°C (WDFW/ODFW 2001). When river temperatures vary above or below normal, eulachon may fail to spawn in normal areas, delay spawning, or migrate into other tributaries (Smith and Saalfeld 1955, WDFW/ODFW 2001).

Snyder (1970, as cited in Gustafson et al. 2010) reported on studies in 1968 and 1969 that examined the temperature tolerance of adult eulachon and eggs taken from the Columbia and Cowlitz rivers and found that eggs were more tolerant to temperature increases than were adults. Increases of 2.8°C and 5.6°C killed 50% and 100% of adult smelt, respectively, within 8 days. Even when exposed to temperatures elevated by 9°C for a single hour, 50% of adult eulachon were dead after 32 hours. When placed in water 3.9°C above river temperatures, females failed to deposit eggs (Snyder 1970, as cited in Gustafson et al. 2010). Slightly different results were reported by Blahm and McConnell (1971, as cited in Gustafson et al. 2010) on effects of increased temperature on eulachon collected from the Cowlitz River in 1968 and 1969. They reported that the incipient lethal temperature for eulachon acclimated to 5°C was 11°C. All eulachon exposed to 11°C were dead after 8 days exposure. When eulachon had been acclimated to 10°C, a sudden exposure to 18°C for one hour followed by return to 10°C resulted in at least 50% mortality within 50 hours (Blahm and McConnell 1971, as cited in Gustafson et al. 2010). All female fish exposed to elevated temperatures failed to deposit eggs within 50 hours, in contrast to female eulachon in control conditions that successfully deposited eggs (Snyder and Blahm 1971, as cited in Gustafson et al. 2010).

When evaluating temperature criteria for Washington's water quality standards, Hicks (2000, p. 99; as cited in Gustafson et al. 2010) stated that:

> The studies on smelt indicate they have a lower lethal temperature limit than do the salmonids and a lower optimum temperature preferendum…given that adult spawners

> and outgoing juveniles may be in fresh waters as late as March to mid-April, and their temperature requirements may be stricter than most salmonids, the protection of smelt is an important consideration in setting water quality standards. In waters supporting smelt, it is recommended that the 7-day average of the daily maximum temperatures not exceed 12–14°C prior to May 1, with no single daily maximum temperature greater than 16°C.

In 2014 (NMFS 2014), NMFS evaluated the effects of the Federal Columbia River Power System (FCRPS) on eulachon and their habitat and concluded that:

> [the FCRPS] will continue to alter the hydrograph of the Columbia River in a manner that will continue to alter water quality (reduced spring turbidity levels), water quantity (seasonal changes in flows and consumptive losses resulting from use of stored water for agricultural, industrial, or municipal purposes), water temperatures, and water velocity (reduced spring flows and increased cross-sectional areas of the river channel).
>
> In general, flow regulation has increased minimum winter temperatures when adult eulachon are migrating through and spawning in the Columbia River and has reduced average spring temperatures compared to an undeveloped system. These patterns are due to the increased thermal inertia of large volumes of stored water, increased solar radiation over the larger surface area of the reservoirs, and altered seasonal flow regimes. Temperatures in the reach below Bonneville Dam are also affected by tidal exchange with the ocean and by tributaries to the estuary (especially the Lewis, Cowlitz, Elochoman, and Grays rivers in Washington and the Willamette and Clatskanie rivers and several smaller streams in Oregon).
>
> Hicks (2000) evaluated proposed water quality standards for temperature in Washington State proposed for the protection of salmonids and char and their protectiveness for other indigenous fish species in Washington State, including eulachon. Hicks identified a temperature range of 2°C to 10°C for spawning and migration; for successful egg deposition, Hicks noted water temperatures of less than 13°C were protective; and Hicks identified 18°C as rapidly lethal to adult eulachon.
>
> Water temperatures measured at tidal freshwater sites, in the mixing zone, and at marine sites near the mouth of the estuary ranged from about 4°C to 10°C during January through April in 2003 to 2006. These data indicate that temperatures eulachon encounter within the Columbia River estuary during the months of January through April do not exceed the range needed for the conservation of the species.
>
> The months of January through April are considered the peak activity level for all eulachon life stages. To look at water temperature effects to eulachon during the non-peak activity level of May through July, we used the U.S. Geological Survey (USGS) water temperature data for the Columbia River, and the EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards (USEPA 2003).

First, we looked at water temperatures measured by the USGS between May 30, 2013 through July 30, 2013 at Washougal, WA, RM 121; during this period, water temperatures ≥16°C were first reported on June 6, 2013, continuing through the end of July with temperatures ≥18°C reported on June 18, 2013, and water temperatures reaching a high 22.1°C on July 27, 2013 (USGS 2013). Second, we looked at water temperatures measured by the USGS between May 30, 1998 through July 30, 1998 (available time series), at Wauna, OR, RM 42. During this period, water temperatures ≥16°C were first reported on June 9, 1998, continuing through the end of July with temperatures ≥18°C reported on June 24, 1998, and water temperatures reaching a high of 23.4°C on July 29, 1998 (USGS 2013). The range of temperatures ≥16°C overlap with the presence of all eulachon life stages (non-peak activity level) in the Columbia River. As with salmon and steelhead, eulachon exposed to temperatures ≥16°C, measured as the 7-day average of the daily maximum, are likely to be subjected to adverse water quality conditions with an increased risk of reduced egg viability, disease, reduced growth, and mortality (USEPA 2003).

Conclusion

Based on this information, the threat occurs at a moderate severity and there is a medium-to-high level of uncertainty. Thus, the relative impact to recovery is ranked moderate.

Threat—Catastrophic Events				
Subpopulation	**Klamath**	**Columbia**	**Fraser**	**BC**
BRT Ranking	7	8	10	5
BRT Threat Severity	Very Low	Low	Very Low	Low
Listing Factor	A	A	A	A

Catastrophic events, such as volcanic eruptions and large-scale wildfires, can, depending on the nature, magnitude, extent, and duration of the event, increase a species' extinction risk.

Emmett et al. (1990, as cited in Gustafson et al. 2010) documented the effects of the dramatic increase in turbidity in the Columbia River on fishes in the estuary following the May 18, 1980 eruption of Mount St. Helens, which resulted in introduction of large quantities of volcanic ash and sediment into the Columbia River. Although hampered by the absence of long-term pre-eruption data, Emmett et al. (1990, as cited in Gustafson et al. 2010) showed that densities of benthic invertebrates, particularly amphipods, were significantly reduced and feeding habits and distribution of estuarine fishes were altered following the eruption.

Conclusion

Based on this information, the threat occurs at a low to very low severity and there is a high level of uncertainty. Thus, the relative impact to recovery is ranked low.

Threat—Shoreline Construction				
Subpopulation	**Klamath**	**Columbia**	**Fraser**	**BC**
BRT Ranking	7	8	10	5
BRT Threat Severity	Very Low	Moderate	Moderate	Low
Listing Factor	A	A	A	A

Adverse effects of shoreline construction to natural resources include: reduced or degraded habitat for breeding, spawning, feeding, growing, and thermoregulation for a variety of fish and wildlife species; impaired movement of organisms between aquatic and terrestrial habitat; altered physical structure of the water's edge, with resultant changes to hydrology; local changes in water quality, including changes to temperature, nutrients and contaminants; and increased erosion of the adjacent natural shorelines and scouring in front of the structure. Together these factors may reduce the amount and quality of spawning and rearing habitats available to eulachon, limit access to other historically productive habitats, and degraded watershed processes and functions that once created healthy ecosystems for eulachon production.

The following is a summary of shoreline construction-related effects on eulachon based on Gustafson et al. (2010).

Columbia River—Estuarine habitat in the Columbia River has been modified through "shoreline armoring and construction of structures over water, channel dredging and removal of large woody debris, channelization by pile dikes, and other structures" (Bottom et al. 2005, p. 18; as cited in Gustafson et al. 2010). Thomas (1983, as cited in Gustafson et al. 2010) estimated that estuarine acreage at the time of his study was only about 76% of the acreage of the estuary in 1870. This reduction was largely the result of dike and levee construction. Approximately 43% of tidal marshes and 77% of tidal swamps in the Columbia River estuary were estimated to have been lost since 1870 (Thomas 1983, as cited in Gustafson et al. 2010). Sherwood et al. (1990, p. 299; as cited in Gustafson et al. 2010) also reviewed historical changes in the Columbia River estuary and found that "large changes in the morphology of the estuary have been caused by navigational improvements (jetties, dredged channels, and pile dikes) and by the diking and filling of much of the wetland area." Sherwood et al. (1990, as cited in Gustafson et al. 2010) suggested that the greatest cause of change in the morphology of the Columbia River estuary was due to construction of permeable pile dikes and jetties, particularly jetties at the mouth of the river. LCFRB (2004a, p. A-157; as cited in Gustafson et al. 2010) reported that:

> Artificial channel confinement has altered river discharge and hydrology, as well as disconnected the [Columbia] river from much of its floodplain. … Additionally, channel manipulations for transportation or development have also had substantial influence on river discharge and hydrologic processes in the river.

Bottom et al. (2005, p. xxii; as cited in Gustafson et al. 2010) provided a chronology of changes in the Columbia River estuary and stated that:

> The productive capacity of the estuary has likely declined over the past century through the combined effects of diking and filling of shallow-water habitats…. Loss of approximately 65% of the tidal marshes and swamps that existed in the estuary prior to 1870, combined with the loss of 12% of deep-water area, has contributed to a 12–20% reduction in the estuary's tidal prism.

Columbia River Tributaries—The LCFRB (2004a, p. E-89; as cited in Gustafson et al. 2010) observed that "the mainstem Cowlitz below Mayfield Dam has been heavily altered due to adjacent land uses including agriculture, rural residential development, transportation corridors, urbanization, and industry." The LCFRB (2004a, p. E-30; as cited in Gustafson et al. 2010) also reported that "the lower 20 miles of the Cowlitz has experienced severe loss of floodplain connectivity due to dikes, riprap, or deposited dredge spoils originating from the Mount St. Helens eruption." Major population centers in the lower Cowlitz River basin with their associated industrial and residential development include the towns of Castle Rock, Longview, and Kelso (LCFRB 2004a, as cited in Gustafson et al. 2010).

The only urban area in the Kalama River basin is the City of Kalama, located near the river's mouth where dikes have been constructed in the historical floodplain to protect nearby roads and industrial developments (Wade 2000a, LCFRB 2004a; as cited in Gustafson et al. 2010). Future development is likely to be concentrated along the lower mainstem Kalama River, where increasing residential development has also occurred in recent years (LCFRB 2004a, as cited in Gustafson et al. 2010).

Much of the lower mainstem Lewis River is also "disconnected from its floodplain by dikes and levees" (LCFRB 2004a, p. G-55; as cited in Gustafson et al. 2010) and "the largest urban population center, the City of Woodland, lies near the mouth of the river" (Wade 2000a, p. 23; as cited in Gustafson et al. 2010). According to (LCFRB 2004a, p. G-87; as cited in Gustafson et al. 2010), "the mainstem Lewis below Merwin Dam has been heavily altered due to adjacent land uses including agriculture, residential development, transportation corridors, and industry."

British Columbia—Pickard and Marmorek (2007, as cited in Gustafson et al. 2010) reported that results of a DFO workshop to determine research priorities for eulachon indicated that shoreline construction in the form of roads, bridges, dikes, piers, wharfs, and so forth may have an impact on eulachon in the Skeena, Kitimat, Kemano, Fraser, and Columbia rivers. According to Pickard and Marmorek (2007, p. 14; as cited in Gustafson et al. 2010):

> There is evidence of change in the habitat in developed rivers such as the Fraser and Kitimat. These changes include the loss of side channels, loss of habitat complexity/diversity, and increase in velocity. These habitat changes are thought to affect eulachon, however the magnitude of the effect is not clear.

Pickard and Marmorek (2007, as cited in Gustafson et al. 2010) also suggested that an increase in river velocities likely would result in eggs and larvae being rapidly washed downstream, where they may encounter high salinities at an early age. The fate of eggs and larvae that may be prematurely washed out to sea is unknown.

The largest city in British Columbia, Vancouver, together with all of its associated industrial and urban development, abuts the Fraser River estuary (Birtwell et al. 1988, as cited in Gustafson et al. 2010). Moody (2008) indicated that an extensive system of dikes was constructed in the lower Fraser River following the 1948 flood. According to Plate (2009, p. 3 and p. iii; as cited in Gustafson et al. 2010), recent plans to construct "a new 10-lane Port Mann Bridge [over the Fraser River] represents a major addition to shoreline and in-river construction on the lower Fraser River" and is of concern because "eulachon spawn directly beneath the [current] Port Mann Bridge pillars and in the close upstream vicinity of the bridge, and as expected eulachon use all channels under the bridge for migration to upstream areas."

Conclusion

Based on this information, the threat occurs at a very low to moderate severity and there is a medium level of uncertainty. Thus, the relative impact to recovery is ranked moderate.

Threat—Dams/Water Diversions				
Subpopulation	**Klamath**	**Columbia**	**Fraser**	**BC**
BRT Ranking	2	4	8	11
BRT Threat Severity	Moderate	Moderate	Very Low	Very Low
Listing Factor	A	A	A	A

Both individually and cumulatively, dams fundamentally transform river ecosystems in several ways: (a) They alter the downstream flux of water and sediment, which modifies biogeochemical cycles as well as the structure and dynamics of aquatic and riparian habitats; (b) they change water temperatures, which influences organismal bioenergetics and vital rates; (c) and they create barriers to upstream–downstream movement of organisms and nutrients, which hinders biotic exchange. These fundamental alterations have significant ecological ramifications at a range of spatial and temporal scales (Poff and Hart 2002).

Klamath River and Trinity Rivers—The six hydroelectric dams on the Klamath and Trinity Rivers, as well as associated irrigation withdrawals in the upper Klamath River basin, have shifted the spring peak flow of the lower Klamath River from its historical peak in April to its current peak in March, one full month earlier (NRC 2004, as cited in Gustafson et al. 2010).

Columbia River Basin—In the Columbia River Basin, there are more than 470 dams, with more than 150 hydroelectric projects throughout the basin, and a vast network of dams and irrigation canals. These dams and water control structures have significantly altered the natural hydrologic pattern of the Columbia River (Sherwood et al. 1990, Bottom et al. 2005, as cited in Gustafson et al. 2010). Development of a large-scale hydropower system in the Columbia River Basin has changed seasonal flow rates, reduced sediment transport, and discharge (i.e., the rate of flow) to the nearshore ocean environment (ISAB 2000). Physical changes in the estuary and regulation of river flow have also altered the dynamics of seawater intrusion, circulation, and sedimentation processes in the estuary, and have had large ecosystem-level consequences (ISAB 2000).

Since the development of the Canadian and Federal Columbia River Power System (FCRPS) storage projects in the upper Columbia basin (1940s through 1970s), water is store during spring and released for power production and flood control during winter, shifting the annual hydrograph. Water withdrawals and flow regulation have reduced the Columbia River's average flow, altered its seasonality, and altered sedimentation processes and seasonal turbidity events, e.g., estuary turbidity maximum (Simenstad et al. 1982, 1990; Sherwood et al. 1990; NRC 1996; Weitkamp 1994, as cited in NMFS 2008a). Water withdrawals and flow regulation have significantly affected the timing, magnitude and duration of the spring freshet through the Columbia River estuary such that they are about one-half of the pre-development levels (NMFS 2008a), all of which are important for eulachon adult, larval, and egg life stages.

In the Columbia River estuary, both the quantity and timing of instream flows have changed from historical conditions (Fresh et al. 2005). Jay and Naik (2002) reported a 16% reduction of annual mean flow over the past 100 years and a 44% reduction in spring freshet flows. Jay and Naik (2002) also reported a shift in flow patterns in the Columbia to 14 to 30 days earlier in the year, meaning that spring freshets are occurring earlier in the seasons. In addition, the interception and use of spring freshets (for irrigation, reservoir storage, etc.) has caused increased flows during other seasons (Fresh et al. 2005). It is unknown what effect these changes in hydrology may have on eulachon habitat

The Columbia River plume is a freshwater/saltwater interface where freshwater exiting the Columbia River meets and rises above the denser saltwater of the Pacific Ocean. The plume's location varies seasonally with discharge, prevailing near-shore winds, and ocean currents. In summer, the plume extends far to the south and offshore along the Oregon coast. During the winter, it shifts northward and inshore along the Washington coast. Strong density gradients between ocean and plume waters create "fronts" (i.e., interfaces or transition zones) where organic matter and organisms are concentrated (Fresh et al. 2005, as cited in Gustafson et al. 2010). Water management in the Columbia basin has reduced the size, shape and intensity of the plume.

NMFS (2014) evaluated the effects of the FCRPS on eulachon and their habitat and concluded that:

> [The FCRPS] will continue to alter the hydrograph of the Columbia River in a manner that increases flows during the fall–winter period by 8.9%, 12.4%, 15.1%, 27%, 19.7%, and 10.2%, respectively, during the months of October through March, and diminishes flows during the spring–summer period by 0.7%, 10.4%, 12.7%, 10.4%, 2.5%, and 1.4%,

respectively, during the months of April through September, relative to pre-development of the dams in the basin. These operational effects on the hydrograph have the potential to affect eulachon spawning production, egg incubation, and larval and juvenile growth, development, and survival in the estuary–plume environment.

The fraction of the hydrograph of the Columbia River that is due to the operations of the FCRPS is approximately 30% (BPA et al. 2001) of the overall change in the hydrograph under the 2008/2010 RPA. NOAA Fisheries calculated these net changes in flows based on the HYDSIM model simulated-mean monthly Columbia River flows at Bonneville Dam for the water years 1929–1978 (USBR 1999, as cited in NOAA 2015; BPA et al. 2001).

Although habitat–related effects to eulachon as a result of the continued operations of the FCRPS has the potential to affect eulachon spawning behavior; egg viability; and larvae and juvenile growth, development, and survival, the principal habitat-related effects to eulachon as a result of the continued operations of the FCRPS are the hydrological effects on the estuary–plume environment, which is utilized by eulachon larvae and juveniles for rearing and maturation. Continued operations of the FCRPS, especially during the April through July period, a period that coincides with eulachon larval ocean entry and residence timing, is likely to affect the chemical and physical processes of the estuary–plume environment (NMFS 2008a, as cited in NOAA 2015), and therefore may have negative impacts on marine survival of eulachon larvae and juveniles during the freshwater–ocean transition period.

The extent to which freshwater-derived dissolved and particulate matter to the ocean may influence the survival of eulachon larvae during the freshwater–ocean transition period is unclear. However, Gustafson et al. (2010) noted that variable year-class strength in marine fishes with pelagic larvae is dependent on survival of larvae prior to recruitment and is driven by match-mismatch of larvae and their planktonic food supply, oceanographic transport mechanisms, and variable environmental ocean conditions. Based on this link between planktonic food supply, environmental ocean conditions, and eulachon larvae, decreased freshwater inputs during the months of April through September are likely to affect the chemical and physical processes of the estuary–plume environment, and thus planktonic food supply, as a result of water management operations via the FCRPS.

In a ten-year study on the biotic and abiotic factors influencing forage fish and pelagic nekton communities in the Columbia River plume throughout the upwelling season, Litz et al. (2013, as cited in NMFS 2014) examined the assemblages of forage fish, predator fish, and other pelagic nekton in coastal waters associated with the Columbia River plume. They found that resident euryhaline[24] forage fish species, such as smelts, showed a high affinity for inshore habitat and the lower salinity plume during spring. Overall, their study revealed that temporal dynamics in abundance and community composition were associated with seasonal abiotic phenomenon, but not interannual, large-scale oceanographic processes. Forage fish assemblages differed seasonally and spatially from the assemblages of major piscivorous predators, suggesting a potential role of the plume as refuge for forage fish.

These studies highlight the connection between river-derived nutrients, coastal-upwelling, chemical and physical process in the estuary–plume environment, primary productivity, and the importance of the estuary–plume environment to eulachon, especially eulachon larvae and juveniles. In the absence of direct data on the link between decreases in freshwater inputs into the estuary-plume environment and effects on eulachon larvae and juveniles to assess the significance of effects, we determined, based on available information, that the magnitude of reduced freshwater delivery to the estuary–plume environment via water management operations under the FCRPS during the months of April through September (0.7%, 10.4%, 12.7%, 10.4%, 2.5%, and 1.4% reduction, respectively is likely to be of a magnitude, duration, frequency, and spatial extent sufficient to adversely affect primary productivity such that eulachon larvae and juveniles in the estuary-plume environment will be subjected to decreases in food availability and quality (caloric content), which is likely to reduce the species' fitness and survival potential.

Bonneville Dam (RKM 235) also impedes migration of eulachon to historical spawning habitat above the dam in the Hood River and possibly the Klickitat River (Smith and Saalfeld 1955, WDFW and ODFW 2008; as cited in Gustafson et al. 2010). Eulachon reportedly are unable to ascend fish ladders designed for Pacific salmon (LCFRB 2004a, as cited in Gustafson et al. 2010).

Overall, the available evidence indicates that shifts in the timing, magnitude, and duration of the hydrograph of the Columbia River via water management operations are likely to continue to affect the Columbia River subpopulation of eulachon. These effects will disproportionately manifest on eulachon larvae compared to habitat–related effects on adult and juvenile eulachon that reside in the estuary–plume environment, especially during the months of May through July when freshwater inputs to the estuary–plume are significantly diminished, which in turn may affect phytoplankton production—the primary food resource for eulachon larvae in the estuary–plume.

[24] Species that are able to live in waters of a wide range of salinity.

Columbia River Tributaries—In the Cowlitz River watershed, there are two major dams on the mainstem Cowlitz River: Mayfield Dam at RKM 83.7 forms Mayfield Lake and Mossyrock Dam at RKM 104.6 forms Riffe Lake (Wade 2000b, as cited in Gustafson et al. 2010). These dams and other run-of-river dams in the hydropower system largely control flow in the mainstem Cowlitz River. Following the eruption of Mount St. Helens in 1980, the USACE constructed a sediment retention structure (SRS) on the North Fork Toutle "to prevent the continuation of severe downstream sedimentation of stream channels, which created flood conveyance, transportation, and habitat degradation concerns" (LCFRB 2004a, p. E-374, as cited in Gustafson et al. 2010). The SRS was constructed in 1989 about 49 km above the confluence of the Toutle and Cowlitz rivers, is approximately 50 m in height, and extends 600 m across the valley of the North Fork Toutle River. The SRS continues to be a source of fine sediment to the lower Cowlitz River (LCFRB 2004a, as cited in Gustafson et al. 2010). Anderson (2009, p. 5 as cited in Gustafson et al. 2010,) stated that:

> The SRS [on the Toutle River], constructed by the USACE, has become ineffective at trapping sediments. Lower Cowlitz River eulachon spawning habitat is considered degraded while the Toutle River is assumed absent of spawning habitat due to this fine sediment inundation. … WDFW considers past and continued fine sediment deposition in the Toutle and Cowlitz rivers as a moderate to high risk for eulachon.

There are three major dams on the mainstem Lewis River, also known as the North Fork Lewis River: Merwin Dam (aka Ariel Dam) at RKM 31.4, built in 1931, forms Lake Merwin; Yale Dam at RKM 55, built in 1953, forms Yale Lake; and Swift Dam at RKM 77.1, built in 1958, forms Swift Creek Reservoir (Wade 2000a, as cited in Gustafson et al. 2010). The Lower Columbia Fish Recovery Board (LCFRB 2004a, p. G-35, as cited in Gustafson et al. 2010) stated that:

> Hydropower regulation has altered the hydrograph of the lower mainstem [of the Lewis River].… Pre-dam data reveals peaks due to fall/winter rains, winter rain-on-snow, and spring snowmelt. Post-dam data shows less overall flow variation, with a general increase in winter flows due to power needs. Post-dam data shows a decrease in spring snowmelt flows due to reservoir filling in preparation for dry summer conditions.… The risk of extreme winter peaks has also been reduced, with the trade-off being the reduction of potentially beneficial large magnitude channel-forming flows. … The long-term effects on channel morphology and sediment supply have not been thoroughly investigated.

Canada—In British Columbia there are an estimated 802 licensed dams in the Fraser River Basin, mostly for irrigation purposes in the dryer areas above Hope (Birtwell et al. 1988, as cited in Gustafson et al. 2010). The impact on eulachon of water withdrawals associated with reservoirs in the Fraser River has not been studied. The other eulachon river in British Columbia where hydrology has been significantly altered by water diversions is the Kemano River where a hydroelectric plant began operating in 1954 (Lewis et al. 2002, as cited in Gustafson et al. 2010).

Conclusion

Based on this information, the threat occurs at a very low to moderate severity and there is a high level of uncertainty. Thus, the relative impact to recovery is ranked moderate-to-high.

Threat—Dredging				
Subpopulation	**Klamath**	**Columbia**	**Fraser**	**BC**
BRT Ranking	No Ranking	6	7	12
BRT Threat Severity	Not Scored	Moderate	Very Low	Very Low
Listing Factor	A	A	A	A

Dredging impacts physical habitat features by altering the geomorphic structure of the river bottom with resultant changes in hydraulic geometry (Leopold and Maddock 1953) and sediment transport, negatively affecting habitat forming processes and ecological and biological interactions.

The following is a summary of expected dredging-related effects on eulachon based on Gustafson et al. (2010).

Potential dredging impacts on eulachon consist of direct effects of entrainment of adults and eggs and potential for smothering of eggs with sediment (Howell and Uusitalo 2000, Howell et al. 2001; as cited in Gustafson et al. 2010). Indirect effects may consist of altering the freshwater spawning habitat and estuarine nursery habitat. Larson and Moehl (1990) documented direct entrainment of small amounts of eulachon by hopper dredge at the mouth of the Columbia River during May-October 1985–1988. Johnston (1981, p. 427; as cited in Gustafson et al. 2010) reviewed dredging activities in estuarine environments and listed "increased turbidity; altered tidal exchange, mixing, and circulation; reduced nutrient outflow from marshes and swamps; increased saltwater intrusion; and creation of an environment highly susceptible to recurrent low dissolved oxygen levels" as negative impacts.

Hay and McCarter (2000) indicated that dredging during the eulachon spawning season in the Fraser River continued until the late 1990s. Tutty and Morrison (1976, as cited in Gustafson et al. 2010) estimated about 0.9 mt of adult eulachon were directly entrained during hopper dredging activities between March 15 and June 4, 1976, on the lower Fraser River. Hay and McCarter (2000, p. 38) stated that "the direct loss of about 1 tonne of eulachons may have been small relative to potential deleterious impacts on survival of eulachons eggs—either from the direct effect of entrainment of spawned eggs, or the silt-induced smothering of eggs deposition [sic] in waters downstream of the dredging operations." Hay and McCarter (2000) suggested dredging [in the Fraser River] should be confined to periods outside of the spawning season to minimize impacts on eulachon and that the effects of sediment removal on eulachon spawning habitats should be a topic of research.

FREMP (2007, as cited in Gustafson et al. 2010) estimated that from 0.76 to 3.22 million cubic meters of sediment were dredged annually from the lower Fraser River during the years 1997–2007 to prevent grounding of commercial shipping. Increases in vessel size have required deepening of the shipping channel in recent years (FREMP 2007, as cited in Gustafson et al. 2010). As mentioned in Pickard and Marmorek (2007, as cited in Gustafson et al. 2010), suction dredging is currently restricted to months when eulachon are not spawning in the Fraser and Kitimat rivers. According to FREMP (2006, p. 40; as cited in Gustafson et al. 2010), "hydraulic suction dredging and large-scale clamshell dredging undertaken in the Fraser River estuary is restricted so that there is no dredging conducted from March 1 to June 15 of any given year."

It has been suggested that eulachon spawning distribution in the Fraser River has changed in response to dredging and channelization and that dredging, even outside of the spawning period, affects eulachon by destabilization of substrates (Pickard and Marmorek 2007, as cited in Gustafson et al. 2010). Pickard and Marmorek (2007, p. 8; as cited in Gustafson et al. 2010) reported in their summary of findings of a DFO workshop to determine research priorities for eulachon that "there is consensus that dredging is not the cause of the coastwide decline in eulachon, but there is disagreement about the importance of dredging impacts on eulachon resilience in rivers where it occurs."

USACE (2007, as cited in Gustafson et al. 2010) stated that:

> …as much as 414 million cubic yards (mcy) of material will erode from the Mount St. Helens sediment avalanche through year 2035. In addition, it was estimated that over the period from 2000 to 2035 as much as 27 mcy of this material would be deposited in the lower Cowlitz River and will need to be removed in order to maintain flood protection levels in Kelso, Longview, Castle Rock, and Lexington. … This trend is a result of increased sedimentation from the Toutle River watershed from sediments being passed through the sediment retention structure (SRS) in greater amounts. The ability of the SRS to trap sand has decreased since 1998 when the sediment reservoir behind the dam filled in. All flow now passes through the spillway as designed, carrying sediment downstream. … Significant sand deposition … continues to occur at the mouth of the Cowlitz River, which has severely reduced the capacity of the river channel to transport sand. … Channel capacity and the authorized levels of flood protection for Kelso, Longview, Lexington, and Castle Rock have been reduced below authorized levels due to sediment deposition in the lower Cowlitz River. … In addition to the initial dredging effort, annual follow-on dredging from the transition area to Cowlitz RM 2.5 [RKM 4.0] to maintain the dredged channel depths and bottom widths will be needed to maintain flood protection levels for the next 5 years. The Corps is also investigating long-term dredging

> and non-dredging alternatives that would maintain the authorized levels of flood protection for the communities on the lower Cowlitz River through the year 2035.

Furthermore, USACE's environmental assessment of interim dredging activities on the Cowlitz River (USACE 2007, p. 33; as cited in Gustafson et al. 2010) indicated that:

> The proposed … dredging action may affect spawning adults, outmigrating juveniles, and larvae [of eulachon] in the water column by entrainment. Eggs may be affected by removing substrate needed to allow egg adhesion for incubation and by covering of incubating eggs by increasing suspended sediment.

Sherwood et al. (1990, as cited in Gustafson et al. 2010) provided a detailed analysis of historical dredging activities in the Columbia River estuary through the 1980s. They estimated that about 300 million cubic meters of largely sand-sized material were removed from the estuary and river channels between 1909, when substantial dredging started, and 1982. Currently, USACE routinely dredges the mainstem Columbia River shipping channel. The Washington and Oregon Eulachon Management Plan (WDFW/ODFW 2001, p. 25; as cited in Gustafson et al. 2010) stated that this "Dredging should not be conducted in winter and early spring to avoid entrainment of eulachon adults or larvae." Romano et al. (2002) suggested that the dynamic nature of sand sediments in areas proposed for channel deepening in the Columbia River were unlikely to support eulachon egg incubation and that direct effects of dredging in these areas on eulachon would be minimal. However, "[eulachon] eggs incubating in near-shore areas in the proximity of dredging activities might be affected if these activities alter flow patterns or increase sedimentation" (Romano et al. 2002, p. 8).

In response to an earlier draft of the present status review document, Anderson (2009, p. 4–5; as cited in Gustafson et al. 2010) stated that:

> Risks dependent on timing, location, and life history stage in relation to dredging and in-water dredge material disposal pose a low to moderate threat for adult eulachon and a high risk for incubating eggs. … WDFW considers dredging effects on adult eulachon as a low risk in the mainstem Columbia River and a low to moderate risk in the tributaries. … The risk to larval eulachon from mainstem Columbia River dredging activities is low and in the tributaries is moderate. … Dredging activities can affect egg survival through direct entrainment and from suffocation through burial. The risk to eulachon eggs from dredging and in-water dredge material disposal in eulachon spawning habitat is high.

Conclusion

Based on this information, the threat occurs at a very low to moderate severity and there is a medium level of uncertainty. Thus, the relative impact to recovery is ranked moderate.

B. Over-utilization for Commercial, Recreational, Scientific, or Educational Purposes

Threat—Commercial Harvest				
Subpopulation	**Klamath**	**Columbia**	**Fraser**	**BC**
BRT Ranking	No Ranking	9	6	No Ranking
BRT Threat Severity	Not Scored	Low	Low	Not Scored
Listing Factor	B	B	B	B

Threat—Tribal/First Nations Fisheries				
Subpopulation	**Klamath**	**Columbia**	**Fraser**	**BC**
BRT Ranking	11	14	13	10
BRT Threat Severity	Very Low	Very Low	Very Low	Low
Listing Factor	B	B	B	B

Threat—Recreational Harvest				
Subpopulation	**Klamath**	**Columbia**	**Fraser**	**BC**
BRT Ranking	13	13	14	14
BRT Threat Severity	Very Low	Low	Very Low	Very Low
Listing Factor	B	B	B	B

Historically, eulachon were caught in commercial, recreational, and tribal/First Nations fisheries along the West Coast of the United States and Canada.

Columbia River Subpopulation:

The historical landings data for the Columbia River subpopulation goes back as far as 1888[25] (Figure 2-2) with newspaper reports as far back as 1866[26]. For the Columbia River subpopulation, we considered the historical landings data (commercial and sport dip net fishery) as a minimum measure of fish abundance. Based on the commercial landings data, we assumed that in order to maintain a commercial fishery of 22,000,000[27] (the geometric mean of the commercial landings data for the years 1936 through 1992[28]; range 6,000,000 to 64,000,000 fish) fish per year over the 56-year period (1936 through 1992), that the total run size must have been substantially higher than the geometric mean of 22,000,000 fish[29] landed. In addition to the commercial fishery, is the sport dip net

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[25] Ceremonial and subsistence fishery for Washington and Oregon Indian Tribes in the Columbia River Basin has taken place for thousands of years. However, there are no reliable records for landings.
[26] The Oregonian, 24 February, 1866.
[27] All landings estimates were rounded.
[28] Commercial harvest data is available from 1888 – 2010 for the whole Columbia River system (most years, a few missing) and broken down by state (early years) and/or tributaries (mostly after 1935). Harvest is reported as pounds landed (converted to numbers of fish). We restrict the data to the period 1936 – present so that we have a consistent set of tributary data, and because earlier data may be more unreliable.
[29] For example, based on results from the spawning stock biomass estimations in 2013-2014, the estimated run size of eulachon in the Columbia River ranged from 83,000,000 to 330,000,000 fish, with a mean estimate of 186,000,000 fish.

fishery, first reported in 1865[30]. However, there are no reliable landings data available for the sport dip net fishery other than an exploratory sampling program conducted by the WDFW in 1978 on the Cowlitz River[31]. Based on the information collected from this exploratory sampling program, WDFW estimated that the sport dip net fishery was comparable to the commercial harvest. As this exploratory sampling program is the only reliable landings data for the sport dip net fishery available, we used it as a proxy for the sport dip net fishery for the years 1936 through 1992 as part of our run size estimations. This approach results in a recreational harvest potential of 22,000,000 fish per year, and a combined commercial and sport fishery of 12,000,000 to 128,000,000, adult eulachon per year.

[30] Huntington 1963.
[31] WDFW memorandum—Cowlitz River smelt sport dip net fishery total catch estimate.

Table 2-3. Annual Columbia River eulachon run size 2000-2017; pounds converted to numbers of fish at 11.16 fish/pound (WDFW 2016). The estimates were calculated based on methods developed by (Parker 1985), Jackson and Cheng (2001), and Hay et al. (2002) to estimate spawning biomass of pelagic fishes. For 2000 through 2010 estimates were back-calculated using historical larval density data.

Maximum Estimates	Mean Estimates	Minimum Estimates	Year
8,971,500	5,421,500	3,205,200	2000
128,960,500	77,512,900	35,121,600	2001
76,645,800	59,114,500	42,541,900	2002
99,395,400	64,670,000	45,137,700	2003
—	—	—	2004
1,450,800	783,400	226,500	2005
3,527,700	1,233,200	387,300	2006
3,272,100	1,605,900	863,800	2007
6,510,700	2,418,400	713,100	2008
10,034,000	4,873,600	1,984,200	2009
4,281,000	1,759,900	612,700	2010
69,661,800	36,775,900	17,860,400	2011
61,437,400	35,722,100	20,008,600	2012
197,943,400	107,794,900	45,546,700	2013
323,778,300	185,965,200	84,243,100	2014
207,570,500	123,582,000	57,525,700	2015
111,991,000	54,556,500	21,654,800	2016
34,071,100	18,307,100	8,148,600	2017

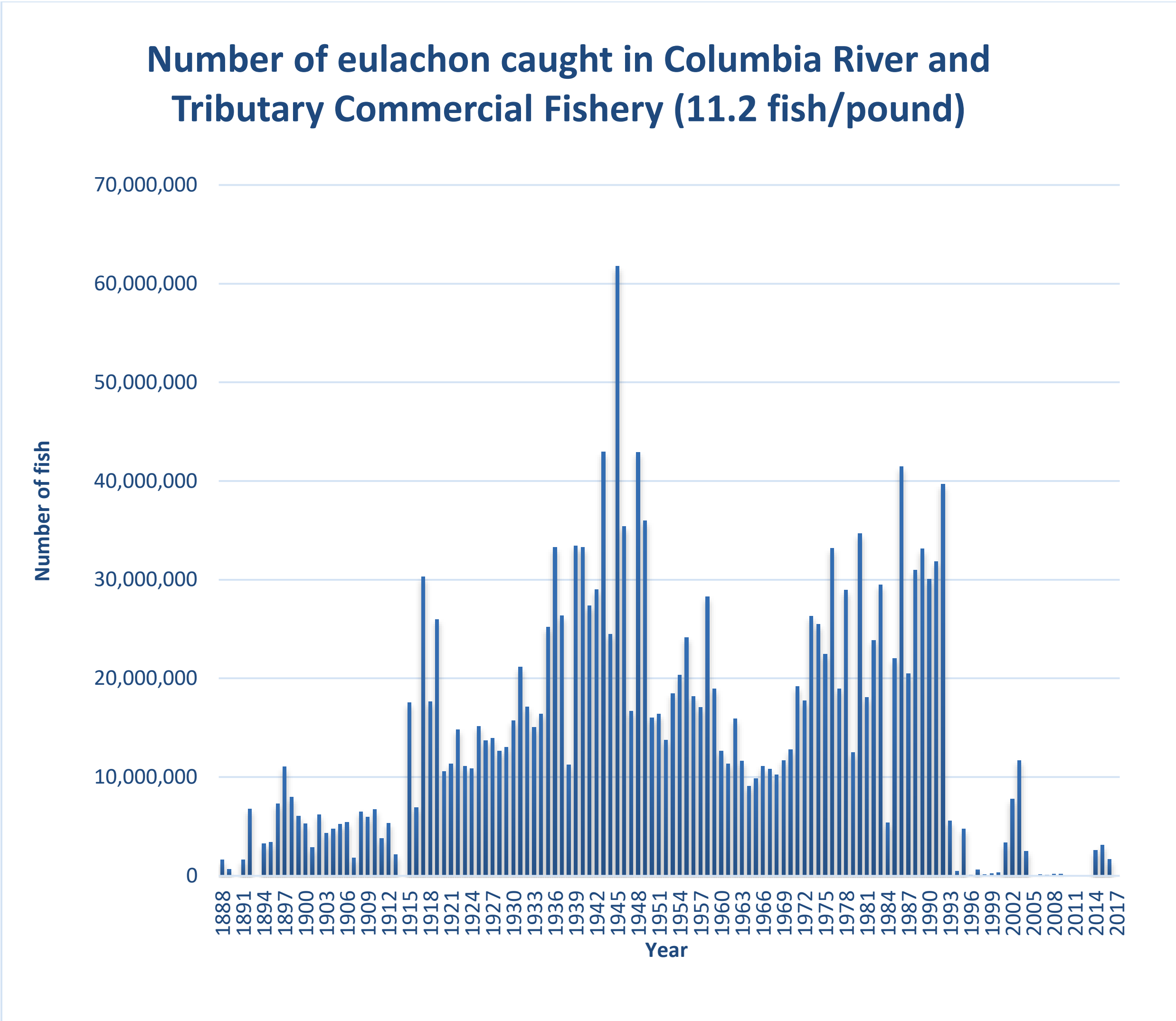

Figure 2-2. Number of eulachon caught in the Columbia River and Tributary commercial fishery, 1888-2017.

Year	Total run size (pounds)	Harvest (pounds): Commercial Mainstem	Commercial Tributary	Sport [1]	Tribal	Combined	Exploitation
2000	485,760	28,760	0	0	N/A	28,760	*5.9%*
2001	6,945,650	158,810	154,320	154,320	N/A	467,450	*6.7%*
2002	5,296,940	57,980	663,180	663,180	N/A	1,384,340	*26.1%*
2003	5,794,780	66,880	1,016,500	1,016,500	N/A	2,099,880	*36.2%*
2004	N/A	14,790	216,230	216,230	N/A	447,250	N/A
2005	78,210	110	100	100	N/A	310	*0.4%*
2006	130,800	13,100	0	0	N/A	13,100	*10.0%*
2007	257,100	8,700	1,200	1,200	N/A	11,100	*4.3%*
2008	243,180	11,380	5,900	5,900	N/A	23,180	*9.5%*
2009	870,220	5,540	12,090	12,090	N/A	29,720	*3.4%*
2010	180,440	3,540	0	0	N/A	3,540	*2.0%*
2011	3,297,000	0 [2]	0 [2]	0 [2]	N/A	0	*0.0%*
2012	3,198,700	0 [2]	0 [2]	0 [2]	N/A	0	*0.0%*
2013	9,649,500	0 [2]	0 [2]	0 [2]	7,470	7,470	*0.1%*
2014	16,621,510	18,560	0 [2]	203,880	6,970	229,410	*1.4%*
2015	11,404,120	16,550	0 [2]	290,770	10,400	317,720	*2.8%*
2016	5,119,800	4,820	0 [2]	141,050	8,330	154,200	*3.0%*
2017	1,647,330	5,090	0 [2]	540	1,900	7,530	*0.5%*

[1] *The sport fishery was only surveyed in 2014, 2015, 2016, and 2017. For 2000-2010, sport harvest was assumed equal to tributary commercial dipnet landings based on results reported in Chiabi (1977) for the 1977 Cowlitz River creel survey. Chiabi concluded that in 1977 sport harvest matched tributary commercial harvest.*

[2] *Closed to fishing.*

Figure 2-3. Annual Columbia River eulachon run size, harvest, and exploitation rate estimates, 2000- 2017 (WDFW).

Fraser River Subpopulation:

The historical landings data for the Fraser River subpopulation goes back as far as 1881 (Figure 2-4). For the Fraser River subpopulation, we considered the historical landings data as a minimum measure of fish. Based on the landings data, we assumed that in order to maintain a commercial fishery of 1,100,000[32] (geometric mean; range 90,000 to 8,000,000 fish) fish per year over a 56 year period (1936 through 1992)[33], that the total escapement must have had to have been substantially higher than the geometric mean of 1,100,000 fish landed.

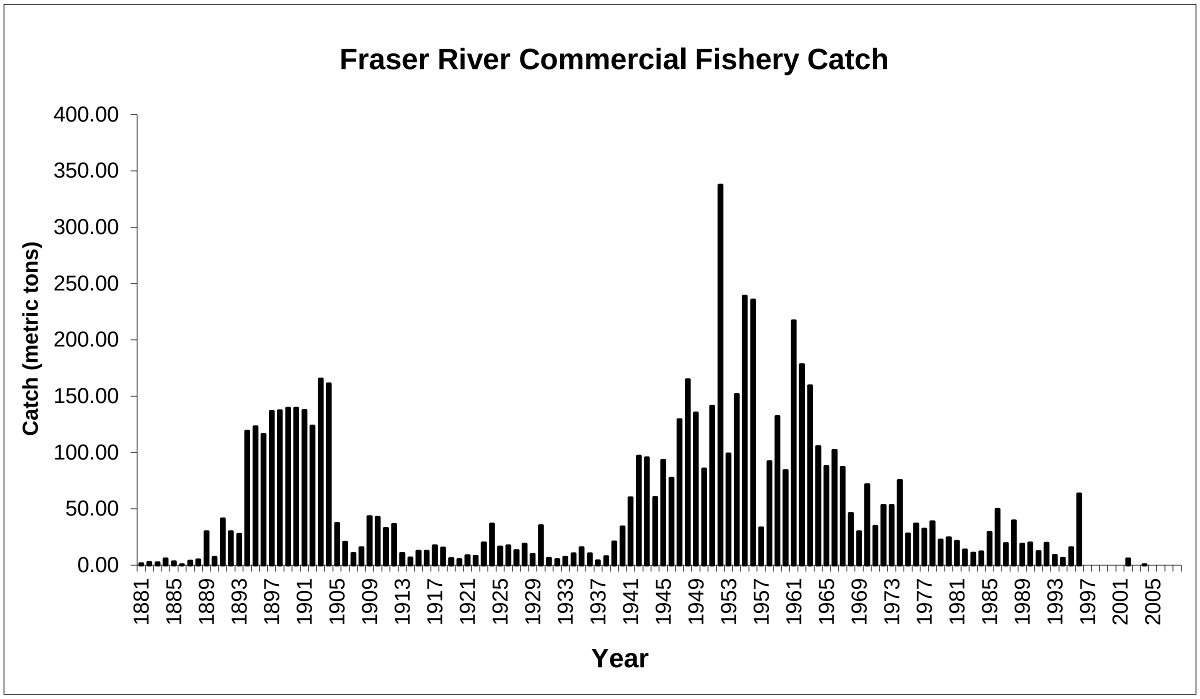

Figure 2-4. Landings data for the commercial fishery on the Fraser River for the years 1881 through 2004.

[32] All landings estimates were rounded.

[33] Commercial harvest data is available from 1881 – 2004 for the Fraser River. Harvest is reported as metric tons landed (converted to numbers of fish). We restrict the data to the period 1936 – present so that we have a consistent set of data with the Columbia River, and because earlier data may be more unreliable.

Table 2-4. Annual Fraser River eulachon run size 1995-2017. The estimates were calculated based on methods developed by Parker (1985), Jackson and Cheng (2001), and Hay *et al.* (2002) to estimate spawning biomass of pelagic fishes.

Combined Biomass/Pounds	Number of Fish at 9.9 Fish/Pound	Number of Fish at 13.3 Fish/Pound	Year
665,796	6,591,380	8,855,087	1995
4,213,034	41,709,037	56,033,352	1996
163,142	1,615,106	2,169,789	1997
299,829	2,968,307	3,987,726	1998
921,532	9,123,167	12,256,376	1999
286,601	2,837,350	3,811,793	2000
1,342,615	13,291,889	17,856,780	2001
1,089,084	10,781,932	14,484,817	2002
586,430	5,805,657	7,799,519	2003
72,753	720,255	967,615	2004
35,274	349,213	469,144	2005
63,934	632,947	850,322	2006
90,390	894,861	1,202,187	2007
22,046	218,255	293,212	2008
30,865	305,564	410,505	2009
11,023	109,128	146,606	2010
68,343	676,596	908,962	2011
264,555	2,619,095	3,518,582	2012
220,462	2,182,574	2,932,145	2013
145,505	1,440,500	1,935,217	2014
698,865	6,918,764	9,294,905	2015
97,003	960,330	1,290,140	2016
77,162	763,901	1,026,251	2017

BC Subpopulation:

The historical landings data for the BC subpopulation goes back as far as 1877 (Figure 2-5). For the BC subpopulation, we considered the historical landings data as a minimum measure of fish. Based on the landings data, we assumed that in order to maintain a First Nations fisheries of 800,000[34] (geometric mean; range 9,000 to 5,000,000 fish[35]) fish over a 56 year period (1936 through 1992)[36], that the total escapement must have been substantially higher than the mean of 800,000 fish landed.

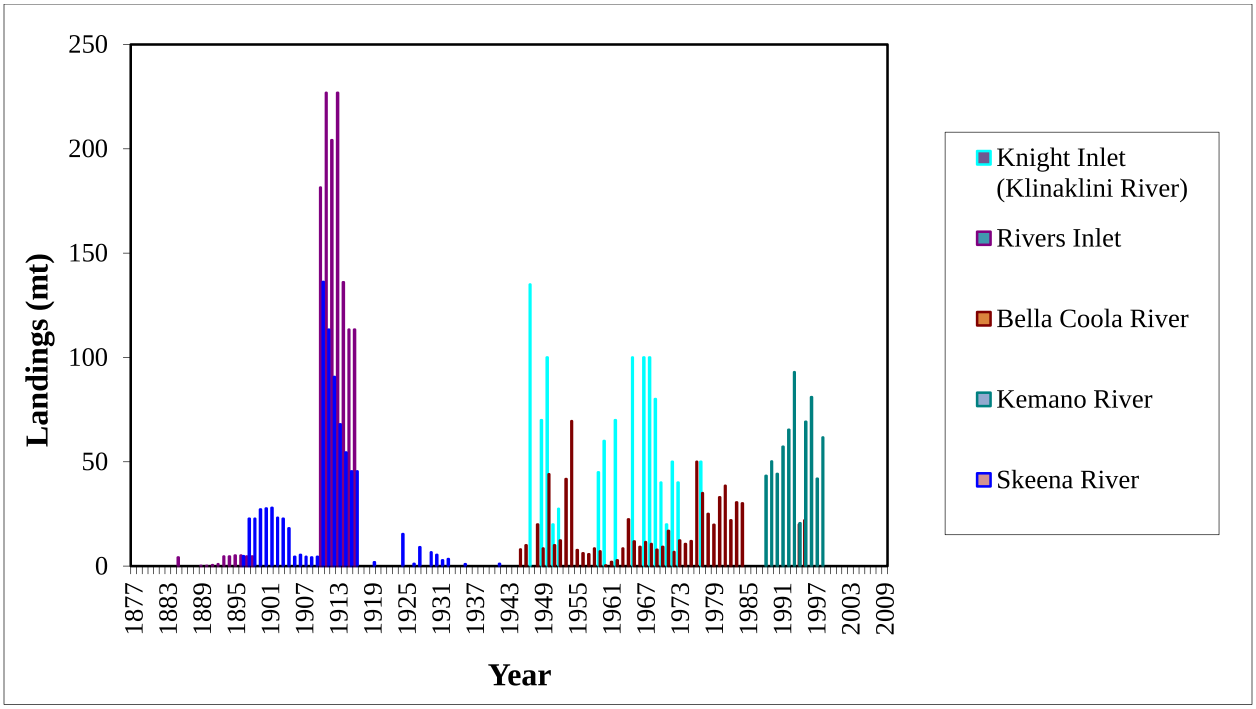

Figure 2-5. Landings data for the BC coastal subpopulation 1877-2009.

Klamath River Subpopulation:

The historical landings data for the Klamath River subpopulation is extremely limited. The only reliable landings data is for 1963, when a total of 650,000[37] fish were reported to have been landed. Based on the limited nature of the data we cannot estimate the fraction of the harvest relative to the total run (escapement). Nonetheless, what is known is that eulachon harvests have

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[34] All landings estimates were rounded.
[35] In 2001 DFO conducted a spawning stock biomass estimation for the Skeena River with a mean estimate of 10,733,968 fish, Lewis et al. (2009).

[36] Harvest data is available from 1887 – 2009 for the BC subpopulation (multiple rivers). Harvest is reported as metric tons landed (converted to numbers of fish). We restrict the data to the period 1936 – present so that we have a consistent set of data with the Columbia and Fraser River, and because earlier data may be more unreliable.
[37] All landings estimates were rounded.

been documented for this subpopulation for more than 100 years, albeit intermittently, as far back as 1879, and in the years 1919, 1963, 1968, 1969, 1976, 1978, 1979, and 1980 (Gustafson et al. 2010). Recent reports from Yurok tribal fisheries biologists report capturing adult eulachon in presence/absence surveys (seine/dip nets) in the Klamath River over a four-year period [2011 (7 eulachon), 2012 (40 eulachon), 2013 (112 eulachon), and 2014 (1,000 eulachon)][38].

Conclusion

Based on this information, the threat occurs at a very low to low severity and there is a medium level of uncertainty. Thus, the relative impact to recovery is ranked low-to-moderate.

Threat—Scientific Monitoring				
Subpopulation	**Klamath**	**Columbia**	**Fraser**	**BC**
BRT Ranking	No Ranking	16	16	15
BRT Threat Severity	Not Scored	Very Low	Very Low	Very Low
Listing Factor	B	B	B	B

Scientific monitoring on eulachon is very limited.

Conclusion

Based on this information, the threat occurs at a very low severity and there is a low level of uncertainty. Thus, the relative impact to recovery is ranked very low.

C. Disease or Predation

Threat—Disease				
Subpopulation	**Klamath**	**Columbia**	**Fraser**	**BC**
BRT Ranking	8	11	11	7
BRT Threat Severity	Very Low	Very Low	Very Low	Very Low
Listing Factor	C	C	C	C

The following is a summary of disease-related effects on eulachon based on Gustafson et al. (2010).

Eulachon can be infected by a variety of bacterial, viral, fungal, and microparasitic pathogens. Numerous diseases can result from pathogens that occur naturally in the wild. The BRT (as cited in Gustafson et al. 2010) found very little information relative to impacts of diseases on eulachon. Hedrick et al. (2003, as cited in Gustafson et al. 2010) isolated viral hemorrhagic septicemia virus (VHSV) for the first time from adult eulachon collected in March 2001 in Oregon's Sandy River. Six of 15 pooled samples, each consisting of 5 fish, tested positive for VHSV. The overall impact of this virus on eulachon is difficult to assess. This virus has been

[38] E-mail from Barry McCovey, Yurok Indian Tribe on March 17, 2014, to Robert Anderson, NMFS.

isolated from a wide range of marine fish hosts and given the right conditions may "cause significant disease associated with morbidity and mortality in populations of marine fish" (Hedrick et al. 2003, p. 212; as cited in Gustafson et al. 2010).

Conclusion

Based on this information, the threat occurs at a very low severity and there is a medium level of uncertainty. Thus, the relative impact to recovery is ranked low.

Threat—Predation				
Subpopulation	**Klamath**	**Columbia**	**Fraser**	**BC**
BRT Ranking	5	7	3	3
BRT Threat Severity	Moderate	Moderate	Moderate	Moderate
Listing Factor	C	C	C	C

The following is a summary of expected predation-related effects on eulachon based on Gustafson et al. (2010).

Significant numbers of eulachon are lost to fish, avian, and pinniped predators in freshwater and marine environments. Beach et al. (1981, 1985; as cited in Gustafson et al. 2010) and Jeffries (1984, as cited in Gustafson et al. 2010) observed that harbor seals, California sea lions, and Steller sea lions (*Eumetopias jubatus*) move into the Columbia River to feed on eulachon runs in the winter. Jeffries (1984, p. 20; as cited in Gustafson et al. 2010) observed that "harbor seals were frequently reported in the area where the Cowlitz River enters the Columbia" and "these population increases … were apparently due to the migration of eulachon into spawning tributaries." Many harbor seals migrate from Grays Harbor and Willapa Bay to the Columbia River in the winter (Beach et al. 1985, as cited in Gustafson et al. 2010). Between 1,000 and 1,500 harbor seals have been observed using haul out sites as far as 45 miles upriver on the Columbia River at this time of year and "are frequently seen as far upriver as Longview, Washington (RM 55 [RKM 88.5]), apparently following eulachon runs into this area" (Beach et al. 1981, p. 73; as cited in Gustafson et al. 2010). NMFS (1997, p. 29; as cited in Gustafson et al. 2010) stated that the highest counts of seals in the river coincide with the winter spawning of eulachon.

Based on the presence of otoliths in harbor seal scat collected from the Columbia River during 1981–1982, Jeffries (1984, as cited in Gustafson et al. 2010) reported that eulachon were eaten by 50%, 87%, 44%, and 12% of the harbor seals present in January, February, March, and April, respectively. Brown et al. (1989, as cited in Gustafson et al. 2010) determined that 98% of the prey eaten by harbor seals in the Columbia River during the winters of 1986 to 1988 was eulachon, and that 100% of harbor seal stomachs examined contained eulachon (Brown et al. 1989, NMFS 1997; as cited in Gustafson et al. 2010). Brown et al. (1989, as cited in Gustafson et al. 2010) also estimated that the more than 2,000 harbor seals present during mid-winter 1987 in the Columbia River consumed from 2.5 to 10.2 million eulachon or from 105 to 428 mt (assuming an average weight of 42 g per eulachon), which is equal to 12% to 50% of the Columbia River commercial fishery landings of eulachon for that year.

Although accounting for only 0.4% of the diet, Olesiuk (1993, as cited in Gustafson et al. 2010) estimated that the 12,000–15,000 harbor seals present in the Strait of Georgia during 1988 consumed an average of approximately 40 mt of eulachon. Eulachon are also a primary prey species of California sea lions in the Columbia River in January to June (Beach et al. 1985, Brown et al. 1995, NMFS 1997; as cited in Gustafson et al. 2010), and California sea lions have been observed near Longview at the time of the eulachon run (Beach et al. 1981, as cited in Gustafson et al. 2010). Jeffries (1984, p. 17, as cited in Gustafson et al. 2010) observed that peak numbers of California sea lions (200–250) in the Columbia River occurred during the months of February and March and they were believed to "move upriver following and feeding on the annual eulachon smelt runs." Maximum numbers of Steller sea lions (80–100) in the Columbia River also occurred during this time of year when they "have been observed feeding upriver on eulachon" (Jeffries 1984, p. 19; as cited in Gustafson et al. 2010). Seals and sea lions have also been observed above New Westminster in the Fraser River during the eulachon spawning migration (Hay and McCarter 2000).

Northern fur seals consume eulachon in the California Current (Antonelis and Fiscus 1980, as cited in Gustafson et al. 2010) and particularly offshore of Oregon and Washington (Antonelis and Perez 1984, as cited in Gustafson et al. 2010). Peak numbers of northern fur seals appear off Oregon and Washington in April (Antonelis and Perez 1984, as cited in Gustafson et al. 2010). Based on fur seal diet analyses, Antonelis and Perez (1984, as cited in Gustafson et al. 2010) calculated that fur seals consumed a yearly average of 600 mt of eulachon in this offshore region between 1958 and 1974. Spalding (1964, as cited in Gustafson et al. 2010) reported that about 100 yearling fur seals congregated at the head of Knight Inlet in March 1961 and that four of these fur seals had been feeding exclusively on eulachon in the Klinaklini River estuary, while another 60 fur seals in the middle of the inlet were feeding on squid. Clemens et al. (1936, p. 6; as cited in Gustafson et al. 2010) reported on an analysis of stomach contents of 593 northern fur seals sampled from late March to late June off the west coast of Vancouver Island and stated that:

> Eulachon proved to be the third most important organism in the food of the fur seals [after herring and salmon]. It was found to occur in some 20% of the full stomachs but as a rule in rather small quantities. It comprised about 3% of the total food.

Eulachon occurred in 100% of 229 spiny dogfish stomachs containing food taken in the Fraser River in May 1953, and in 23% and 92% of stomachs analyzed outside the river's mouth in May 1950 and 1953, respectively (Chatwin and Forrester 1953, as cited in Gustafson et al. 2010). According to Chatwin and Forrester (1953, p. 38), "The dogfish which support the fishery in the Fraser River in mid-May are clearly dependent upon the appearance of the eulachon." Analyses of more than 14,000 spiny dogfish stomachs in British Columbia waters over a 30-year period ending in 1977 revealed that eulachon represented approximately 5.5% of the annual dogfish diet, and represented a greater percentage of food types consumed for young (13.4%) and immature (10.2%) dogfish than for adults (1.6%) (Jones and Geen 1977, as cited in Gustafson et al. 2010).

Eulachon occurred at low frequency (<1%) in 416 Pacific cod stomachs examined in British Columbia (Hart 1949, as cited in Gustafson et al. 2010). Eulachon are also eaten by large Pacific hake, which become increasingly piscivirous as they age, with euphausiids being the dominant prey of small Pacific hake (Rexstad and Pikitch 1986, Buckley and Livingston 1997; as cited in Gustafson et al. 2010). Livingston (1983, p. 630; as cited in Gustafson et al. 2010) determined that eulachon off Oregon in the spring of 1980 "comprised 22% by weight of the diet of 450–549 mm Pacific whiting [hake] and 79.6% by weight of the diet of 550+ mm fish." The offshore Pacific hake stock migrates northward from winter spawning grounds to feed off the coast of the Pacific Northwest in the summer. This stock represents 61% of the offshore pelagic biomass in the California Current system (Ware and McFarlane 1995), and recent evidence (Benson et al. 2002, Cooke et al. 2006, Phillips et al. 2007; as cited in Gustafson et al. 2010) indicates that the feeding migration of Pacific hake may be extending further north within the northern California Current system. Although only about 5% of Pacific hake stomachs examined by Outram and Haegele (1972, as cited in Gustafson et al. 2010) off the west coast of Vancouver Island in 1970 contained eulachon, the large biomass of Pacific hake in this region in summer may have a significant impact on eulachon biomass in the area (Hay and McCarter 2000).

Conclusion

Based on this information, the threat occurs at a moderate severity and there is a high level of uncertainty. Thus, the relative impact to recovery is ranked moderate.

D. Inadequacy of Existing Regulatory Mechanisms

Inadequacy of Regulatory Mechanisms				
Subpopulation	**Klamath**	**Columbia**	**Fraser**	**BC**
BRT Ranking	No Ranking	No Ranking	No Ranking	No Ranking
BRT Threat Severity	Not Scored	Not Scored	Not Scored	Not Scored
Listing Factor	D	D	D	D

At the time of listing, the primary factors responsible for the decline of eulachon are the destruction, modification, or curtailment of habitat and inadequacy of existing regulatory mechanisms (75 FR 13012), specifically the lack of regulations concerning bycatch of eulachon in commercial fisheries.

E. Other Natural or Manmade Factors Affecting its Continued Existence

Threat—Eulachon Bycatch				
Subpopulation	**Klamath**	**Columbia**	**Fraser**	**BC**
BRT Ranking	3	2	2	2
BRT Threat Severity	Moderate	High	Moderate	High
Listing Factor	E	E	E	E

The following is a summary of bycatch-related effects on eulachon based on Gustafson et al. (2010), Gustafson et al. (2015, 2016, 2017), Hannah and Jones (2012), and Hannah et al. (2015).

Bycatch-Shrimp Fishery—Ocean shrimp fisheries began in California in 1952 and expanded into Oregon and Washington by the mid- to late-1950s (Frimodig et al. 2009, as cited in Gustafson et al. 2017). Ocean shrimp in commercial quantities are found from Point Arguello, California north to Queen Charlotte Sound, British Columbia, typically over well-defined beds of green mud or green mud and sand (Frimodig et al. 2009, as cited in Gustafson et al. 2017). Because ocean shrimp undergo a vertical diel migration, dispersing into surface waters during nighttime hours and returning to near bottom aggregations in the daytime (Zirges and Robinson 1980, Frimodig et al. 2009, as cited in Gustafson et al. 2017), ocean shrimp vessels generally trawl in depths ranging from 91–256 m (50 to 140 fathoms) during daylight hours.

The ocean shrimp season is open April 1 through October 31 in all three states and vessels deliver catch to shore-based processors. Total coast-wide ocean shrimp landings have ranged from a low of 1,888 mt in 1957 to a high of 46,494 mt in 2015 (Fig. 2-6). The portion of the catch that is not marketable or for which regulations prohibit landing is discarded at-sea.

Incidental Bycatch

Prior to 2000, bycatch in the ocean shrimp fishery ranged from 32 to 61% of the total catch (Hannah and Jones 2007, as cited in Gustafson et al. 2010). Indirect mortality includes mortality of fish harvested incidentally to the target species, fish that die after being captured by fishing gear but not landed, and fish that die after being caught and released. Despite the various methods used to target a specific species, incidental bycatch—the harvest of non-targeted species— still occurs, largely because various species intermingle in the marine environment. Eulachon occur as bycatch in shrimp trawl fisheries off the coasts of Washington, Oregon, California, and British Columbia (Hay et al. 1999a, 1999b, Olsen et al. 2000, NWFSC 2008, Hannah and Jones 2009; as cited in Gustafson et al. 2010). Offshore trawl fisheries for ocean shrimp (*Pandalus jordani*) occur from the west coast of Vancouver Island to the U.S. West Coast off Cape Mendocino, California (Hannah and Jones 2003, as cited in Gustafson et al. 2010). *Pandalus jordani* is known as the ocean pink shrimp or smooth pink shrimp in Washington, pink shrimp in Oregon, and Pacific Ocean shrimp in California. Herein we use the common name ocean shrimp in reference to *P. jordani* as suggested by the American Fisheries Society

(McLaughlin et al. 2005, as cited in Gustafson et al. 2010). Similar trawl fisheries operate in British Columbia, which mainly target ocean shrimp (aka smooth pink shrimp in Canada), northern pink shrimp (*P. borealis eous*), and sidestripe shrimp (*Pandalopsis dispar*) (Hay et al. 1999a, 1999b, Olsen et al. 2000, Hannah and Jones 2007, NWFSC 2008, DFO 2009c; as cited in Gustafson et al. 2010).

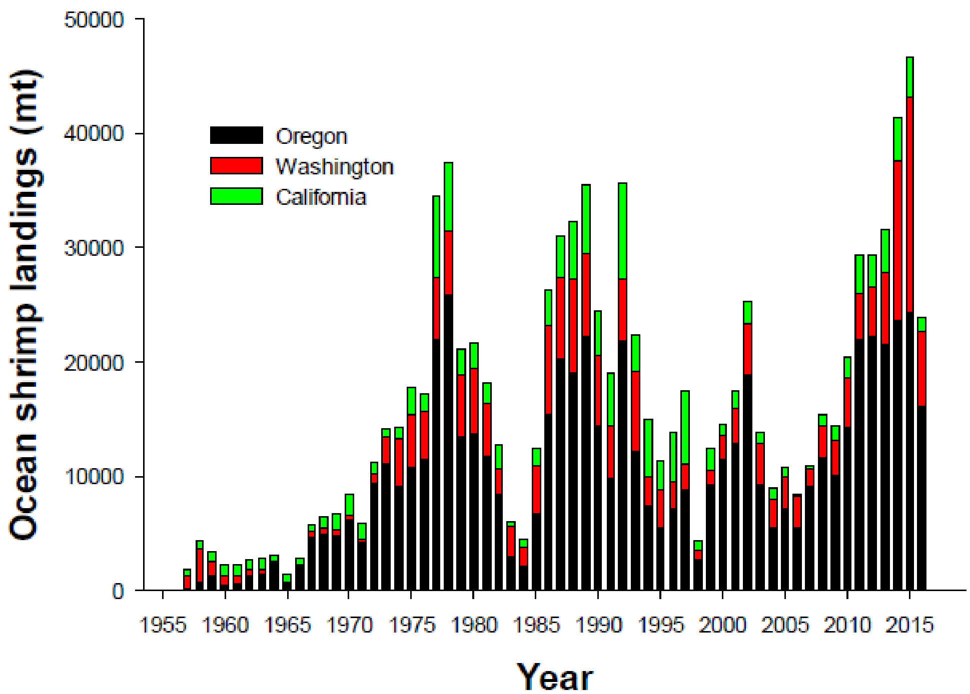

Figure 2-6. Commercial landings in ocean shrimp trawl fisheries off the U.S. west coast through 2016 (Gustafson et al. 2017).

Following recognition that large numbers of eulachon were occurring as bycatch in Queen Charlotte Sound shrimp fisheries (Hay and McCarter 2000, Olsen et al. 2000; as cited in Gustafson et al. 2010) and of a concurrent decline in central coast British Columbia eulachon stocks, DFO closed the Queen Charlotte Sound shrimp trawl fishery in 1999, which has remained closed "because of concerns for central coast eulachon stocks" (DFO 2009c, p. 11; as cited in Gustafson et al. 2010). Concerns over eulachon bycatch in the offshore west coast Vancouver Island shrimp trawl fisheries also led DFO to set eulachon bycatch action levels for west coast Vancouver Island (DFO 2009c, 2009d; as cited in Gustafson et al. 2010). This action level is set at 1% of the west coast Vancouver Island eulachon abundance index, which is based on biomass estimates of eulachon derived from the annual shrimp abundance survey (DFO 2009c, p. 11; as cited in Gustafson et al. 2010). If estimated eulachon bycatch exceeds this 1% level, additional "management actions could include: closure of the shrimp trawl fishery, closure of certain areas to shrimp trawling, or restricting trawling to beam trawlers which have been found to have a lower impact on eulachon than otter trawlers" (DFO 2009d, p. 15; as cited in Gustafson et al. 2010). Similar action levels are not in place off the U.S. West Coast.

Bycatch Reduction Efforts

Beginning in 2000 in British Columbia and 2003 in Washington, Oregon, and California, mandated use of BRDs in offshore shrimp trawl fisheries has substantially reduced bycatch of fin fish in these fisheries (Hannah and Jones 2007, Frimodig 2008; as cited in Gustafson et al. 2010). Currently, ocean shrimp vessels are required to use bycatch reduction devices (BRDs) that serve as deflecting grids to guide fin-fish towards an escape opening, which is usually on the top of the net. The primary goal of mandatory BRDs is to reduce bycatch of groundfish species, and more recently, protected species such as eulachon. BRDs became mandatory in California in 2002 (Frimodig 2008, Frimodig et al. 2009, as cited in Gustafson et al. 2017) and in Washington and Oregon in 2003. Current 2017 regulations in Washington and Oregon, adopted by both states in 2012, require ocean shrimp trawl fishery BRDs to consist of a rigid panel or grate of narrowly spaced bars (usually constructed of aluminum) with no gaps between the bars exceeding 0.75 inches (19.1 mm). Approved BRDs for use in the ocean shrimp fishery in California include: (1) rigid- or semi-rigid grate excluders consisting of vertical bars with no gaps between the bars exceeding 2 inches (50.8 mm); (2) soft-panel excluders, usually made of a soft mesh material "with individual meshes no large than 6 inches;" and (3) fisheye excluders, which have a forward facing escape opening that is maintained by a rigid frame.

Bycatch Estimations—2004-2015

Total estimated bycatch of eulachon in the Washington ocean shrimp fisheries ranged from a low of over 64 thousand (95% CI; 23,950–132,532) fish in 2010 to a high of over 22.4 million (95% CI; 16,809,929–28,991,135) fish in 2015 (Table A2, as cited in Gustafson et al. 2017). Mean estimated total biomass of eulachon bycatch in the Washington fishery during this time period (2010–2015) ranged from 2.1–219.8 mt (Table A2, as cited Gustafson et al. 2017). The Washington sector bycatch ratio, on a kg of eulachon per metric ton of retained shrimp basis, was highest during 2012 (37.9 kg/mt) and 2013 (32.9 kg/mt) and lowest in 2010 (0.5 kg/mt) and 2011 (1.3 kg/mt). Recently, this bycatch ratio has somewhat declined from high levels in 2012–2013 to 10.2 kg/mt in 2014 and 11.7 kg/mt in 2015 (Table A2, as cited in Gustafson et al. 2017).

The Washington ocean shrimp fishery was also observed separately in 2011 and 2012 by a team of state-deployed fishery bycatch observers (Wargo et al. 2014, as cited in Gustafson et al. 2017). Wargo et al. 2014 (as cited in Gustafson et al. 2017) reported a fleetwide eulachon bycatch in the Washington state ocean shrimp fishery of "7.8 mt (17,132 pounds) for 2011 and 171 mt (378,011 pounds) for 2012." These bycatch estimates are approximately 30% and 10% greater than the estimates for the Washington ocean shrimp fishery as reported in the present document of 5.5 and 156.8 mt in 2011 and 2012, respectively. In the 2011 Washington ocean shrimp trawl fishery 24% of trips were observed by the state observers (Wargo et al. 2014, as cited in Gustafson et al. 2017), whereas the West Coast Groundfish Observer Program (WCGOP) observed 16.6% of the total ocean shrimp landings (Table xx). In 2012, 16% of trips were observed by the state observer program (Wargo et al. 2014, as cited in Gustafson et al. 2017) and 14.8% of shrimp landings were observed by the WCGOP (Table xx).

Table 2-5. Numbers and weight of eulachon observed and bycatch ratios from ocean shrimp trawl vessels that landed their catch in Washington (2010–2015). Bycatch ratios were calculated for each year by dividing the observed catch of eulachon (in numbers of eulachon and in kg of eulachon) by the observed weight (in mt) of retained ocean shrimp. A fleet-wide bycatch estimate (in both weight and number of fish) was obtained by multiplying the bycatch ratios by fleet-wide ocean shrimp landings. 95% bootstrapped confidence intervals (CI) are provided for the estimates. Asterisks (*) signify strata with fewer than three observed vessels.

	State observed								State fleetwide				
Year	Bycatch (kg of eulachon)	Bycatch (no. of eulachon)	Observed ocean shrimp catch (mt)	Bycatch ratio (kg per mt of ocean shrimp)	95% CI	Bycatch ratio (no. per mt of ocean shrimp)	95% CI	Percent landings observed	Fleet ocean shrimp landings (mt)	Bycatch estimate (kg eulachon)	95% CI	Bycatch estimate (no. of eulachon)	95% CI
2004	--	--	--	--	-- --	--	-- --	0.0	2,440.5	--	-- --	--	-- --
2005	--	--	--	--	-- --	--	-- --	0.0	2,841.8	--	-- --	--	-- --
2006	--	--	--	--	-- --	--	-- --	0.0	2,804.4	--	-- --	--	-- --
2007	--	--	--	--	-- --	--	-- --	0.0	1,517.4	--	-- --	--	-- --
2008	--	--	--	--	-- --	--	-- --	0.0	2,853.3	--	-- --	--	-- --
2009	--	--	--	--	-- --	--	-- --	0.0	3,180.0	--	-- --	--	-- --
2010	198.0	6,214	412.4	0.5	0.3 0.8	15.1	5.6 30.9	9.6	4,295.6	2,062.9	1,321.7 3,341.2	64,735	23,950 132,532
2011	917.7	19,976	697.2	1.3	1.0 1.6	28.7	16.6 46.6	16.2	4,312.1	5,675.7	4,112.2 6,989.5	123,543	71,620 200,806
2012	23,135.3	2,099,376	626.0	37.0	27.3 45.6	3,353.9	2,053.7 4,461.5	14.8	4,239.4	156,689.4	115,871.7 193,403.4	14,218,507	8,706,595 18,914,078
2013	20,646.3	1,740,163	626.8	32.9	27.9 37.2	2,776.2	1,930.9 3,480.7	10.2	6,157.9	202,827.8	171,874.1 229,367.1	17,095,225	11,890,427 21,433,552
2014	10,053.1	948,397	980.9	10.2	5.5 14.2	966.9	529.7 1,568.9	7.1	13,876.2	142,222.1	76,530.4 196,539.5	13,417,079	7,350,640 21,770,031
2015	25,127.9	2,559,825	2,151.1	11.7	10.2 15.2	1,190.0	893.5 1,540.9	11.4	18,814.3	219,779.6	191,465.8 286,177.6	22,389,318	16,809,929 28,991,135

Eulachon bycatch in the Oregon ocean shrimp fishery was estimated at well under a million individual fish (range of 146–845 thousand) from 2004–2011 (although the fishery was over 28.1 million (95% CI; 18.0–39.3 million) and 34.7 million (95% CI; 19.9–52.5 million), respectively (Table A3, as cited in Gustafson et al. 2017). Similarly, total weight of estimated eulachon bycatch in Oregon increased from 20.4 mt (95% CI; ~16.3–22.8 mt) in 2011 to nearly 428 mt (95% CI; ~387–497 mt) in 2012 and to over 540 mt (95% CI; ~430–736 mt) in 2013. Subsequently, estimated eulachon bycatch has remained high in the Oregon ocean shrimp trawl sector, reaching over 54.7 million fish (95% CI; 37.6–74.1 million) and 636 mt (95% CI; ~510–770 mt) in 2014 and over 35.3 million fish (95% CI; 23.1–50.4 million) and 361 mt (95% CI; ~271–380 mt) in 2015 (Table A3, as cited in Gustafson et al. 2017). As in the Washington sector, bycatch ratios in the Oregon sector, (measured as both kg and numbers of eulachon per metric ton of retained ocean shrimp observed) also increased dramatically from 2011 to 2012, and remained high in 2013–2015 (Table A3, as cited in Gustafson et al. 2017). Observed bycatch ratios were at their highest in 2014 (27.0 kg/mt and 2,232 eulachon/mt). In 2015, the Oregon sector bycatch ratios declined to 14.9 kg/mt and 1,458 eulachon/mt.

Table 2-6. Numbers and weight of eulachon observed and bycatch ratios from ocean shrimp trawl vessels that landed their catch in Oregon (2010–2015). Bycatch ratios were calculated for each year by dividing the observed catch of eulachon (in numbers of eulachon and in kg of eulachon) by the observed weight (in mt) of retained ocean shrimp. A fleet-wide bycatch estimate (in both weight and number of fish) was obtained by multiplying the bycatch ratios by fleet-wide ocean shrimp landings. 95% bootstrapped confidence intervals (CI) are provided for the estimates. Asterisks (*) signify strata with fewer than three observed vessels.

	State observed								State fleetwide				
Year	Bycatch (kg of eulachon)	Bycatch (no. of eulachon)	Observed ocean shrimp catch (mt)	Bycatch ratio (kg per mt of ocean shrimp)	95% CI	Bycatch ratio (no. per mt of ocean shrimp)	95% CI	Percent landings observed	Fleet ocean shrimp landings (mt)	Bycatch estimate (kg eulachon)	95% CI	Bycatch estimate (no. of eulachon)	95% CI
2004	221.8	11,291	427.2	0.5	0.0 1.5	26.4	0.0 82.8	7.7	5,537.0	2,875.3	221.8 8,260.2	146,338	11,291 458,456
2005	278.7	11,669	402.9	0.7	0.4 2.2	29.0	3.0 58.4	5.6	7,159.4	4,953.3	2626.5 15,780.6	207,362	21,542 418,275
2006	--	--	--	--	-- --	--	-- --	0.0	5,531.8	--	-- --	--	-- --
2007	277.8	14,084	650.0	0.4	0.1 1.3	21.7	0.1 57.5	7.1	9,128.6	3,901.7	643.8 11,720.1	197,807	14,084 525,035
2008	600.3	22,634	672.5	0.9	0.5 1.2	33.7	9.4 63.4	5.8	11,575.9	10,332.6	5,598.7 13,703.9	389,604	108,426 734,054
2009	650.9	63,175	751.2	0.9	0.3 2.3	84.1	21.7 184.1	7.5	10,048.7	8,707.4	3,461.3 23,250.9	845,081	218,424 1,849,900
2010	1,635.3	88,373	1,705.4	1.0	0.6 1.1	51.8	33.3 73.8	11.9	14,290.4	13,702.6	8,686.2 15,632.0	740,501	476,074 1,054,691
2011	2,786.7	65,524	2,986.0	0.9	0.7 1.0	21.9	14.9 30.8	13.6	21,915.1	20,452.9	16,312.7 22,755.2	480,907	326,139 674,713
2012	57,865.9	3,794,927	3,014.2	19.2	17.4 22.3	1,259.0	806.4 1,763.4	13.5	22,291.6	427,946.2	387,937.7 496,644.5	28,065,308	17,975,466 39,308,140
2013	58,004.9	3,725,425	2,313.2	25.1	20.0 34.2	1,610.5	922.1 2,436.5	10.7	21,537.8	540,062.9	430,973.7 736,470.9	34,686,116	19,859,260 52,476,489
2014	61,855.3	5,320,324	2,291.3	27.0	21.6 32.2	2,321.9	1,595.4 3,145.1	9.7	23,573.3	636,365.9	509,709.9 759,788.9	54,735,346	37,608,999 74,140,221
2015	34,028.1	3,326,275	2,282.1	14.9	11.2 15.7	1,457.6	954.1 2,081.6	9.4	24,226.1	361,234.5	270,858.0 380,036.3	35,310,975	23,113,342 50,428,497

Eulachon bycatch in the California ocean shrimp fishery followed a very different trajectory from that observed in Washington and Oregon during 2011–2013. Eulachon bycatch in California remained below 25 thousand fish from 2004 to 2008 (the fishery was not observed in 2006), rose dramatically in 2010 to over 267 thousand (95% CI; 40,040–702,623) fish; fell to its lowest observed level of just 471 fish (95% CI; 198–827) in 2011, increased again dramatically in 2012 to over 337 thousand (95% CI; 148,647–606,034) fish, and then fell to just over 16 thousand (95% CI; 3,816–33,998) fish in 2013 (Table A4, as cited Gustafson et al. 2017). Biomass of eulachon bycatch and bycatch ratios have shown similar fluctuations over the time period from 2010–2013 (Table A4, as cited Gustafson et al. 2017). Eulachon bycatch again increased from 2014–2015 in the California ocean shrimp trawl sector; estimated bycatch was over 611 thousand fish (95% CI; 241,491–1,063,825) and 6.6 mt in 2014 and increased to over 2 million fish (95% CI; 960,061–3,567,063) and 32.3 mt in 2015 (Table A4, as cited Gustafson et al. 2017). The tonnage of observed ocean shrimp and of fleet-wide landings were relatively stable over from 2011–2015, indicating that yearly differences in eulachon distribution, or in the catchability of eulachon, likely contributed to the extreme fluctuations in eulachon bycatch in the California ocean shrimp fishery. Like Washington, but unlike Oregon, the bycatch ratio of eulachon increased from 2014 to 2015 in the California sector of the ocean shrimp trawl fishery.

The bycatch ratios in the California sector (measured as both kg and numbers of eulachon per metric ton of retained ocean shrimp observed) increased from 1.7 to 9.7 kg/mt shrimp and from 159 to 594 eulachon/mt shrimp between 2014 and 2015 (Table A4, as cited Gustafson et al. 2017).

Table 2-7. Numbers and weight of eulachon observed and bycatch ratios from ocean shrimp trawl vessels that landed their catch in California (2010–2015). Bycatch ratios were calculated for each year by dividing the observed catch of eulachon (in numbers of eulachon and in kg of eulachon) by the observed weight (in mt) of retained ocean shrimp. A fleet-wide bycatch estimate (in both weight and number of fish) was obtained by multiplying the bycatch ratios by fleet-wide ocean shrimp landings. 95% bootstrapped confidence intervals (CI) are provided for the estimates. Asterisks (*) signify strata with fewer than three observed vessels.

	State observed								State fleetwide				
Year	Bycatch (kg of eulachon)	Bycatch (no. of eulachon)	Observed ocean shrimp catch (mt)	Bycatch ratio (kg per mt of ocean shrimp)	95% CI	Bycatch ratio (no. per mt of ocean shrimp)	95% CI	Percent landings observed	Fleet ocean shrimp landings (mt)	Bycatch estimate (kg eulachon)	95% CI	Bycatch estimate (no. of eulachon)	95% CI
2004	*	*	*	0.3	0.1 0.7	11.5	0.0 40.6	*	996.8	311.1	108.9 711.6	11,442	351 40,431
2005	*	*	*	0.3	0.0 0.5	11.4	0.0 40.7	*	860.6	225.9	25.1 404.7	9,848	0 35,051
2006	--	--	--	--	-- --	--	-- --	--	63.6	--	-- --	--	-- --
2007	*	*	*	0.6	0.3 0.9	39.6	0.0 86.3	*	289.1	168.4	86.8 272.0	11,450	978 24,943
2008	*	*	*	0.3	0.0 0.5	26.2	0.0 66.0	*	945.5	251.5	82.9 517.8	24,793	5,908 62,402
2009	*	*	*	0.6	0.3 1.2	96.2	16.0 270.3	*	1,183.5	740.6	405.2 1,399.5	113,815	18,953 319,844
2010	367.9	40,040	265.5	1.4	0.4 2.2	150.8	16.0 396.7	15.0	1,771.0	2,454.0	718.6 3,927.1	267,057	40,040 702,623
2011	3.7	59	420.6	0.0	0.0 0.0	0.1	0.1 0.2	12.6	3,333.0	29.6	15.2 33.0	471	198 827
2012	857.2	42,018	347.6	2.5	1.4 5.3	120.9	53.3 217.2	12.5	2,790.7	6,882.0	4,023.3 14,793.4	337,344	148,647 606,034
2013	65.8	1,533	359.8	0.2	0.1 0.3	4.3	1.0 8.7	9.2	3,915.4	715.9	221.5 1,295.2	16,684	3,816 33,998
2014	1,020.2	94,976	597.5	1.7	0.8 2.4	158.9	62.8 276.7	15.5	3,845.0	6,564.9	2,901.4 9,327.7	611,152	241,491 1,063,825
2015	3,134.5	198,759	334.7	9.4	5.9 14.7	593.9	278.0 1,033.0	9.7	3,453.0	32,341.9	20,503.8 50,622.0	2,050,791	960,061 3,567,063

The combined estimates of the weight and number of eulachon caught in the Oregon and California ocean shrimp trawl fishery as bycatch from 2004–2015 (except for 2006 when these fisheries were not observed) and in Washington from 2010–2015 are presented in (Table A5, as cited in Gustafson et al. 2017). Total estimated bycatch of eulachon in the Oregon and California ocean shrimp fisheries ranged from nearly 158 thousand fish (95% CI; 11,642–492,887) in 2004 to a high of nearly 959 thousand (95% CI; 237,377–2,169,745) fish in 2009. Estimated eulachon bycatch in the Washington ocean shrimp fishery in 2010 (its first year of observation) was nearly 65 thousand fish, and the total 2010 estimated eulachon bycatch for all three states combined was over one million (95% CI; 540,065–1,889,846). Coastwide eulachon bycatch decreased to about 605 thousand (95% CI; 397,957–876,346) fish in 2011 (Table A5, as cited in Gustafson et al. 2017). However, as seen earlier, eulachon bycatch increased dramatically in all three states in 2012, topping out at over 42.6 million (95% CI; ~26.8–58.8 million) individual eulachon. Bycatch increased again in Washington and Oregon, but not California in 2013, resulting in an estimated total eulachon bycatch for all three states combined of over 51.8 million fish (95% CI;

~31.8–73.9 million) (Table A5, as cited in Gustafson et al. 2017). Estimated weight of these bycaught eulachon in 2013 was over 743 mt (95% CI; ~603–967 mt) (Table A5). Coastwide eulachon bycatch in ocean shrimp trawl fisheries again increased in 2014 to an all-time high of 68.8 million fish (95% CI; ~45.2–97.0 million) and 785 mt (95% CI; ~589–966 mt). In 2015, coastwide bycatch declined, relative to 2014, due to declining bycatch in the Oregon ocean shrimp sector; however, bycatch increased in both the Washington and the California sectors in 2015 (Table A5, as cited in Gustafson et al. 2017). Estimated coastwide bycatch in 2015 amounted to 59.8 million fish (95% CI; ~40.9–83.0 million) and 613 mt (95% CI; ~482–716 mt) (Table A5, as cited in Gustafson et al. 2017). Bycatch ratios were higher in Washington than in the Oregon fishery in both 2012 and 2013 (Tables A2–A3, Fig. A2, as cited in Gustafson et al. 2017). In 2015, bycatch ratios declined in the Oregon sector but rose in both the Washington and California sectors of the ocean shrimp trawl fishery (Gustafson et al. 2017).

Table 2-8. Total estimated bycatch of eulachon (number of individuals and mt) in ocean shrimp fisheries observed by the West Coast Groundfish Observer Program from 2004-2015. Ocean shrimp fisheries were not observed in 2006 (Gustafson et al. 2017).

	Eulachon bycatch (mt)					Eulachon bycatch (numbers of fish)				
Year	Washington	Oregon	California	Coastwide bycatch	95% CI	Washington	Oregon	California	Coastwide bycatch	95% CI
2004	--	2.88	0.31	3.19	0.33 8.97	--	146,388	11,442	157,780	11,642 498,887
2005	--	4.95	0.23	5.18	2.65 16.19	--	207,362	9,848	217,210	21,542 453,326
2006	--	--	--	--	-- --	--	--	--	--	-- --
2007	--	3.90	0.17	4.07	0.73 11.99	--	197,807	11,450	209,257	15,062 549,978
2008	--	10.33	0.25	10.58	5.68 14.22	--	389,604	24,793	414,397	114,334 796,455
2009	--	8.71	0.74	9.45	3.87 24.65	--	845,081	113,815	958,896	237,377 2,169,745
2010	2.06	13.70	2.45	18.22	10.73 22.90	64,735	740,501	267,057	1,072,294	540,065 1,889,846
2011	5.68	20.45	0.03	26.16	20.44 29.78	123,543	480,907	471	604,921	397,957 876,346
2012	156.69	427.95	6.88	591.52	507.83 704.84	14,218,507	28,065,308	337,344	42,621,159	26,830,708 58,828,252
2013	202.83	540.06	0.72	743.61	603.07 967.13	17,095,225	34,686,116	16,684	51,798,025	31,753,502 73,944,039
2014	142.22	636.37	6.56	785.15	589.14 965.66	13,417,079	54,735,346	611,152	68,763,577	45,201,130 96,974,077
2015	219.78	361.23	32.34	613.36	482.83 716.84	22,389,318	35,310,975	2,050,791	59,751,084	40,883,332 82,986,695

Collateral BRD Mortality

Although data on survivability of BRDs by small pelagic fishes such as eulachon are scarce, many studies on other fishes indicate that "among some species groups, such as small-sized pelagic fish, mortality may be high" and "the smallest escapees often appear the most vulnerable" (Suuronen 2005, p. 13–14; as cited in Gustafson et al. 2010). Results of several studies have shown a direct relationship between length and survival of fish escaping trawl nets, either with or without deflecting grids (Sangster et al. 1996, Suuronen et al. 1996, Ingólfsson et al. 2007; as cited in Gustafson et al. 2010), indicating that smaller fish with their poorer swimming ability and endurance may be more likely to suffer greater injury and stress during their escape from trawl gear than larger fish (Broadhurst et al. 2006, Ingólfsson et al. 2007; as cited in Gustafson et al. 2010). A recent workshop (Pickard and Marmorek 2007, p. 31–33; as cited in Gustafson et al. 2010) to determine research priorities for eulachon in Canada recommended the need to research the effectiveness of BRDs and the need to estimate mortality, not just bycatch.

Hannah and Jones (2012) used underwater video technology to examine behavior of eulachon when encountering rigid-grate BRDs in an ocean shrimp trawl net. The purpose of this research was to determine fish condition and survival following exclusion by the BRDs and the effectiveness of these types of BRDs at reducing mortality rates. Hannah and Jones (2012) stated that:

> Almost 80% of the large eulachon maintained an upright vertical orientation throughout their escape and exited the trawl in a forward-swimming orientation. Large eulachon maintained distance from the deflecting grid better than the other species encountered ($P < 0.001$) and typically showed no contact or only minimal contact with it (63%). Only about 20–30% of the large eulachon showed behaviors indicating fatigue, such as laying on or sliding along the grid.

Hannah and Jones (2012) concluded that:

> …data on behavior of large eulachon escaping from a shrimp trawl show that most have enough residual swimming ability to minimize their physical contact with the deflecting grid, maintain their vertical orientation and to continue actively swimming in a forward direction as they exit. This suggests that the use of deflecting grids in the ocean shrimp fishery is likely reducing eulachon mortality rates, as well as bycatch.

It is unclear why bycatch ratios were highest in the Washington, intermediate in the Oregon, and lowest in the California sectors of the ocean shrimp trawl fishery in 2012 and 2013. The sharp increases in the level of eulachon bycatch in both the Washington and Oregon ocean shrimp trawl fisheries in 2012 and 2013 occurred in spite of regulations, enacted in 2012, requiring the use of BRDs with a minimum 19 mm (0.75 inch) bar spacing. In 2014, eulachon bycatch ratios declined in Washington, but increased in both the Oregon and California sectors of the ocean shrimp trawl fishery. In 2015, both eulachon bycatch ratios and overall bycatch increased in both the Washington and California sectors of the ocean shrimp trawl fishery, but declined in the Oregon sector. Some of these patterns may be influenced by the degree to which artificial lights have been used to illuminate portions of trawl nets in different sectors of these fisheries.

Bycatch Reduction Efforts

Reducing bycatch in this fishery has long been an active field of research (Hannah et al. 1996, 2003, 2011, 2015; Hannah and Jones 2000, 2003, 2007, 2012; Frimodig et al. 2009; as cited in Gustafson et al. 2017) and great progress has been made in reducing bycatch, particularly for larger-bodied fishes. Use of BRDs in offshore shrimp trawl fisheries, which was mandated beginning in 2002 in California and 2003 in Washington and Oregon has substantially reduced bycatch of fin fish in these fisheries (Hannah and Jones 2007, Frimodig et al. 2009; as cited in Gustafson et al. 2017). As of 2005, following required implementation of BRDs, the total bycatch by weight had been reduced to about 7.5% of the total catch (Hannah and Jones 2007). However, some of these studies were done at a time (mid 2000s) when eulachon were at a historically low level of abundance.

None of the shrimp trawl BRDs in use today eliminate all incidental catch, and residual bycatch of fish (Hannah et al. 2011), especially of eulachon, remains a problem. Recent experimentation with artificial light to illuminate portions of trawl nets in the Oregon ocean shrimp fishery has shown great promise for significantly reducing bycatch of eulachon (Hannah and Jones 2014, 2015; Hannah et al. 2015; Groth et al. 2017; as cited in Gustafson et al. 2017). In 2014, researchers compared bycatch levels (Figures 2-7 and 2-8) over 42 paired trials between lighted and unlighted trawl nets using double-rigged vessels that could tow paired shrimp trawl nets (Hannah et al. 2015). When 10 green LED lights were placed along the trawl fishing line of ocean shrimp trawl nets with rigid-grate BRDs with 0.75 inch (19.1 mm) bar spacing installed and then were compared with identical trawls nets without lights, the bycatch of eulachon was reduced by 91%, with little or no effect on shrimp catch. Hannah et al. (2015, p. 60, as cited in Gustafson et al. 2017) stated that “How the addition of artificial light is causing these changes in fish behavior and bycatch reduction is not known,” but the authors speculated that illumination of the trawl fishing line may possibly allow the fish to see the approaching net sooner and react in time to avoid being entrained, and “likely encouraged some species to also move downwards, perhaps exploiting a natural tendency to move towards the seafloor when threatened” (Hannah et al. 2015, p. 66, as cited in Gustafson et al. 2017).

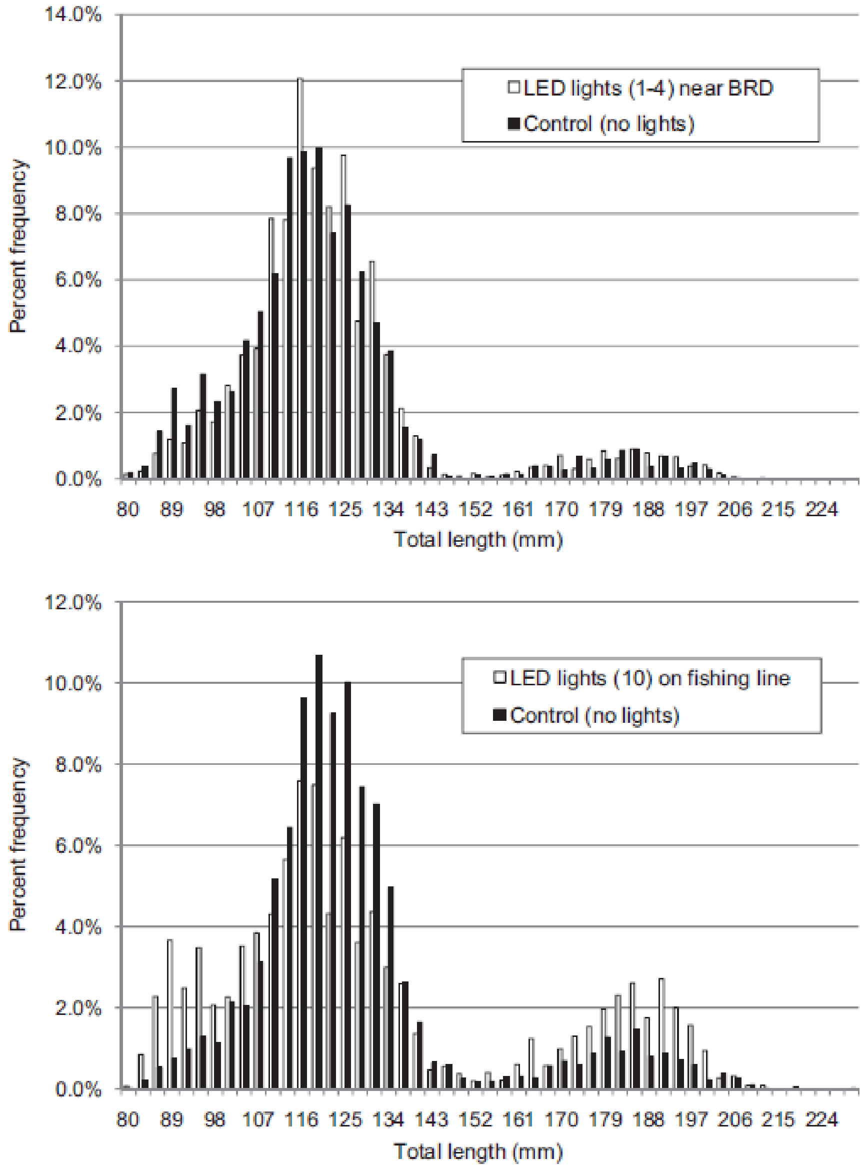

Figure 2-7. Percent length frequency of eulachon (total length, mm) captured in ocean shrimp trawl nets with and without 1–4 LED lights attached in the vicinity of the bycatch reduction device (upper panel) and with and without 10 LED lights attached to the trawl fishing line (lower panel). (Hannah et al. 2015).

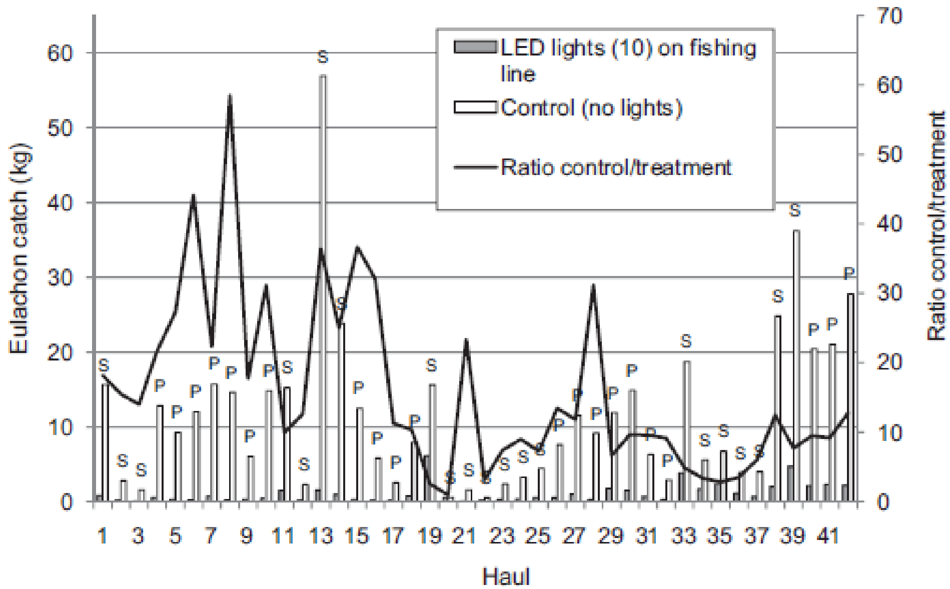

Figure 2-8. Haul-by-haul comparison of the catch of eulachon (kg) in the two nets of a double-rigged shrimp trawl vessel with one side incorporating 10 LED lights on the fishing line and the other acting as a control. The ratio of control/treatment catch is also shown (solid line). Label "P" or "S" denotes the side of trawl gear (port or starboard) used as the control net (Hannah et al. 2015).

Hannah and Jones (2016, p. 6, as cited in Gustafson et al. 2017) stated that to their knowledge "all shrimpers that fished in 2015 [in the Oregon ocean shrimp fishery] used LED (Light Emitting Diode) lights when trawling" and that "all said they used lights and were happy with the resulting bycatch reduction." Hannah and Jones (2016, as cited in Gustafson et al. 2017) also discussed several technical developments concerning types of lights that have been used and lighting configurations that are being tried to increase eulachon avoidance of shrimp trawl nets. Although use of LED lights on ocean shrimp trawl nets is not currently regulated in U.S. waters, Hannah and Jones (2016, p. 9, as cited in Gustafson et al. 2017) proposed regulations in Oregon be imposed to require use of footrope lighting devices such as the "Lindgren-Pitman Electralume Light Emitting Diode (LED) lights" or "other footrope lighting devices that are deemed by the Department to have comparable or greater total illumination may be approved for use, on a case-by-case basis, through issuance of an Experimental Gear Permit (EGP)."

According to Groth et al. (2017, p. 11, as cited in Gustafson et al. 2017), "NMFS observer data from 2015 showed that of the 2,137 hauls observed [in the Oregon sector]: 1,466 used LEDs, 66 did not use LEDs, and on the 605 remaining hauls, this data was not reported." Thus a minimum of about 69% of hauls in Oregon had some form of lights installed on the trawl nets in 2015. Furthermore, Groth et al. (2017, p. 11, as cited in Gustafson et al. 2017) stated that, "In 2016, we talked to 66 vessels landing shrimp into Oregon; of these, 57 vessels reported using LEDs 100% of the time, 7 reported using them sometimes (depending on bycatch rates, deferred maintenance cost, etc.), and 2 reported not using them at all." Groth et al. (2017, p. 9 and 12, as cited in Gustafson et al. 2017) emphasized "that proper installation of LEDs is key to bycatch reduction" and that research efforts in 2017 "will further examine use of LEDs in bycatch reduction." According to Groth et al. (2017, p. 9, as cited in Gustafson et al. 2017), ODFW experiments planned for up to 16 days at sea in 2017, in collaboration with the Pacific States Marine Fisheries Commission.

Bycatch Hotspots

Ward et al. (2015, as cited in Gustafson et al. 2017) applied spatiotemporal models to both fishery-dependent observations of eulachon bycatch and eulachon fisheries-independent survey data to 1) estimate population trends of eulachon, 2) understand eulachon bycatch risk in shrimp fisheries, and 3) identify persistent bycatch hotspots that may be used in future management actions to reduce eulachon bycatch rates. Two spatial data sets for the period from 2007–2012 were examined: WCGOP catch data of shrimp and eulachon in the California, Oregon, and Washington ocean shrimp trawl fisheries and fishery-independent incidental eulachon catch in the West Coast Bottom Trawl Survey (Ward et al. 2015, as cited in Gustafson et al. 2017). Ward et al. (2015, as cited in Gustafson et al. 2017) found support for a greater than 40% annual increase in eulachon density based on the bycatch dataset and a greater than 55% annual increase based on the fisheries-independent survey dataset over the duration of the datasets. The later dataset also suggested that eulachon density was "substantially higher in 2012 than in any recent period" (Ward et al. 2015, as cited in Gustafson et al. 2017). These data also imply "that increases in bycatch [are] not due to an increase in incidental targeting of eulachon by fishing vessels, but likely because of an increasing population size of eulachon." Ward et al. (2015, as cited in Gustafson et al. 2017) found that the coastal areas just south of Coos Bay, Oregon; between the Columbia River and Grays Harbor, Washington; and just south of La Push, Washington were consistent hotspots of eulachon bycatch across years.

Summary: Bycatch-Shrimp Fishery

Although the use of bycatch reduction devices clearly are beneficial to eulachon, without a better understanding of bycatch as a proportion of eulachon in the marine environment, and its impact on recruitment, it is impossible to quantify the benefit. Nonetheless, NMFS acknowledges that the use of bycatch reduction devices represents a significant step in bycatch reduction and the threat bycatch poses to the persistence of eulachon.

Bycatch—Groundfish Fishery—The Pacific Ocean shore-based limited entry (LE) groundfish trawl fishery was established in 1994 for midwater and bottom trawl gear and operates year-round off the coasts of Washington, Oregon, and southward to Morro Bay in California (Gustafson et al. 2017). Groundfish trawl vessels deliver their permitted and marketable catch to shore-side processors, and the majority of the portion of their catch which is prohibited by regulations or that is unmarketable is discarded at sea. The Individual Fishing Quota (IFQ) program for the limited entry shore-based bottom trawl fleet was implemented in 2011, under the West Coast Groundfish Trawl Catch Share Program. This catch shares system divides the portion of the trawl fisheries annual catch limits (ACL) for various groundfish stocks and stock complexes into shares controlled by individual fishermen or groups of fishermen (cooperatives), which can be harvested at the fishermen's discretion. In 2011, the LE trawl sector became a catch share program with 100% NMFS-certified observer. In 2015, exempted fishing permits (EFP) were issued for a subset of the fleet to carry electronic monitoring (EM) systems for compliance and quota management rather than observers; these vessels are still required to carry an observer for additional scientific data collection on ~ 20 to 30% of trips.

Eulachon were not observed as bycatch in the LE bottom trawl fishery in Washington from 2002–2010 (Gustafson et al 2017). From 2011 to 2015, a total of 442 individual eulachon were estimated as fleet-wide bycatch in the Washington IFQ non-hake bottom and midwater trawl fishery (Gustafson et al 2017). However, no eulachon were observed or estimated as bycatch in the Washington sector in 2015. Within the Oregon portion of the LE bottom trawl fishery, eulachon bycatch occurred in four of the nine years from 2002–2010 with 80% (783/974) of this estimated bycatch occurring in the year 2002 (Gustafson et al 2017). However, no eulachon bycatch was recorded in the Oregon LE bottom trawl fishery in 2004, 2005, 2006, 2008, or 2010 (Gustafson et al 2017). Between 2011 and 2015, the Oregon IFQ bottom trawl fishery had an estimated eulachon bycatch of 3,972 individual fish with nearly 63% (2,516 individuals) of this total occurring in the year 2014 (Gustafson et al 2017). Eulachon bycatch in the Oregon sector declined from a high point in 2014 to an estimated 641fish during 2015 (Gustafson et al. 2017). Eulachon were rarely caught in the California LE bottom trawl fishery; 5 fish in 2004 and 22 fish in 2010 (Gustafson et al. 2017). Not a single eulachon was recorded as bycatch in the California IFQ bottom and midwater trawl fishery from 2011–2014. Eulachon bycatch in this California sector in 2015, consisted of an estimated 2 total fish.

Eulachon were encountered sporadically in the at-sea Pacific hake fishery as bycatch. The at-sea catcher-processor sector of the Pacific hake fishery has caught more eulachon than other at-sea Pacific hake sectors (Gustafson et al 2017). No eulachon bycatch was reported in the catcher-processor sector from 2002–2005, or in 2010. The estimated eulachon bycatch in the catcher-processor sector was 147; 1,268; and 242 fish in 2006, 2011, and 2014, respectively (Gustafson et al 2017). The bycatch estimate in 2011 amounted to 69% of the total eulachon bycatch estimate of 1,841 fish between 2002 and 2015. In all other years fewer than 40 individual eulachon were observed in the catcher-processor Pacific hake sector as bycatch, except for 2015 when an estimated 56 fish were caught (Gustafson et al 2017).

The non-tribal mothership Pacific hake sector had a total estimated eulachon bycatch of 379 individual fish between 2002 and 2015, with 73% of this bycatch occurring in 2013 (277 fish). No eulachon bycatch occurred in 2002–2006 or in 2010 or 2015, and fewer than 10 individual fish were estimated caught in 2007, 2008, 2009 and 2012 (Gustafson et al. 2017). Eulachon bycatch estimate in the tribal mothership Pacific hake fishery was 32 fish in 2009 and 160 fish in 2011. Eulachon bycatch was not observed in this sector from 2002–2008 or in 2010. The tribal mothership sector did not participate in the Pacific hake fishery in 2013–2015, and fewer than three vessels were observed in 2012 (Gustafson et al 2017).

In 2015, the shoreside midwater sector of the IFQ Pacific hake fishery was reported separately as either a midwater Pacific hake sector or as a midwater rockfish sector. When more than 50% of a vessel's landings on a day were Pacific hake, the vessel's landing were reported as midwater hake; when landings were less than 50% hake by weight, the vessel's landings were reported in the midwater rockfish sector. No recorded eulachon bycatch occurred in either the midwater hake or the midwater rockfish sectors in 2015 (Gustafson et al 2017).

A summary of eulachon bycatch in all U.S. west coast groundfish fisheries observed by the WCGOP and the A-SHOP that reported eulachon catch from 2002–2015 is provided in Table 2-9. From 2002–2015, all groundfish sectors caught an estimated 11,968 individual eulachon. About 89% of this bycatch of eulachon occurred during 2011–2015, when efforts to identify eulachon in the bycatch of these fisheries became a priority and when other indices of eulachon abundance were highly positive.

Table 2-9. Estimated bycatch of eulachon (number of individual fish) in U.S. west coast groundfish fisheries that were observed by the West Coast Groundfish Observer Program (WCGOP) and the At-Sea Hake Observer Program (A- SHOP) from 2002–2015 (Gustafson et al. 2017).

	Non-hake bottom and midwater groundfish fisheries [1]			Shoreside Pacific hake /rockfish	At-sea Pacific hake fisheries			
Year	WA	OR	CA		Tribal Mothership	Non-Tribal Mothership	Catcher Processor	Total bycatch estimate
2002	0	783	0	--	0	0	0	783
2003	0	52	0	--	0	0	0	52
2004	0	0	5	--	0	0	0	5
2005	0	0	0	--	0	0	0	0
2006	0	0	0	--	0	0	147	147
2007	0	72	0	--	0	4	6	82
2008	0	0	0	--	0	6	37	43
2009	0	67	0	--	32	6	30	135
2010	0	0	22	--	0	0	0	22
2011	12	127	0	0	160	54	1,268	1,621
2012	1	167	0	0	0	7	16	191
2013	137	521	0	4,139	na	277	39	5,113
2014	292	2,516	0	0	na	25	242	3,075
2015	0	641	2	0	na	0	56	699

Conclusion

Based on this information, the threat occurs at a moderate to high severity for the ocean shrimp fisheries, and occurs at a very low severity for the U.S. west coast groundfish fisheries, with a medium-to-high level of uncertainty. Thus, the relative impact to recovery is ranked high.

Threat—Competition				
Subpopulation	**Klamath**	**Columbia**	**Fraser**	**BC**
BRT Ranking	9	12	12	9
BRT Threat Severity	Low	Low	Low	Low
Listing Factor	E	E	E	E

The following is a summary of competition-related effects on eulachon based on Gustafson et al. (2010).

Competition

Competition is a natural process that helped shape the abundance of eulachon throughout their evolutionary history. The pressures of natural selection on eulachon promoted development of an array of life history strategies, involving differences in migration timing and habitat usage, so that populations could avoid competing for limited spatial and food resources and, ultimately, maximize their marine survival. Euphausiids (principally *Thysanoessa spiniferia* and *Euphausia pacifica*) are a primary prey item of eulachon in the open ocean and are also eaten by many other competing species. Tanasichuk et al. (1991, as cited in Gustafson et al. 2010) showed that euphausiids were the most important prey for both spiny dogfish and Pacific hake off the lower west coast of Vancouver Island. Livingston (1983) determined that euphausiids constituted 72% and 90% of the diet by weight of Pacific hake examined off Oregon and Washington, respectively, in 1967, and 97% of the diet by weight of Pacific hake 350–449 mm long off Oregon in 1980. Similarly, Outram and Haegele (1972) indicated that euphausiids were the most numerous prey items of Pacific hake off the British Columbia coast in 1970, occurring in 94% of Pacific hake stomachs analyzed. Rexstad and Pikitch (1986, p. 955; as cited in Gustafson et al. 2010) stated that "euphausiids constitute the primary source of food for Pacific hake in the North Pacific." The offshore Pacific hake stock migrates northward from winter spawning grounds to feed off the coast of the Pacific Northwest in the summer. This stock represents the largest component of the offshore pelagic fish biomass in the California Current system (Ware and McFarlane 1995, as cited in Gustafson et al. 2010). Recent evidence (Benson et al. 2002, Cooke et al. 2006, and Phillips et al. 2007; as cited in Gustafson et al. 2010) indicates that Pacific hake spawning may be shifting further north within the northern California Current system. This places more young of the year Pacific hake in that ecosystem (Phillips et al. 2007, as cited in Gustafson et al. 2010) in direct competition with eulachon for their preferred prey, euphausiids.

Euphausiid Fisheries

A commercial fishery for euphausiids (also known as krill) occurs in the British Columbia portion of the Strait of Georgia (DFO 2007b, as cited in Gustafson et al. 2010). According to DFO (2007b, p. 6), euphausiid biomass in British Columbia waters "is dominated by five [species]: *Euphausia pacifica, Thysanoessa spinifera, T. inspinata, T. longipes and T. raschii," and E. pacifica* accounts for 70–100% of the biomass in the Strait of Georgia. The Integrated Fisheries Management Plan for euphausiids limits annual total allowable catch (TAC) of euphausiids in the Strait of Georgia to 500 mt (DFO 2007b, as cited in Gustafson et al. 2010). DFO (2007b, p. 3 of its Appendix A; as cited in Gustafson et al. 2010) stated that this level of harvest is considered to "be conservative and sustainable" within the Strait of Georgia. Eulachon originating from rivers draining into the Strait of Georgia likely leave the strait for waters over the continental shelf prior to reaching a size where they would begin consuming euphausiids, and thus the impact of this euphausiid fishery on eulachon is expected to be minor.

Conclusion

Based on this information, the threat occurs at a low severity and there is a low level of uncertainty. Thus, the relative impact to recovery is ranked low.

Threat—Nonindigenous Species				
Subpopulation	**Klamath**	**Columbia**	**Fraser**	**BC**
BRT Ranking	12	15	15	13
BRT Threat Severity	Very Low	Low Very	Very Low	Very Low
Listing Factor	E	E	E	E

The following is a summary of nonindigenous species-related effects on eulachon based on Gustafson et al. (2010).

Nonindigenous Species

Non-indigenous species (plant, animal, or microbe) may adversely affect ecosystems they invade. Potential impacts and risks of nonindigenous aquatic species to native fish species include increased predation, increased competition for habitats and food, alteration of food webs, and transmission of new diseases and parasites (ISAB 2008, as cited in Gustafson et al. 2010). The negative impact of nonindigenous species is recognized as one of the leading factors causing imperilment of native North American freshwater aquatic species (Lassuy 1995, ISAB 2008; as cited in Gustafson et al. 2010) and was listed as a factor leading to the extinction of 40 North America fish species and subspecies, representing a full 68% of those lost over the past 100 years (Miller et al. 1989, as cited in Gustafson et al. 2010). NRC (2004, as cited in Gustafson et al. 2010) reported that 17 nonindigenous fish species inhabit the Klamath River basin, but their impact on eulachon has not been studied. Schade and Bonar (2005, as cited in Gustafson et al.

2010) estimated that the percent of total fish species that are nonnative in streams in California, Oregon and Washington, were 39.6%, 24.5%, and 18.4%, respectively.

Conclusion

Based on this information, the threat occurs at a very low severity and there is a low-to-medium level of uncertainty. Thus, the relative impact to recovery is ranked very low.

2. Conservation Actions

Eulachon are protected in the U.S. under the ESA (listed as threatened). In Canada, the Fraser River eulachon Designatable Unit (DU) and the Central Pacific Coast eulachon DU remain under consideration for listing as endangered under Canada's Species at Risk Act (SARA). In the U.S. and Canada, several actions have been taken, both before and since their listing, to reduce impacts on the species and its habitats. The following is a list of significant actions taken to protect eulachon and/or advance eulachon conservation:

Ocean Shrimp Fisheries – Effective December 2010, the state of Oregon required all shrimpers fishing within the Oregon Fisheries Conservation Zone are required to use rigid-grate bycatch reduction devices. The state of Washington adopted rigid-grate BRD regulation effective in January 2012. The Oregon Fish and Wildlife Commission changed the administrative rules governing the use of BRDs in the pink shrimp fishery to reduce the bycatch of eulachon. The new rules require the use of rigid-grate BRDs with bar spacing no more than 1.0 inch starting in 2011, and 0.75 inch beginning in 2012. Current 2014–2015 regulations in Washington and Oregon, adopted by both states in 2012, require ocean shrimp trawl fishery BRDs to consist of a rigid panel or grate of narrowly spaced bars (usually constructed of aluminum) with no gaps between the bars exceeding 0.75 inches (19.1 mm). Approved BRDs for use in the ocean shrimp fishery in California include: (1) rigid- or semi-rigid grate excluders consisting of vertical bars with no gaps between the bars exceeding 2 inches (50.8 mm); (2) soft-panel excluders, usually made of a soft mesh material "with individual meshes no large than 6 inches;" and (3) fisheye excluders, which have a forward facing escape opening that is maintained by a rigid frame.

Oregon Department of Fish and Wildlife - In 2014 the ODFW conducted research on eulachon using light emitting diode lights (LEDs) attached to fishing gear (pink shrimp fishery) to assess the potential to reduce bycatch of eulachon associated with the ocean shrimp fishery. In 2015, NMFS observer data showed that of the 2,137 hauls observed, 1,466 used LEDs, 66 did not use LEDs, and on the 605 remaining hauls, use of LEDs was unreported. In 2016, 66 of 57 vessels landing shrimp reported using LEDs 100% of the time, 7 reported using them sometimes, and 2 reported not using them at all (Gustafson et al. 2017).

Department of Fisheries and Oceans, Canada – Since 1995 DFO has suspended commercial eulachon fisheries in the Fraser River; closed the shrimp fishery in Queen Charlotte

Sound; adopted "eulachon action levels" by DFO management that warn of possible shrimp fishing closures when cumulative eulachon bycatch level is reached; and required BRDs installed in shrimp trawls to reduce eulachon bycatch.

Department of Fisheries and Oceans, Canada – First Nations Fisheries: Aboriginal harvest for food, social and ceremonial purposes is authorized by communal licenses in the lower Fraser River; a total of eight bands may apply for licenses for small amounts of eulachon.

Department of Fisheries and Oceans, Canada – Recreational Fisheries: Recreational fishing for eulachon with dip nets, gillnets, minnow nets, or cast nets in fresh water, is prohibited throughout British Columbia. Recreational harvest of eulachon is also prohibited in all marine areas of British Columbia due to conservation concerns.

Department of Fisheries and Oceans, Canada – Commercial Fisheries: The commercial eulachon fishery remains closed in the Fraser River. However, there are currently 16 ZU (introduced) eulachon license eligibilities.

Elwha River – In 2000, as part of a comprehensive restoration effort in the Elwha River basin, the Elwha and Glines Canyon dams were acquired by the federal government. In 2014, both dams were removed. These restoration actions likely have indirect benefits to eulachon, especially in the lower reach of the Elwha River via material influx that support spawning and incubation of eulachon.

Klamath River – Pending Congressional approval, the Iron Gate dam, Copco 1 dam, Copco 2 dam, and J.C. Boyle dam are scheduled to be removed in 2020[39].

Department of Fisheries and Oceans, Canada – Beginning in 1995 DFO has suspended dredging in the Fraser River during the eulachon spawning season.

Washington Department of Ecology – the Washington Department of Ecology has issued the U.S. Army Corps of Engineers 401 water quality certifications on their operations and maintenance dredging program for the Columbia River that includes measures to reduce impacts to eulachon in the Columbia River during the spawning season.

Sandy River Dam Removal – In 2007 Marmot Dam was removed and the Little Sandy Dam was taken down in 2008, which should restore much of the Sandy River's natural hydrology and result in significant sediment transport into the lower Sandy River where eulachon have spawned historically.

Habitat Restoration Projects – Habitat restoration projects, mostly for salmon and steelhead, continue to be implemented along the West Coast to improve freshwater and estuarine

[39] Congress has yet to pass a bill to authorize and fund the Klamath Accords.

habitats. These restoration actions likely have indirect benefits to eulachon, especially restoration actions in estuarine habitats that provide material influx that support food web processes.

Fisheries Regulations

U.S. Fishery – The states of Oregon and Washington enacted permanent rules prohibiting directed harvest of eulachon in recreational and commercial fisheries in the Columbia River and its tributaries; commercial fishing closed permanently effective December 1, 2010 and recreational fishing closed permanently effective January 1, 2011. On March 1, 2013, the state of California issued regulations prohibiting the take or possession of eulachon in recreational fisheries. In 2014, 2015, 2016, and 2017 the states of Oregon and Washington opened a limited-opportunity eulachon fishery to: (1) provide essential context for interpreting historical harvest data to better understand trends and variability in eulachon abundance; (2) filling critical information gaps such as the length and age structure of spawning eulachon, as well as the temporal and spatial distribution of the run; (3) supporting the cultural traditions of Northwest tribes who rely on eulachon as a seasonally important food source; and (4) providing a limited public and commercial opportunity for eulachon harvest to maintain a connection between people and the eulachon resource. This connection is important to sustaining public engagement in eulachon conservation and recovery.

The exploitation rate for 2014 was 1.4% of the mean abundance estimate for the Columbia River subpopulation. The exploitation rate for 2015 was 2.8% of the mean abundance estimate for the Columbia River subpopulation. The exploitation rate for 2016 was 3.0% of the mean abundance estimate for the Columbia River subpopulation. The exploitation rate for 2017 was 0.5% of the mean abundance estimate for the Columbia River subpopulation. These exploitation rates are significantly lower than historical rates, which averaged 11.3% (low of 0.4% and high of 36.2%) prior to the listing[40] of eulachon in 2010.

Pacific Fishery Management Council - in 2015 the Pacific Fishery Management Council adopted a Fishery Ecosystem Plan. As part of FEP, no directed fishery on eulachon in marine waters would be allowed without a NMFS-approved Fishery Management Plan.

Chapter 3. Recovery Goals, Objectives, and Delisting Criteria

This section describes the recovery goals, objectives, and delisting criteria that NMFS will use in future ESA status reviews of the southern DPS of eulachon. These reviews will contribute to NMFS' larger objective of delisting the southern DPS of eulachon.

The recovery goals that are incorporated into a recovery plan may include delisting, reclassification (e.g., from endangered to threatened), and/or other "broad sense" goals that may go beyond the requirements for delisting to acknowledge social, cultural, or economic values

[40] Based on data in Figure 2-4 for the years 2000-2010.

regarding the listed species. Delisting criteria must meet ESA requirements, while recovery may be defined more broadly. The ESA requires that recovery plans, to the maximum extent practicable, incorporate objective, measurable criteria which, when met, would result in a determination in accordance with the provisions of the ESA that the species should be removed from the Federal List of Endangered and Threatened Wildlife and Plants (50 CFR 17.11 and 17.12; 50 CFR 223.102 and 224.101). These criteria are of two kinds: the biological viability criteria, which deal with population or demographic parameters, and the "threats" criteria, which relate to the five listing factors detailed in the ESA. The threats criteria define the conditions under which the listing factors, or threats, can be considered to be addressed or mitigated. Together these make up the "objective, measurable criteria" required under section 4(f)(1)(b) for the delisting decision.

A. Recovery Goal

The goal of this Recovery Plan is to:

1. Increase the abundance and productivity of eulachon.

2. Protect and enhance the genetic, life history, and spatial diversity of eulachon throughout its geographical range; and

3. Reduce existing threats to warrant delisting of the species.

Figure ES-1 is a conceptual model that illustrates the linkages of the recovery strategy with the goal, objectives, delisting criteria, and actions.

B. Recovery Objectives and Delisting Criteria

Eulachon will no longer be in danger of extinction or likely to become endangered in the foreseeable future when all four subpopulations exhibit a combination of abundance and productivity sufficient to maintain genetic, life history, and spatial diversity across a range of conditions allowing for adaptation to changing environmental conditions; and threats have been addressed to an extent sufficient to maintain those biological characteristics throughout the foreseeable future.

The recovery goal can be subdivided into discrete component objectives that, collectively, describe the conditions necessary for achieving the recovery goal. The Eulachon Recovery Team identified four recovery objectives:

1. Ensure subpopulation viability.

2. Conserve spatial structure and temporal distribution patterns.

3. Conserve existing genetic and life history diversity and provide opportunities for interchange of genetic material between and within subpopulations.

4. Eliminate or sufficiently reduce the severity of threats.

The Eulachon Recovery Team identified four recovery objectives: 1) ensure subpopulation viability, 2) conserve spatial structure and temporal distribution patterns, 3) conserve existing genetic and life history diversity and provide opportunities for interchange of genetic material between and within subpopulations and, 4) eliminate or sufficiently reduce the severity of threats.

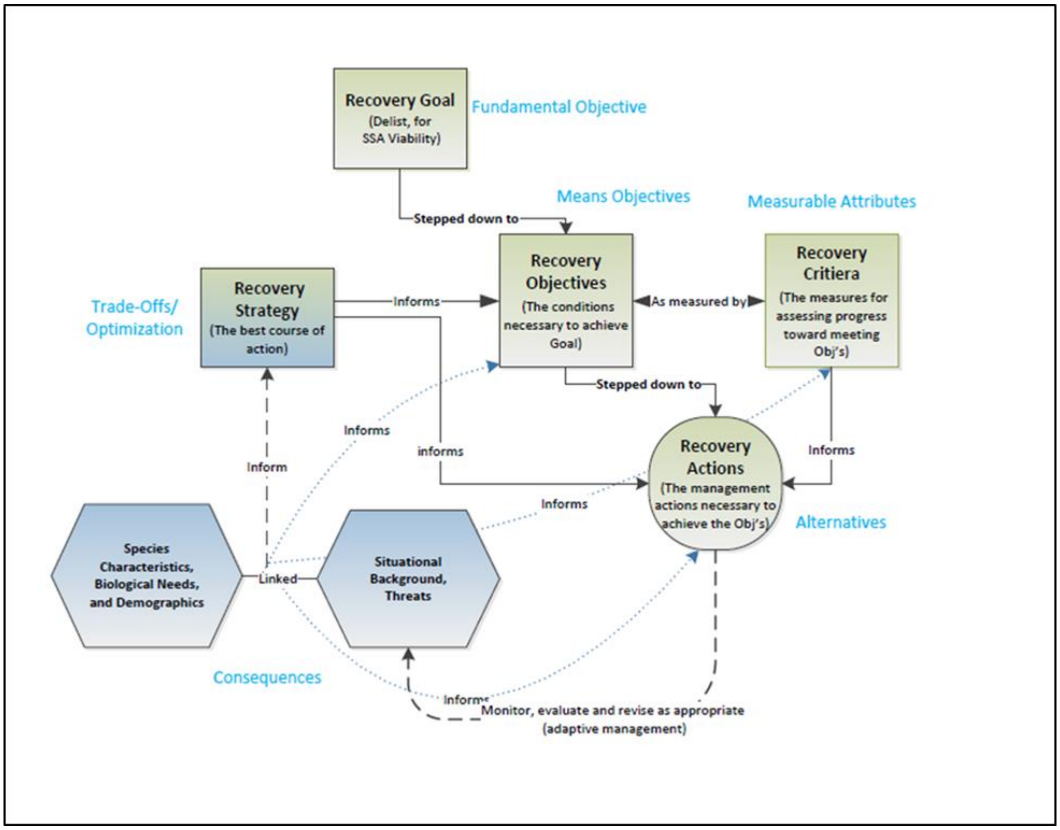

Figure 3-1. Recovery strategy conceptual model.

In order to determine when recovery objectives have been met, we must provide objective, measurable criteria that can be applied to a determination that eulachon be removed from the Endangered Species List. Recovery criteria need to be established for each recovery objective and require evidence that the species' status has improved to a point where it is viable.

The delisting criteria are based on the best available scientific information and incorporate the most current understanding of the DPS and the threats it faces. As this recovery plan is implemented, additional information will become available that can increase certainty about whether the threats have been abated, whether improvements in subpopulation and DPS status have occurred, and whether linkages between threats and changes in eulachon status are understood. These delisting criteria will be assessed through an adaptive management program and NMFS may review whether the criteria may warrant revision during its five-year reviews of the ESU. As the biological status of eulachon improves over time, the ESA five-year status review process can be used to articulate the changes in viability parameters and ESA listing factors that might warrant a review of whether the DPS's should be delisted. The five-year status review process will be used to evaluate this DPS's progress toward recovery and determine if any future change in ESA listing status is warranted.

There is much uncertainty in our knowledge regarding many of the anthropogenic and natural factors that could be limiting eulachon abundance and productivity. If we address the highest ranked threats and do not observe a positive response in the species' demographics, then we may need to develop additional threat-based objectives and criteria. The proposed recovery approach serves to address the most pressing gaps in knowledge, addresses critical demographic factors required for recovery, and targets the reduction or elimination of threats so that the recovery objectives outlined in this plan have the greatest likelihood of being achieved. Because many of the threats to the recovery of eulachon are not directly manageable, the recovery strategy pursues simultaneous actions to address critical demographic factors, the range of threats, and knowledge gaps. Climate impacts on ocean conditions, i.e., as measured by large-scale spatial and temporal shifts in oceanic-atmospheric patterns in the northeast Pacific Ocean associated with both natural climate variability and anthropogenic-forced climate change, is likely the principal threat to eulachon, as it is the one phenomenon that correlates with the recent species-wide declines in abundance. Therefore, actions must be taken to understand the mechanisms by which these large-scale spatial and temporal shifts in oceanic-atmospheric patterns in the northeast Pacific Ocean affect eulachon productivity, recruitment, and persistence.

The criteria are organized below according to (1) biological recovery criteria which address abundance, productivity, spatial structure, and genetic and life history diversity; and (2) qualitative/quantitative threat-based recovery criteria which address the threats impeding recovery.

Recovery Objectives

The recovery goal can be subdivided into discrete component objectives that, collectively, describe the conditions necessary for achieving the recovery goal. The Eulachon Recovery Team identified four recovery objectives:

1. Ensure subpopulation viability.

2. Conserve spatial structure and temporal distribution patterns.

3. Conserve existing genetic and life history diversity and provide opportunities for interchange of genetic material between and within subpopulations.

4. Eliminate or sufficiently reduce the severity of threats.

Delisting Criteria

The ESA requires that recovery plans for listed species contain "measurable and objective criteria" that when met would result in the removal of the species from the endangered species list. To be removed from the list, a species needs to be no longer in danger of or threatened with extinction. Court rulings and NMFS policy indicate that delisting criteria must include both ***biological criteria*** and ***listing factor criteria*** that address the threats to a species (i.e., the five factors in ESA section 4[a][1][b]). The viability criteria relate most directly to the biological delisting criteria; however, they are not synonymous. NMFS establishes delisting criteria based on both science and policy considerations. For instance, science can identify the best metrics for assessing extinction risk and thresholds of those metrics associated with a given level of risk, but setting the acceptable level of risk for purposes of the ESA is a policy decision.

1. Abundance: Each subpopulation is self-sustaining, i.e., each subpopulation has a less than 5% probability of extinction in 100 years.

2. Productivity: Each subpopulation has a stable or increasing growth rate greater than 1 across multiple generations.

3. Spatial Structure and Temporal Distribution: Eulachon subpopulations are distributed in a manner that insulates against loss from local catastrophic events and provides for re-colonization of a subpopulation that is affected by such an event.

4. Genetic and Life History Diversity: Eulachon subpopulations exhibit high certainty that genetic and life history diversity is sufficient to sustain natural production across a range of conditions, and eulachon subpopulations exhibit high certainty that changes in phenotypical traits represent positive natural adaptations to prevailing environmental conditions.

5. Threats: For each subpopulation, the threats listed in Table 2.2 have been diminished such that they do not limit attainment of the desired biological status of the DPS, and all the factors in section 4(a)(l) of the ESA have been addressed.

Chapter 4. Recovery Strategy

Primary Focus and Justification of Recovery Strategy

The purpose of this Recovery Plan is to identify a strategy for rebuilding and assuring the long-term viability of eulachon in the wild, allowing ultimately for the species' removal from the Federal list of endangered and threatened species.

There is much uncertainty in our knowledge regarding how threats (Table 2-2) influence eulachon. Nonetheless, we propose to work on what we can to advance the conservation of eulachon by working with our stakeholders to continue to implement actions that further reduce the severity of threats to eulachon, as well as develop a comprehensive research program to collect the data to enable a greater understanding of eulachon population abundance and demographics, and improve our understanding of the impact that large-scale threats like climate change impacts on ocean conditions have on eulachon productivity, recruitment, and persistence.

Historically, eulachon were a species' with high abundances throughout its range. It is unclear whether undetected local extirpations may have already occurred, or if these declines are part of the species natural variability (intrinsically, eulachon exhibit considerable year-to-year variability) or a long-term shift in the species' productivity induced by natural and/or anthropogenic forcing factors.

Threats to eulachon and their habitat must be sufficiently abated to ensure a high probability of survival into the future. The proposed recovery approach serves to address the most pressing gaps in knowledge, addresses critical demographic factors required for recovery, and targets the reduction or elimination of threats so that the recovery objectives outlined in this plan have the greatest likelihood of being achieved. Because many of the threats to the recovery of eulachon are not directly manageable, the recovery strategy pursues simultaneous actions to address critical demographic factors, the range of threats, and knowledge gaps. Climate impacts on ocean conditions, i.e., large-scale spatial and temporal shifts in oceanic-atmospheric patterns in the northeast Pacific Ocean associated with natural climate variability and anthropogenic-forced climate change, is likely the principal threat to eulachon, as it is the one phenomenon that offers a causative explanation for the recent species-wide declines in abundance. Therefore, actions must be taken to understanding these large-scale spatial and temporal shifts in oceanic-atmospheric patterns in the northeast Pacific Ocean associated with natural climate variability and anthropogenic-forced climate change to identify the primary environmental forcing factors in the marine environment that influence eulachon productivity, recruitment, and persistence.

This Recovery Plan covers the status, threats, recovery goals, objectives, and criteria for eulachon at the species' scale. However, for the most part[41], the recovery actions in this

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[41] Due to the nature of the threats eulachon face, e.g., climate impacts on ocean conditions, as well as the distribution of eulachon in the marine environment, actions to address the species' and the threats it faces will cross political

document are specific to eulachon subpopulations within the jurisdiction of the U.S. For the Fraser River and British Columbia Coast subpopulations, NMFS will, to the extent feasible, collaborate with DFO and First Nations in Canada to develop recovery actions to address threats to eulachon for the Fraser River and BC subpopulations.

Chapter 5. Recovery Program

The Recovery Program for eulachon describes the recovery actions that are necessary to achieve the plan's goals, objectives, and criteria. This section of the plan consists recovery actions and the implementation schedule. The recovery actions are organized around each of the recovery objectives, and the implementation schedule is a specific guide for carrying out recovery actions in terms of action priorities, action descriptions, duration of actions, and estimated costs. NMFS believes that the recovery plan should be a dynamic document that will change over time based on the progress of recovery and the availability of new information. As new information is obtained, additional actions will be identified and incorporated into the plan. As is the case for all recovery plans under the ESA, this plan will be regularly reviewed and the relative success of these actions in protecting eulachon assessed.

Recovery Actions

ACTION 1: Establish a Eulachon Technical Recovery and Implementation Team

1.1 Establish a eulachon technical recovery and implementation team to develop an overall framework for funding, prioritization, implementation, and reporting of recovery actions.

ACTION 2: Implement Outreach and Education Strategies

2.1. Develop outreach and education strategies regarding the ecological, economic, and cultural values of eulachon; foster stewardship of the marine ecosystem; expand funding and research partnerships; and increase involvement of existing regional and international organizations.

ACTION 3: Near-Term Research Priorities

3.1. Conduct annual in-river spawning stock biomass surveys in spawning areas with a high-to-moderate spawning frequency to develop long-term, high resolution abundance estimations for each subpopulation of eulachon.

3.2. Conduct a gap analysis to identify the data needs to develop a survey method to map eulachon spawning areas, with an emphasis on identifying core spawning areas, for each subpopulation.

jurisdictions.

3.2.1. Implement a high resolution mapping survey to identify core eulachon spawning areas for each subpopulation.

3.3. Conduct a gap analysis to identify the data needs to develop an at-sea survey method to create a reliable index of eulachon abundance in the marine environment.

3.3.1 Develop and implement an at-sea survey method to create a reliable index of eulachon abundance in the marine environment.

3.4. Conduct a gap analysis to identify the data needs to develop a genetic mixed stock baseline analysis of eulachon spawning subpopulations.

3.4.1. Conduct a genetic baseline analysis of eulachon spawning subpopulations to determine subpopulation-population structure of eulachon throughout the range of the DPS.

3.5. Conduct a gap analysis to identify the data needs to develop a genetic mixed stock baseline analysis of eulachon in the marine environment.

3.5.1 Conduct a genetic mixed stock baseline analysis of eulachon in the marine environment.

3.6. Conduct a gap analysis to identify the data needs to develop a method to correlate in-river and marine abundance estimations of eulachon.

3.6.1. Conduct an analysis that correlates in-river and marine abundance estimations of eulachon.

3.7. Conduct a gap analysis to identify the data needs to develop an ocean ecosystem indicators model of eulachon marine survival in the California Current Ecosystem.

3.7.1 Develop an ocean ecosystem indicators model of eulachon marine survival in the California Current Ecosystem to determine how short-term and long-term variability in ocean conditions affect eulachon abundance and productivity for each subpopulation.

3.8. Conduct a gap analysis to identify the data needs, e.g., age composition, length-weight relationship, intrinsic mortality rates, sex ratios, fecundity; necessary to parameterize a population viability analysis and develop abundance and productivity criteria for each subpopulation of eulachon.

3.8.1. Develop abundance and productivity criteria for each subpopulation of eulachon.

ACTION 4: Conserve Spatial Structure and Temporal Distribution

4.1. Develop a research and monitoring plan to determine the distribution (presence/absence) of eulachon in low-to-moderate frequency spawning areas by implementing an in-river sampling program, e.g., environmental DNA technology, to assess spatial distribution of eulachon in coastal watersheds of California, Oregon, and Washington.

ACTION 5: Eliminate or Sufficiently Reduce the Severity of Threats

Marine Habitats

5.1. Conduct a gap analysis to identify the data needs to develop a plume-nearshore oceanographic model for the Columbia River subpopulation.

4.1.1 Develop a plume-nearshore oceanographic model to assess the relationship and significance of plume and nearshore ocean environments on eulachon survival, especially larval eulachon, during the freshwater-ocean transition period.

5.2. Develop a research plan to understand physiological requirements for survival (i.e. pH, temperature) and potential impacts of ocean acidification on eulachon larvae.

Bycatch

5.3. Develop a qualitative/quantitative recovery criterion through research and adaptive management. Based on the information gathered in conjunction with eulachon 5-year status reviews, we will evaluate and incorporate, as appropriate, the findings of on-going research on bycatch of eulachon in the ocean shrimp trawl fishery to develop a criterion based on a range of bycatch rates consistent with the recovery requirements of the species.

5.4. Minimize bycatch of eulachon in the ocean shrimp fisheries by fleet-wide implementation of light emitting diode lights, rigid grate bycatch reduction devices, and additional gear-type or operational modifications, to further reduce bycatch of eulachon in the ocean shrimp trawl fisheries.

5.5. Develop a eulachon bycatch assessment model integrating in-river and marine abundance estimations of eulachon to analyze demographic information in order to determine changes in marine abundance and predict effects on freshwater productivity in response to bycatch in the ocean shrimp trawl fisheries.

Freshwater Habitats

5.6. Conduct a gap analysis to identify freshwater habitats with multi-year high water temperatures that fall outside of the range of water temperatures that are optimal for eulachon spawning, incubation, and larval development.

4.6.1. Develop site-specific recovery actions to restore or mitigate the impacts of high water temperatures that impede eulachon spawning, incubation, and larval development.

Predation

5.7. Conduct a gap analysis to identify the data needs to develop a research, monitoring, evaluation, and action plan to assess and reduce, where feasible, impacts of predation on eulachon in estuary and freshwater habitats.

4.7.1. Implement recovery actions to reduce high impact predator consumption rates of eulachon.

Dams/Water Diversions

5.8 Develop a qualitative/quantitative recovery criterion through research and adaptive management. Based on the information gathered in conjunction with eulachon 5-year status reviews, we will evaluate and incorporate, as appropriate, the findings of on-going research on eulachon spawning areas affected by dams or channel-spanning water control structures to develop a criterion based on a range of recovery targets to maximize survival, growth, fitness, and development of eulachon larvae in the freshwater and plume-nearshore environment consistent with the recovery requirements of the species.

5.9 Develop a research and monitoring plan to monitor the effects of post-dam removal, e.g., sediment yields and water quality, in the Klamath River Basin to assess effects on the recruitment and recovery of eulachon.

5.10 Identify and implement actions to reduce the ecological effects caused by water management operations via dams and channel-spanning water control structures on eulachon riverine and estuarine habitats.

5.11 Investigate the long-term effects of the Toutle River Sediment Retention Structure on sedimentation processes in the Toutle, Cowlitz, and Columbia Rivers on eulachon habitat, as it relates to sediment and nutrient inputs into the estuary-plume environment and eulachon reproduction and survival in the freshwater environment.

5.12. Implement the monitoring and evaluation General Measures in the Northwest Power and Conversation Council's Fish and Wildlife Program regarding changes in the hydrograph associated with hydropower development and operations in the Columbia River, and impacts on eulachon survival and recovery.

5.12.1. Monitor and evaluate temporal and spatial species composition, abundance, and foraging rates of juvenile eulachon predators at representative locations in the estuary and plume.

5.12.2. Monitor, and evaluate the causal mechanisms, e.g., shifts in the timing, magnitude, and duration of the hydrograph of the Columbia River, and migration/behavior characteristics affecting survival of larval eulachon during their first weeks in the plume-ocean environment.

5.12.3. Monitor and evaluate the ecological importance of the tidal freshwater, estuary, plume, and nearshore ocean environments to the viability and recovery of the Columbia River subpopulation of eulachon.

Water Quality, Disease, Competition, Shoreline Construction, Tribal/First Nations Fisheries, Recreation Harvest, Commercial Harvest, and Dredging

5.13. Develop qualitative/quantitative recovery criteria through research and adaptive management. Based on the information gathered in conjunction with eulachon 5-year status reviews, we will evaluate and incorporate, as appropriate, the findings of on-going research on water quality, disease, competition, shoreline construction, tribal/first nations fisheries, non-indigenous species, recreational harvest, commercial harvest, and dredging to develop criteria based on a range of targets consistent with the recovery requirements of the species.

5.14. Water Quality: Develop a research and monitoring plan to identify contaminants of concern and sources to determine the significance of water quality degradation to eulachon and their habitats, and to inform the development of recovery actions and a recovery criterion through research and adaptive management.

5.15. Shoreline Construction: Evaluate the impacts of shoreline construction on eulachon and their habitats through research and adaptive management to inform the development of site-specific recovery actions.

5.15.1. Quantify the extent of shoreline construction in the Klamath River from river mile 10.7 to the confluence with the Pacific Ocean, and assess the severity of shoreline construction on the function of eulachon core spawning areas.

5.15.2. Quantify the extent of shoreline construction in the Umpqua River from river mile 39.0 to the confluence with the Pacific Ocean, and assess the severity of shoreline construction on the function of eulachon core spawning areas.

5.15.3. Quantify the extent of shoreline construction in the Columbia River from river mile 146.1 to the confluence with the Pacific Ocean, and assess the severity of shoreline construction on the function of eulachon core spawning areas.

5.15.4. Quantify the extent of shoreline construction in the Cowlitz River from river mile 80.8 the confluence with the Columbia River, and assess the severity of shoreline construction on the function of eulachon core spawning areas.

5.15.5. Quantify the extent of shoreline construction in the Lewis River from river mile 31.1 the confluence with the Columbia River, and assess the severity of shoreline construction on the function of eulachon core spawning areas.

5.5.6. Quantify the extent of shoreline construction in the East Fork of the Lewis River from river mile 9.2 to the confluence with the Lewis River, and assess the severity of shoreline construction on the function of eulachon core spawning areas.

5.15.7. Develop site-specific recovery actions to eliminate, restore, or mitigate the impacts of shoreline construction that impede the function of eulachon core spawning areas.

5.15.8. Implement site-specific recovery actions to eliminate, restore, or mitigate the impacts of shoreline construction that impede the function of eulachon core spawning areas.

5.16. Implement a limited-opportunity eulachon fishery to: (1) provide essential context for interpreting historical harvest data to better understand trends and variability in eulachon abundance; (2) filling critical information gaps such as the length and age structure of spawning eulachon, as well as the temporal and spatial distribution of the run; (3) supporting the cultural traditions of Northwest tribes who rely on eulachon as a seasonally important food source; and (4) providing a limited public and commercial opportunity for eulachon harvest to maintain a connection between people and the eulachon resource. This connection is important to sustaining public engagement in eulachon conservation and recovery.

5.16.1. Tribal/First Nations Fisheries: Minimize impacts related to a directed fishery on eulachon by developing and implementing an abundance-based fishery management and evaluation plan to ensure that exploitation rates do not negatively impact subpopulation productivity.

5.16.2. Recreational Harvest: Minimize impacts related to a directed fishery on eulachon by developing and implementing an abundance-based fishery management and evaluation plan to ensure that exploitation rates do not negatively impact subpopulation productivity.

5.16.3. Commercial Harvest: Minimize impacts related to a directed fishery on eulachon by developing and implementing an abundance-based fishery management and evaluation plan to ensure that exploitation rates do not negatively impact subpopulation productivity.

5.17. Dredging:

5.17.1. Develop a research, monitoring, and adaptive management plan to quantify the impacts of dredging and disposal activities associated with the Columbia River Navigation Channel Operations and Maintenance Dredging Program, including ocean dredged material disposal sites, on habitat forming and maintenance processes and the recruitment and recovery of eulachon.

5.17.2. Develop a research, monitoring, and adaptive management plan to quantify the impacts of dredging and disposal activities associated with the Umpqua River Navigation Channel Operations and Maintenance Dredging Program, including ocean dredged material disposal sites, on habitat forming and maintenance processes and the recruitment and recovery of eulachon.

5.17.3. Implement impact minimization measures to reduce the impacts of dredging and disposal activities associated with maintenance dredging programs—as well as the issuance of permits under section 404 of the Clean Water Act, Section 10 of the Rivers and Harbors Act, and state permits—including ocean dredged material disposal sites, on habitat forming and maintenance processes and eulachon.

ACTION 6: Assess Regulatory Measures—Inadequacy of Existing Regulatory Mechanisms

6.1. Ensure appropriate and effective regulatory, response, restoration, and enforcement mechanisms are in place domestically and internationally for both planned and unplanned impacts. For planned impacts, project planning should ensure no net loss of eulachon critical habitat. Where natural or anthropogenic impacts do occur, an effective and complete response plan, including appropriate compensatory and site restoration, is executed.

ACTION 7: Develop a Research, Monitoring, Evaluation, and Adaptive Management Plan

In 2007, the NMFS Northwest Region (now the West Coast Region) released Adaptive Management for ESA-Listed Salmon and Steelhead Recovery: Decision Framework and Monitoring Guidance (NMFS 2007). This document describes the questions we ask in evaluating species status and making listing and delisting decisions. It offers conceptual-level guidance, not specific instructions, on gathering the information that will be most useful in tracking progress and assessing the status of listed species.

As outlined in the document, a delisting decision is based on evaluation of both the DPS's biological status and the extent to which the threats facing the DPS have been addressed. The document spells out the questions that need to be answered through RME to satisfy the requirements for each component of such a decision.

The document emphasizes that adaptive management is an experimental approach in which the assumptions underlying recovery strategies and actions are clearly stated and subject to evaluation (NMFS 2007). It further states that a monitoring and evaluation plan to support adaptive management should provide (1) a clear statement of the metrics and indicators by which progress toward achieving goals can be tracked, (2) a plan for tracking such metrics and indicators, and (3) a decision framework through which new information from monitoring and evaluation can be used to adjust strategies or actions aimed at achieving the plan's goals.

The adaptive management guidance (NMFS 2007) discusses considerations for prioritizing monitoring and examines the consequences of different sorts of incomplete data. Management and delisting decisions often must be made with incomplete information. Different types of incomplete information pose correspondingly different types of risks for delisting decisions. This discussion is intended to help planners consider how their own implementation and monitoring decisions may affect our assessment of DPS status. In the Recovery Plan, we have adopted this *Framework* for eulachon.

7.1. Develop an adaptive management plan to guide the recovery process by identifying key hypotheses, prioritizing research and monitoring, and evaluating alternative recovery strategies.

7.2. Develop a eulachon status and trend monitoring program.

7.3. Develop a recovery action effectiveness monitoring plan.

7.4. Develop an implementation and compliance monitoring plan.

7.5. Develop a monitoring plan to assess listing factors as they relate to eulachon recovery.

7.6 Conduct a retrospective analysis of land and water management impacts over time for eulachon spawning rivers where the data are available and compare to best estimates of eulachon abundance over time in the same rivers.

Figure 5-1. The adaptive management process.

Implementation Schedule and Costs

An implementation schedule is used to direct and monitor implementation and completion of recovery tasks. Recovery plan recovery action priorities in the third column of the following implementation schedule (Table 5-1) are assigned as follows:

Priority 1- Actions that must be taken to prevent extinction, including research actions to identify those actions that must be taken to prevent extinction.

Priority 2 - Actions that must be taken to prevent a significant decline in species population/habitat quality or in some other significant negative impact short of extinction. This includes research actions to identify those actions that must be taken to prevent such impacts.

Priority 3 - Remaining actions that must be taken to achieve delisting criteria, including monitoring to demonstrate achievement of demographic criteria.

Priority 4 - Actions necessary to facilitate post-delisting monitoring.

Priority 0 - All other actions that are not required for ESA recovery but that would advance broader goals beyond delisting.

Funding is estimated according to the number of years necessary to complete the task once implementation has begun, and does not account for inflation. Estimates are based on information available at the time this plan was finalized; the amount needed to actually complete the task may change as specific actions are pursued. The provision of cost estimates is not meant to imply that appropriate levels of funding will necessarily be available for all eulachon recovery tasks. The costs associated with the various recovery tasks listed below are for those to be implemented in U.S. waters only. Costs associated with promotion of international action have not been estimated.

The Implementation Schedule that follows outlines actions and estimated costs for the recovery program for eulachon, as set forth in the plan. It is a guide for meeting the recovery goals outlined in the plan. This schedule indicates action priorities, action numbers, action descriptions, duration of actions, and the parties responsible for the actions (either funding or carrying out) and estimated costs. Parties with authority, responsibility, or expressed interest to implement a specific recovery action are identified in the Implementation Schedule. The listing of a party in the Implementation Schedule does not require the identified party to implement the action(s) or to secure funding for implementing the actions(s).

This section includes a description of the recovery actions that, once implemented, should achieve the goal of recovering eulachon. Specifically, we will address the greatest threats for which recovery actions were deemed necessary to promote recovery of eulachon. These threats were ranked as high. If these recovery actions are fully implemented and recovery of eulachon is not achieved, then lower level threats will need to be addressed in the future.

Implementation costs are organized by Recovery Action Number, Table 5-1.

Anticipated Date of Recovery

We estimated that it will take approximately 25 to 100 years for the southern DPS of eulachon to achieve recovery.

Total Cost of Recovery

NMFS has developed a set of recovery actions and cost estimates based on the best information currently available. With the many uncertainties involved in predicting the course of recovery and in estimating total costs, we focused on the first five years of implementation and in five-year intervals thereafter to coincide with our 5-year status reviews, with the understanding that before the end of each five-year implementation period, specific actions and costs will be estimated for subsequent years. Based on recovery actions for which we have cost estimates, the cost of implementation in the U.S. jurisdiction over the first 5 fiscal years is $12,205,000. A gross estimate for the total cost of recovery actions to be implemented in the U.S jurisdiction is between $21,358,750 (25 years) to $32,038,125 (100 years). After the first 5 years, we will reevaluate the status of eulachon based on the information gathered over this period. It should be possible to make better informed projections about the time for and expense of recovery as more information is obtained.

Table 5-1. Recovery Actions and Cost Estimates

Recovery Action Number	Action Description	Priority Number	Estimated Fiscal Year Costs (thousands of dollars)					
			FY1	FY2	FY3	FY4	FY5	Total Costs
1								
1.1	Establish a eulachon technical recovery and implementation team to develop an overall framework for funding, implementation, and reporting of recovery actions.	3	75	75	75	25	25	275
2								
2.1	Develop outreach and education strategies regarding the ecological, economic, and cultural values of eulachon; foster stewardship of the marine ecosystem; expand funding and research partnerships; and increase involvement of existing regional and international organizations.	3	50	50	50	50	50	250
3								
3.1	Conduct annual in-river spawning stock biomass surveys in spawning areas with high-to-moderate spawning frequency to develop long-term, high resolution abundance estimations for each subpopulation of eulachon.	3	325	325	250	250	250	1400
3.2	Conduct a gap analysis to identify the data needs to develop a survey method to map eulachon spawning areas, with an emphasis on identifying core spawning areas, for each subpopulation.	3	50	50	-	-	-	100
3.2.1	Implement a high resolution mapping survey to identify core eulachon spawning areas for each subpopulation.	3	-	-	150	150	150	450
3.3	Conduct a gap analysis to identify the data needs to develop an at-sea survey method to create a reliable index of eulachon abundance in the marine environment.	3	75	75	-	-	-	150
3.3.1	Develop and implement an at-sea survey method to create a reliable index of eulachon abundance in the marine environment.	3			100	100	100	300

Recovery Action Number	Action Description	Priority Number	Estimated Fiscal Year Costs (thousands of dollars)					
			FY1	FY2	FY3	FY4	FY5	Total Costs
3.4	Conduct a gap analysis to identify the data needs to develop a genetic mixed stock baseline analysis of eulachon spawning subpopulations.	3	50	50	-	-	-	100
3.4.1	Conduct a genetic baseline analysis of eulachon spawning subpopulations to determine subpopulation-population structure of eulachon throughout the range of the DPS.	3	-	-	75	75	25	200
3.5	Conduct a gap analysis to identify the data needs to develop a genetic mixed stock baseline analysis of eulachon in the marine environment.	3	50	50	-	-	-	100
3.5.1	Conduct a genetic mixed stock baseline analysis of eulachon in the marine environment.	3	-	-	75	75	75	225
3.6	Conduct a gap analysis to identify the data needs to develop a method to correlate in-river and marine abundance estimations of eulachon.	3	75	75	-	-	-	150
3.6.1	Conduct an analysis that correlates in-river and marine abundance estimations of eulachon.	3	-	-	100	75	75	205
3.7	Conduct a gap analysis to identify the data needs to develop an ocean ecosystem indicators model of eulachon marine survival in the California Current Ecosystem.	3	75	75	-	-	-	150
3.7.1	Develop an ocean ecosystem indicators model of eulachon marine survival in the California Current Ecosystem to determine how short-term and long-term variability in ocean conditions affect eulachon abundance and productivity for each subpopulation.	3	-	-	125	125	125	375
3.8	Conduct a gap analysis to identify the data needs, e.g., age composition, length-weight relationship, intrinsic mortality rates, sex ratios, fecundity; necessary to parameterize a population viability analysis and develop abundance and productivity criteria for each subpopulation of eulachon.	3	75	75	-	-	-	150
3.8.1	Develop abundance and productivity criteria for each subpopulation of eulachon.	3	-	-	125	125	125	375

Recovery Action Number	Action Description	Priority Number	Estimated Fiscal Year Costs (thousands of dollars)					
			FY1	FY2	FY3	FY4	FY5	Total Costs
3.9	Develop a research and monitoring plan to determine the distribution (presence/absence) of eulachon in low-to-moderate frequency spawning areas by implementing an in-river sampling program, e.g., environmental DNA technology, to assess spatial distribution of eulachon in coastal watersheds of California, Oregon, and Washington.	3	60	60	60	60	60	300
4								
4.1	Conduct a gap analysis to identify the data needs to develop a plume-nearshore oceanographic model for the Columbia River subpopulation.	3	75	75	-	-	-	150
5								
5.1.1	Develop a plume-nearshore oceanographic model to assess the relationship and significance of plume and nearshore ocean environments on eulachon survival, especially larval eulachon, during the freshwater-ocean transition period.	3	-	-	125	125	125	375
5.2	Develop a research plan to understand physiological requirements for survival (i.e. pH, temperature) and potential impacts of ocean acidification on eulachon larvae.	3	75	75	-	-	-	150
5.3	Develop qualitative/quantitative recovery criteria through research and adaptive management. Based on the information gathered in conjunction with eulachon 5-year status reviews, we will evaluate and incorporate, as appropriate, the findings of on-going research on bycatch of eulachon in the ocean shrimp fishery to develop a criterion based on a range of bycatch rates consistent with the recovery requirements of the species.	3	-	-	-	-	-	50
5.4	Minimize bycatch of eulachon in the ocean shrimp fisheries by fleet-wide implementation of light emitting diode lights, rigid grate bycatch reduction devices, and additional gear-type or operational modifications, to further reduce bycatch of eulachon in the ocean shrimp trawl fisheries.	3	100	50	50	50	-	250

Recovery Action Number	Action Description	Priority Number	Estimated Fiscal Year Costs (thousands of dollars)					
			FY1	FY2	FY3	FY4	FY5	Total Costs
5.5	Develop a eulachon bycatch assessment model integrating in-river and marine abundance estimations of eulachon in order to analyze demographic information to determine changes in marine abundance and predict effects on freshwater productivity in response to bycatch in the ocean shrimp trawl fisheries.	3	-	-	150	150	150	450
5.6	Conduct a gap analysis to identify freshwater habitats with multi-year high water temperatures that fall outside of the range of water temperatures that are optimal for eulachon spawning, incubation, and larval development.	3	50	50	-	-	-	100
5.6.1	Develop site-specific recovery actions to restore or mitigate the impacts of high water temperatures that impede eulachon spawning, incubation, and larval development.	3	-	-	75	75	75	225
5.7	Conduct a gap analysis to identify the data needs to develop a research, monitoring, evaluation, and action plan to assess and reduce, where feasible, impacts of predation on eulachon in estuary and freshwater habitats.	3	100	50	-	-	-	150
5.7.1	Implement recovery actions to reduce high impact predator consumption rates of eulachon.	3	-	-	50	50	-	100
5.8	Develop a qualitative/quantitative recovery criterion through research and adaptive management. Based on the information gathered in conjunction with eulachon 5-year status reviews, we will evaluate and incorporate, as appropriate, the findings of on-going research on eulachon spawning areas affected by dams or channel-spanning water control structures to develop a criterion based on a range of recovery targets to maximize survival, growth, fitness, and development of eulachon larvae in the freshwater and plume-nearshore environment consistent with the recovery requirements of the species.	3	-	-	-	-	-	50

Recovery Action Number	Action Description	Priority Number	Estimated Fiscal Year Costs (thousands of dollars)					
			FY1	FY2	FY3	FY4	FY5	Total Costs
5.9	Develop a research and monitoring plan to monitor the effects of post-dam removal, e.g., sediment yields and water quality, in the Klamath River Basin to assess effects on the recruitment and recovery of eulachon.	3	25	25	25	25	25	125
5.10	Identify and implement actions to reduce the ecological effects caused by water management operations via dams and channel-spanning water control structures on eulachon riverine and estuarine habitats.	3	100	100	100	100	100	500
5.11	Investigate the long-term effects of the Toutle River Sediment Retention Structure on sedimentation processes in the Toutle, Cowlitz, and Columbia Rivers on eulachon habitat, as it relates to sediment and nutrient inputs into the estuary-plume environment and eulachon reproduction and survival in the freshwater environment.	3	-	75	75	75	75	300
5.12	Implement the monitoring and evaluation General Measures in the Northwest Power and Conversation Council’s Fish and Wildlife Program regarding changes in the hydrograph associated with hydropower development and operations in the Columbia River, and impacts on eulachon survival and recovery.	3	-	-	-	-	-	TBD
5.12.1	Monitor and evaluate temporal and spatial species composition, abundance, and foraging rates of juvenile eulachon predators at representative locations in the estuary and plume.	3	-	-	-	-	-	TBD
5.12.2	Monitor, and evaluate the causal mechanisms, e.g., shifts in the timing, magnitude, and duration of the hydrograph of the Columbia River, and migration/behavior characteristics affecting survival of larval eulachon during their first weeks in the plume-ocean environment.	3	-	-	-	-	-	TBD

Recovery Action Number	Action Description	Priority Number	Estimated Fiscal Year Costs (thousands of dollars)					
			FY1	FY2	FY3	FY4	FY5	Total Costs
5.12.3	Monitor and evaluate the ecological importance of the tidal freshwater, estuary, plume, and nearshore ocean environments to the viability and recovery of the Columbia River subpopulation of eulachon.	3	-	-	-	-	-	TBD
5.13	Develop qualitative/quantitative recovery criteria through research and adaptive management. Based on the information gathered in conjunction with eulachon 5-year status reviews, we will evaluate and incorporate, as appropriate, the findings of on-going research on water quality, catastrophic events, disease, competition, shoreline construction, tribal/first nations fisheries, non-indigenous species, recreational harvest, commercial harvest, scientific monitoring, and dredging to develop criteria based on a range of targets consistent with the recovery requirements of the species.	3	-	-	-	-	-	50
5.14	Water Quality: Develop a research and monitoring plan to identify contaminants of concern and sources to determine the significance of water quality degradation to eulachon and their habitats, and to inform the development of recovery actions and a recovery criterion through research and adaptive management.	3	50	50	50	50	50	250
5.15	Shoreline Construction: Develop a research and monitoring plan to assess the impact of shoreline development on eulachon and their habitats to inform the development of site-specific recovery actions.	3	50	-	-	-	-	100
5.15.1	Quantify the extent of shoreline construction in the Klamath River from river mile 10.7 to the confluence with the Pacific Ocean, and assess the severity of shoreline construction on the function of eulachon core spawning areas.	3	-	50	50	-	-	100

Recovery Action Number	Action Description	Priority Number	Estimated Fiscal Year Costs (thousands of dollars)					
			FY1	FY2	FY3	FY4	FY5	Total Costs
5.15.2	Quantify the extent of shoreline construction in the Umpqua River from river mile 39.0 to the confluence with the Pacific Ocean, and assess the severity of shoreline construction on the function of eulachon core spawning areas.	3	-	50	50	-	-	100
5.15.3	Quantify the extent of shoreline construction in the Columbia River from river mile 146.1 to the confluence with the Pacific Ocean, and assess the severity of shoreline construction on the function of eulachon core spawning areas.	3	-	50	50	-	-	100
5.15.4	Quantify the extent of shoreline construction in the Cowlitz River from river mile 80.8 the confluence with the Columbia River, and assess the severity of shoreline construction on the function of eulachon core spawning areas.	3	-	50	50	-	-	100
5.15.5	Quantify the extent of shoreline construction in the Lewis River from river mile 31.1 the confluence with the Columbia River, and assess the severity of shoreline construction on the function of eulachon core spawning areas.	3	-	50	50	-	-	100
5.15.6	Quantify the extent of shoreline construction in the East Fork of the Lewis River from river mile 9.2 to the confluence with the Lewis River, and assess the severity of shoreline construction on the function of eulachon core spawning areas.	3	-	50	50	-	-	100
5.15.7	Develop site-specific recovery actions to eliminate, restore, or mitigate the impacts of shoreline construction that impede the function of eulachon core spawning areas.	3	-	-	-	50	-	50
5.15.8	Implement site-specific recovery actions to eliminate, restore, or mitigate the impacts of shoreline construction that impede the function of eulachon core spawning areas.	3	-	-	-	-	500	500

Recovery Action Number	Action Description	Priority Number	Estimated Fiscal Year Costs (thousands of dollars)					
			FY1	FY2	FY3	FY4	FY5	Total Costs
5.16	Implement a limited-opportunity eulachon fishery to: (1) provide essential context for interpreting historical harvest data to better understand trends and variability in eulachon abundance; (2) filling critical information gaps such as the length and age structure of spawning eulachon, as well as the temporal and spatial distribution of the run; (3) supporting the cultural traditions of Northwest tribes who rely on eulachon as a seasonally important food source; and (4) providing a limited public and commercial opportunity for eulachon harvest to maintain a connection between people and the eulachon resource. This connection is important to sustaining public engagement in eulachon conservation and recovery.	3	-	-	-	-	-	-
5.16.1	Tribal/First Nations Fisheries: Minimize impacts related to a directed fishery on eulachon by developing and implementing an abundance-based fishery management plan to ensure that exploitation rates do not negatively impact subpopulation productivity.	3	100	50	50	-	-	200
5.16.2	Recreational Harvest: Minimize impacts related to a directed fishery on eulachon by developing and implementing an abundance-based fishery management plan to ensure that exploitation rates do not negatively impact subpopulation productivity.	3	100	50	50	-	-	200
5.16.3	Commercial Harvest: Minimize impacts related to a directed fishery on eulachon by developing and implementing an abundance-based fishery management plan to ensure that exploitation rates do not negatively impact subpopulation productivity.	3	100	50	50	-	-	200
5.17	Dredging:		-	-	-	-	-	-

Recovery Action Number	Action Description	Priority Number	Estimated Fiscal Year Costs (thousands of dollars)					
			FY1	FY2	FY3	FY4	FY5	Total Costs
5.17.1	Develop a research, monitoring, and adaptive management plan to quantify the impacts of dredging and disposal activities associated with the Columbia River Navigation Channel Operations and Maintenance Dredging Program, including ocean dredged material disposal sites, on habitat forming and maintenance processes and the recruitment and recovery of eulachon.	3	100	-	-	-	-	100
5.17.2	Develop a research, monitoring, and adaptive management plan to quantify the impacts of dredging and disposal activities associated with the Umpqua River Navigation Channel Operations and Maintenance Dredging Program, including ocean dredged material disposal sites, on habitat forming and maintenance processes and the recruitment and recovery of eulachon.	3	100	-	-	-	-	100
5.17.3	Implement impact minimization measures to reduce the impacts of dredging and disposal activities associated with maintenance dredging programs—as well as the issuance of permits under section 404 of the Clean Water Act, Section 10 of the Rivers and Harbors Act, and state permits—including ocean dredged material disposal sites, on habitat forming and maintenance processes and eulachon.	3	-	25	25	25	25	100
6								
6.1	Ensure appropriate and effective regulatory, response, restoration, and enforcement mechanisms are in place domestically and internationally for both planned and unplanned impacts. For planned impacts, project planning should ensure no net loss of eulachon critical habitat. Where natural or anthropogenic impacts do occur, an effective and complete response plan, including appropriate compensatory and site restoration, is executed.	3	25	25	25	25	25	125
7								

Recovery Action Number	Action Description	Priority Number	Estimated Fiscal Year Costs (thousands of dollars)					
			FY1	FY2	FY3	FY4	FY5	Total Costs
7.1	Develop an adaptive management plan to guide the recovery process by identifying key hypotheses, prioritizing research and monitoring, and evaluating alternative recovery strategies.	3	100	100	50	-	-	250
7.2	Develop a eulachon status and trend monitoring program.	3	50	50	50	-	-	150
7.3	Develop a recovery action effectiveness monitoring plan.	3	100	100	50	-	-	250
7.4	Develop an implementation and compliance monitoring plan.	3	50	50	50	-	-	150
7.5	Develop a monitoring plan to assess listing factors as they relate to eulachon recovery.	3	100	100	50	-	-	250
7.6	Conduct a retrospective analysis of land and water management impacts over time for eulachon spawning rivers where the data are available and compare to best estimates of eulachon abundance over time in the same rivers.	3	-	100	100	100	50	350

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