National Marine Fisheries Service Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat (EFH) Consultation

Consultation on the "Evaluation and Recommended Determination of a Tribal Resource Management Plan Submitted for Consideration Under the Endangered Species Act's Tribal Plan Limit [50 CFR 223.204] for the Period January 1, 2017 – December 31, 2021" affecting Salmon, Steelhead, and Eulachon in the West Coast Region

NMFS Consultation Number: WCR-2016-5800
ARN: 151422WCR2016PR00351

Action Agencies: The National Marine Fisheries Service (NMFS)
Bureau of Indian Affairs (BIA)
U.S. Environmental Protection Agency (EPA)
Northwest Fisheries Science Center (NWFSC)
U.S. Fish and Wildlife Service (USFWS)
U.S. Geological Survey (USGS)

Affected Species and Determinations:

ESA-Listed Species	Status	Is Action Likely To Adversely Affect Species?	Is Action Likely To Jeopardize the Species?	Is Action Likely To Adversely Affect Critical Habitat?	Is Action Likely To Destroy or Adversely Modify Critical Habitat?
Puget Sound (PS) Chinook salmon (*O. tshawytscha*)	Threatened	Yes	No	No	No
PS steelhead (*O. mykiss*)	Threatened	Yes	No	No	No
Hood Canal summer-run (HCS) chum salmon (*O. keta*)	Threatened	Yes	No	No	No
Southern (S) eulachon (*Thaleichthys pacificus*)	Threatened	Yes	No	No	No
Southern Resident (SR) killer whales (*Orcinus orca*)	Threatened	No	No	No	No

Fishery Management Plan That Describes EFH in the Project Area	Does Action Have an Adverse Effect on EFH?	Are EFH Conservation Recommendations Provided?
Pacific Coast Salmon	No	No

Consultation Conducted By: National Marine Fisheries Service, West Coast Region

Issued By:

Barry A. Thom
Regional Administrator

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1. INTRODUCTION

This Introduction section provides information relevant to the other sections of this document and is incorporated by reference into Sections 2 and 3 below.

1.1 Background

The National Marine Fisheries Service (NMFS) prepared the biological opinion (opinion) and incidental take statement (ITS) portions of this document in accordance with section 7(b) of the Endangered Species Act (ESA) of 1973 (16 USC 1531 et seq.), and implementing regulations at 50 CFR 402. It constitutes NMFS' review of the "Evaluation and Recommended Determination of a Tribal Resource Management Plan Submitted for Consideration Under the Endangered Species Act's Tribal Plan Limit [50 CFR 223.204] for the Period January 1, 2017 – December 31, 2021" and is based on information provided in the Northwest Indian Fisheries Commission (NWIFC) Tribal Salmon Research Plan (Tribal Plan) (2017-2021), published and unpublished scientific information on the biology and ecology of listed salmonids and eulachon in the action areas, and other sources of information.

We also completed an essential fish habitat (EFH) consultation on the proposed action, in accordance with section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801 et seq.) and implementing regulations at 50 CFR 600.

We completed pre-dissemination review of this document using standards for utility, integrity, and objectivity in compliance with applicable guidelines issued under the Data Quality Act (DQA) (section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001, Public Law 106-554). The document will be available through NMFS' Public Consultation Tracking System [https://pcts.nmfs.noaa.gov/pcts-web/homepage.pcts]. A complete record of this consultation is on file at Portland, OR.

1.2 Consultation History

The Northwest Indian Fisheries Commission (NWIFC) submitted a Tribal Plan (2017-2021) on behalf of eighteen tribes and tribal organizations in the Puget Sound for review under the Tribal Plan Limit. The Tribes and tribal organizations covered by the Tribal Plan (2017-2021) are: Nooksack Tribe, Lummi Indian Nation, Swinomish Tribe, Upper Skagit Tribe, Sauk-Suiattle Tribe, Skagit River System Cooperative, Tulalip Tribes, Stillaguamish Tribe, Puyallup Indian Tribe, Muckleshoot Indian Tribe, Squaxin Island Tribe, Nisqually Tribe, Port Gamble S'KlallamTribe, Skokomish Tribe, Lower Elwha Klallam Tribe, Jamestown S'Klallam Tribe, Suquamish Tribe, and Point No Point Treaty Council. The Tribal Plan (2017-2021) identifies a variety of research and assessment activities intended to provide the technical basis for harvest and hatcheries management, and conserving and restoring salmon stocks and their habitat. The majority of the current research is motivated by a need to improve our understanding of salmonid freshwater and marine survival. Many of the activities are also intended to provide information to help plan, implement, and monitor habitat protection and restoration efforts. The following provides a brief summary of the Tribal Plan (2017-2021) and sets the context for NMFS' review.

The West Coast Region's Protected Resources Division (PRD) received a draft Tribal Plan (2017-2021) from the NWIFC on July 28, 2016. Comments and recommended edits were sent back to the NWIFC on August 10, 2016. Between August 30 and September 2, 37 project applications were submitted by the NWIFC through the NOAA APPS website to be included in the Tribal Plan (2017-2021). On September 27, 2016, a second draft of the Tribal Plan (2017-2021) was received. On October 5, 2016, additional comments and recommended edits on the Tribal Plan (2017-2021) were sent back to the NWIFC. Additionally, the 37 previously submitted applications and two additional applications were analyzed for completeness and scientific integrity. Comments and recommended edits were also sent to NWIFC on October 5, 2016. After two more drafts (October 18th and October 26th) were received and commented on, the final draft of the Tribal Plan (2017-2021) with the 39 project applications was received on October 27, 2016.

The affected species are PS Chinook salmon, HCS chum salmon, PS steelhead, and S eulachon. The proposed actions also have the potential to affect SR killer whales and their critical habitat by diminishing the whales' prey base. We concluded that the proposed activities are not likely to adversely affect SR killer whales or their critical habitat and the full analysis is found in the "Not Likely to Adversely Affect" Determination section (2.11). A complete record of this consultation is maintained by the PRD and kept on file in Portland, Oregon.

1.3 Proposed Action

"Action" means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies (50 CFR 402.02). "Interrelated actions" are those that are part of a larger action and depend on the larger action for their justification. "Interdependent actions" are those that have no independent utility apart from the action under consideration (50 CFR 402.02). In this instance, we found no actions that are interrelated to or interdependent with the proposed research actions. Thus, the proposed actions here are the activities proposed by the NWFSC, BIA, EPA, USFWS, USGS, and NMFS' approval of the Tribal Plan (2017-2021).

We are proposing to approve the Tribal Plan (2017-2021). NMFS has reviewed the Tribal Plan (2017-2021) and determined that it meets the requirements of the Tribal Plan Limit. The Tribal Plan (2017-2021) is consistent with the 4(d) limit for Tribal plans (50 CFR 223.204) and adequately minimizes the risk to PS Chinook salmon, HCS chum salmon, PS steelhead, and S eulachon. Our review of the Tribal Plan (2017-2021) is set out in the October 27, 2016 document entitled "Evaluation and Recommended Determination of a Tribal Resource Management Plan Submitted for Consideration Under the Endangered Species Act's Tribal Plan Limit [50 CFR 223.204] for the Period January 1, 2017 – December 31, 2021" (Evaluation/Pending Determination Document). The 4(d) limit would apply to the Tribal Plan (2017-2021) for five years (through December 31, 2021). The Tribal Plan (2017-2021) contains 39 separate scientific research and monitoring projects.

The research and monitoring activities entail: (1) observation activities (such as snorkeling, spawning surveys, and habitat surveys) that may harass listed fish; (2) capturing fish with traps, nets, hook and line, and backpack electrofishing equipment; (3) anesthetizing and handling fish to obtain biometric samples, mark or tag fish, and document existing marks and tags; (4) non-lethal sampling for stomach contents and tissue samples; and (5) lethal tissue sampling. During the five-year duration of the Tribal Plan (2017-2021), the Tribes may find it necessary to modify, add, or eliminate studies and, in such cases, the tribes or the NWIFC tribal coordinator would do so through the NOAA APPS website (https://apps.nmfs.noaa.gov/index.cfm). NMFS will evaluate those changes and determine if they meet the requirements of the Tribal Plan Limit. Further, NMFS will require annual reports on each project covered by the Tribal Plan (2017-2021) by January 31st of the following year. For each calendar year, each project will also need to reapply for Tribal Plan (2017-2021) inclusion through the NOAA APPS website.

The activities identified in the Tribal Plan (2017-2021) would be funded in part by the Federal agencies listed above (and NMFS would authorize them). These agencies are responsible for complying with section 7 of the ESA. Because this consultation examines the actions they propose to fund, it also fulfills their section 7 consultation obligations with respect to the funding, since the funding of the action would not raise any potential for effects to ESA-listed salmonids and eulachon beyond those already raised in consideration of the underlying actions themselves.

The specific research projects and related take estimates are described in detail in the Tribal Plan (2017-2021). Additionally, NMFS' Evaluation/Pending Determination Document contains a summary of the proposed activities, gives details about the types and levels of anticipated take, and analyzes the research activities' effects on the biological requirements of the species.

"Take" is defined in section 3 of the ESA; it means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect [a listed species] or to attempt to engage in any such conduct. This opinion constitutes formal consultation and an analysis of effects solely for the evolutionarily significant units (ESUs) and distinct population segments (DPSs) that are the subject of this opinion.[1]

The proposed Federal action regarding this authorization is for NMFS to approve the Tribal Plan (2017-2021). As the action agency, NMFS is responsible for complying with section 7 of the ESA, which requires Federal agencies to ensure any actions they fund, permit, or carry out are not likely to jeopardize listed species' continued existence nor destroy or adversely modify their critical habitat. This consultation examines the effects of the proposed research on PS Chinook salmon, HCS chum salmon, PS steelhead, and S eulachon. Therefore, this consultation fulfills NMFS's section 7 consultation obligations for those species.

[1] An ESU of Pacific salmon (Waples 1991) and a DPS of steelhead (71 FR 834) are considered to be "species" as the word is defined in section 3 of the ESA. In addition, it should be noted that the terms "artificially propagated" and "hatchery" are used interchangeably in the Opinion, as are the terms "naturally propagated" and "natural."

2. ENDANGERED SPECIES ACT: BIOLOGICAL OPINION AND INCIDENTAL TAKE STATEMENT

The ESA establishes a national program for conserving threatened and endangered species of fish, wildlife, plants, and the habitat upon which they depend. As required by section 7(a)(2) of the ESA, each Federal agency must ensure that its actions are not likely to jeopardize the continued existence of endangered or threatened species, or adversely modify or destroy their designated critical habitat. Per the requirements of the ESA, Federal action agencies consult with NMFS and section 7(b)(3) requires that, at the conclusion of consultation, NMFS provides an opinion stating how the agency's actions would affect listed species and their critical habitats. If incidental take is reasonably certain to occur, section 7(b)(4) requires NMFS to provide an incidental take statement (ITS) that specifies the impact of any incidental taking and includes non-discretionary reasonable and prudent measures (RPMs) and terms and conditions to minimize such impacts.

The NMFS determined that the proposed action is not likely to adversely affect PS Chinook salmon, HCS chum salmon, PS steelhead, and S eulachon or their critical habitat. Our concurrence is documented in the "Not Likely to Adversely Affect" Determinations section (2.11).

2.1 Analytical Approach

This biological opinion includes both a jeopardy analysis and/or an adverse modification analysis. The jeopardy analysis relies upon the regulatory definition of "to jeopardize the continued existence of" a listed species, which is "to engage in an action that would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species" (50 CFR 402.02). Therefore, the jeopardy analysis considers both survival and recovery of the species.

This biological opinion relies on the definition of "destruction or adverse modification," which "means a direct or indirect alteration that appreciably diminishes the value of critical habitat for the conservation of a listed species. Such alterations may include, but are not limited to, those that alter the physical or biological features essential to the conservation of a species or that preclude or significantly delay development of such features" (81 FR 7214).

The designation(s) of critical habitat for (species) use(s) the term primary constituent element (PCE) or essential features. The new critical habitat regulations (81 FR 7414) replace this term with physical or biological features (PBFs). The shift in terminology does not change the approach used in conducting a ''destruction or adverse modification'' analysis, which is the same regardless of whether the original designation identified PCEs, PBFs, or essential features. In this biological opinion, we use the term PBF to mean PCE or essential feature, as appropriate for the specific critical habitat.

We use the following approach to determine whether a proposed action is likely to jeopardize listed species or destroy or adversely modify critical habitat:

- *Identify the rangewide status of the species and critical habitat likely to be adversely affected by the proposed action.* This section describes the current status of each listed species and its critical habitat relative to the conditions needed for recovery. For listed salmon and steelhead, NMFS has developed specific guidance for analyzing the status of the listed species' component populations in a "viable salmonid populations" paper (VSP; McElhany et al. 2000). The VSP approach considers the abundance, productivity, spatial structure, and diversity of each population as part of the overall review of a species' status. For listed salmon and steelhead, the VSP criteria therefore encompass the species' "reproduction, numbers, or distribution" (50 CFR 402.02). In describing the range-wide status of listed species, we rely on viability assessments and criteria in technical recovery team documents and recovery plans, where available, that describe how VSP criteria are applied to specific populations, major population groups, and species. We determine the rangewide status of critical habitat by examining the condition of its PBFs - which were identified when the critical habitat was designated. Species and critical habitat status are discussed in Section 2.2.

- *Describe the environmental baseline in the action area*. The environmental baseline includes the past and present impacts of Federal, state, or private actions and other human activities *in the action area*. It includes the anticipated impacts of proposed Federal projects that have already undergone formal or early section 7 consultation and the impacts of state or private actions that are contemporaneous with the consultation in process. The environmental baseline is discussed in Section 2.4 of this opinion.
- *Analyze the effects of the proposed action on both species and their habitat using an "exposure-response-risk" approach.* In this step, NMFS considers how the proposed action would affect the species' reproduction, numbers, and distribution or, in the case of salmon and steelhead, their VSP characteristics. NMFS also evaluates the proposed action's effects on critical habitat features. The effects of the action are described in Section 2.5 of this opinion.
- *Describe any cumulative effect in the action area*. Cumulative effects, as defined in NMFS' implementing regulations (50 CFR 402.02), are the effects of future state or private activities, not involving Federal activities, that are reasonably certain to occur within the action area. Future Federal actions that are unrelated to the proposed action are not considered because they require separate section 7 consultation. Cumulative effects are considered in Section 2.6 of this opinion.
- *Integrate and synthesize the above factors by: (1) Reviewing the status of the species and critical habitat; and (2) adding the effects of the action, the environmental baseline, and cumulative effects to assess the risk that the proposed action poses to species and critical habitat.* In this step, NMFS adds the effects of the action (Section 2.5) to the environmental baseline (Section 2.4) and the cumulative effects (Section 2.6) to assess whether the action could reasonably be expected to: (1) appreciably reduce the likelihood of both survival and recovery of the species in the wild by reducing its numbers, reproduction, or distribution; or (2) reduce the value of designated or proposed critical habitat for the conservation of the species. These assessments are made in full consideration of the status of the species and critical habitat (Section 2.2). Integration and synthesis occurs in Section 2.7 of this opinion.
- *Reach a conclusion about whether species are jeopardized or critical habitat is adversely modified*. Conclusions regarding jeopardy and the destruction or adverse modification of critical habitat are presented in Section 2.8. These conclusions flow from the logic and rationale presented in the Integration and Synthesis section (2.7).
- *If necessary, suggest a reasonable and prudent alternative to the proposed action.*

2.2 Rangewide Status of the Species and Critical Habitat

This opinion examines the status of each species that would be adversely affected by the proposed action. The status is determined by the level of extinction risk that the listed species face, based on parameters considered in documents such as recovery plans, status reviews, and listing decisions. This informs the description of the species' likelihood of both survival and recovery. The species status section also helps to inform the description of the species' current "reproduction, numbers, or distribution" as described in 50 CFR 402.02. The opinion also examines the condition of critical habitat throughout the designated area, evaluates the conservation value of the various watersheds and coastal and marine environments that make up the designated area, and discusses the current function of the essential PBFs that help to form that conservation value.

The ESA defines species to include "any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." NMFS adopted a policy for identifying salmon DPS in 1991 (56 FR 58612). It states that a population or group of populations is considered an ESU if it is "substantially reproductively isolated from conspecific populations," and if it represents "an important component of the evolutionary legacy of the species." The policy equates an ESU with a DPS. Hence, the Chinook, chum, and sockeye salmon listing units in this biological opinion constitute ESUs of the species *O. tshawytscha, O. keta,* and *O. nerka,* and the listed steelhead units in this biological opinion constitute DPSs of the species *O. mykiss.* The ESUs and DPSs of salmon and steelhead include natural-origin populations and hatchery populations, as described below. Finally, all eulachon listing units in this biological opinion constitute DPSs.

Section 4(d) protective regulations prohibit the take of naturally spawned salmonids and of listed hatchery fish with an intact adipose fin, but do not prohibit take of listed hatchery salmonids that have their adipose fins removed prior to release into the wild (70 FR 37160 and 71 FR 834). As a result, researchers do not require a permit to take hatchery fish that have had their adipose fin removed. Nevertheless, this document evaluates impacts on both natural and hatchery fish to allow a full examination of the effects of the action on the species as a whole. Furthermore, we have promulgated no protective regulations for S eulachon under section 4(d); thus, we can issue no permit to take them. Nonetheless, because they are a listed species with proposed or designated critical habitat, we must perform the jeopardy and adverse modification analyses laid out in the previous section.

2.2.1 Climate Change

The Intergovernmental Panel on Climate Change (IPCC) and U.S. Global Change Research Program recently published updated assessments of anthropogenic influence on climate, as well as projections of climate change over the next century (IPCC 2013; Melillo et al. 2014). Reports from both groups document ever-increasing evidence that recent warming bears the signature of rising concentrations of greenhouse gas emissions. There is moderate certainty that the 30-year average temperature in the Northern Hemisphere is now higher than it has been over the past 1,400 years. In addition, there is high certainty that ocean acidity has increased with a drop in pH of 0.1 (NWFSC 2015).

Projected Climate Change

Trends in warming and ocean acidification are highly likely to continue during the next century (IPCC 2013). In winter across the west, the highest elevations (e.g. in the Rocky Mountains) will shift from consistent longer (>5 months) snow-dominated winters to a shorter period (3-4 months) of reliable snowfall (Klos et al. 2014); lower, more coastal or more southerly watersheds will shift from consistent snowfall over winter to alternating periods of snow and rain ("transitional"); lower elevations or warmer watersheds will lose snowfall completely, and rain-dominated watersheds will experience more intense precipitation events and possible shifts in the timing of the most intense rainfall (e.g., Salathe et al. 2014). Warmer summer air temperatures will increase both evaporation and direct radiative heating. When combined with reduced winter water storage, warmer summer air temperatures will lead to lower minimum flows in many watersheds. Higher summer air temperatures will depress minimum flows and raise maximum stream temperatures even if annual precipitation levels do not change (e.g., Sawaske and Freyberg 2014) (NWFSC 2015).

Higher sea surface temperatures and increased ocean acidity are predicted for marine environments in general (IPCC 2013). However, regional marine impacts will vary, especially in relation to productivity. The California Current is strongly influenced by seasonal upwelling of cool, deep, water that is high in nutrients and low in dissolved oxygen and pH. An analysis of 21 global climate models found that most predicted a slight decrease in upwelling in the California Current, although there is a latitudinal cline in the strength of this effect, with less impact toward the north (Rykaczewski et al. 2015; NWFSC 2015).

Freshwater environments

During 2014 and 2015, sea surface temperatures across the Northeast Pacific Ocean were anomalously warm which has contributed to above average terrestrial temperatures in the PNW (Bond et al. 2015). Mean air temperatures for Washington, Oregon, and Idaho were the warmest on record for the 24-month period ending in August 2015 (from a 120-year record starting in 1895). In contrast, precipitation in the PNW was slightly above average during 2014. Since January 2015, however, precipitation has been below average and the 8-month period from January to August was the 11th driest on record. The exceptionally warm air during the winter of 2014/2015 and below average precipitation from January-April resulted in anomalously low snow pack conditions in the Olympic and Cascade Mountains, with most areas having less than 25 percent of average snow pack in April 2015 (compared to the 1981-2010 record). The combined effects of low flows and high air temperatures resulted in higher than normal stream temperatures and reports of fish kills of salmon and sturgeon in the Willamette and mainstem Columbia Rivers in late June and July 2015 (NWFSC 2015).

Impacts on Salmon

Studies examining the effects of long-term climate change to salmon populations have identified a number of common mechanisms by which climate variation is likely to influence salmon sustainability. These include direct effects of temperature such as mortality from heat stress, changes in growth and development rates, and disease resistance. Changes in the flow regime (especially flooding and low flow events) also affect survival and behavior. Expected behavioral responses include shifts in seasonal timing of important life-history events, such as the adult migration, spawn timing, fry emergence timing, and juvenile migration (NWFSC 2015).

Climate impacts in one life stage generally affect body size or timing in the next life stage and can be negative across multiple life stages (Healey 2011; Wade et al. 2013; Wainwright and Weitkamp 2013). Changes in winter precipitation will likely affect incubation and/or rearing stages of most populations. Changes in the intensity of cool season precipitation could influence migration cues for fall and spring adult migrants, such as coho salmon and steelhead. Egg survival rates may suffer from more intense flooding that scours or buries redds. Changes in hydrological regime, such as a shift from mostly snow to more rain, could drive changes in life history, potentially threatening diversity within an ESU (Beechie et al. 2006). Changes in summer temperature and flow will affect both juvenile and adult stages in some populations, especially those with yearling life histories and summer migration patterns (Quinn 2005; Crozier and Zabel 2006; Crozier et al. 2010). Adults that migrate or hold during peak summer temperatures can experience very high mortality in unusually warm years. For example, in 2015 only 4 percent of adult Redfish Lake sockeye survived the migration from Bonneville to Lower Granite Dam after confronting temperatures over 22°C in the lower Columbia River. Marine migration patterns could also be affected by climate induced contraction of thermally suitable habitat. Abdul-Aziz et al. (2011) modeled changes in summer thermal ranges in the open ocean for Pacific salmon under multiple IPCC warming scenarios. For chum salmon, pink salmon, coho salmon, sockeye salmon, and steelhead, they predicted contractions in suitable marine habitat of 30-50 percent by the 2080s, with an even larger contraction (86-88 percent) for Chinook salmon under the medium and high emissions scenarios (A1B and A2) (NWFSC 2015).

2.2.2 Status of the Species

For Pacific salmon, steelhead, and eulachon, NMFS commonly uses four parameters to assess the viability of the populations that, together, constitute the species: spatial structure, diversity, abundance, and productivity (McElhany et al. 2000). These “viable salmonid population” (VSP) criteria therefore encompass the species’ “reproduction, numbers, or distribution” as described in 50 CFR 402.02. (Though these criteria were not expressly established for non-salmonids during the listing process for those animals, they are nonetheless critical to understanding the species’ statuses and we therefore use them when discussing any of the species covered by this opinion.) When these parameters are collectively at appropriate levels, they maintain a population’s capacity to adapt to various environmental conditions and allow it to sustain itself in the natural environment. These attributes are influenced by survival, behavior, and experiences throughout a species’ entire life cycle, and these characteristics, in turn, are influenced by habitat and other environmental conditions.

“Spatial structure” refers both to the spatial distributions of individuals in the population and the processes that generate that distribution. A population’s spatial structure depends fundamentally on habitat quality and spatial configuration and the dynamics and dispersal characteristics of individuals in the population.

“Diversity” refers to the distribution of traits within and among populations. These range in scale from DNA sequence variation at single genes to complex life-history traits (McElhany et al. 2000).

"Abundance" generally refers to the number of naturally-produced adults (i.e., the progeny of naturally-spawning parents) in the natural environment (e.g., on spawning grounds).

"Productivity," as applied to viability factors, refers to the entire life cycle; i.e., the number of naturally-spawning adults produced per parent. When progeny replace or exceed the number of parents, a population is stable or increasing. When progeny fail to replace the number of parents, the population is declining. McElhany et al. (2000) use the terms "population growth rate" and "productivity" interchangeably when referring to production over the entire life cycle. They also refer to "trend in abundance," which is the manifestation of long-term population growth rate.

For species with multiple populations, once the biological status of a species' populations has been determined, NMFS assesses the status of the entire species using criteria for groups of populations, as described in recovery plans and guidance documents from technical recovery teams. Considerations for species viability include having multiple populations that are viable, ensuring that populations with unique life histories and phenotypes are viable, and that some viable populations are both widespread to avoid concurrent extinctions from mass catastrophes and spatially close to allow functioning as metapopulations (McElhany et al. 2000).

A species' status is a function of how well its biological requirements are being met; the greater degree to which its requirements are fulfilled, the better the species' status. Information on the status and distribution of all the species considered here can be found in the following discussions and documents:

- Status review of West Coast steelhead from Washington, Idaho, Oregon, and California (Busby et al. 1996)
- Status review of chum salmon from Washington, Idaho, Oregon, and California (Johnson et al. 1997)
- Status review of Chinook salmon from Washington, Idaho, Oregon, and California (Myers et al. 1998)
- Updated status of Federally listed ESUs of West Coast salmon and steelhead (Good et al. 2005)
- Status review of Puget Sound steelhead (*Oncorhynchus mykiss*) (Hard et al. 2007)
- Status review of eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California (Gustafson et al. 2010)
- Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest (Ford 2011)
- Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest (NWFSC 2015)
- Status review update of eulachon (*Thaleichthys pacificus*) listed under the Endangered Species Act: Southern Distinct Population Segment (Gustafson et al. 2016)

2.2.2.1 Puget Sound Chinook Salmon

Description and Geographic Range

On June 28, 2005, NMFS listed PS Chinook salmon—both natural-origin and some artificially-propagated fish—as a threatened species (70 FR 37160). The species includes all naturally spawned

Chinook salmon populations from rivers and streams flowing into Puget Sound including the Straits of Juan De Fuca from the Elwha River, eastward. This includes rivers and streams flowing into Hood Canal, South Sound, North Sound, and the Strait of Georgia in Washington. The following 26 artificial propagation programs are part of the species and are also listed (79 FR 20802; Table 1): Kendall Creek Hatchery Program; Marblemount Hatchery Program (spring subyearlings and summer-run), Harvey Creek Hatchery Program (summer-run and fall-run), Whitehorse Springs Pond Program, Wallace River Hatchery Program (yearlings and subyearlings), Tulalip Bay Program, Issaquah Hatchery Program, Soos Creek Hatchery Program, Icy Creek Hatchery Program, Keta Creek Hatchery Program, White River Hatchery Program, White Acclimation Pond Program, Hupp Springs Hatchery Program, Voights Creek Hatchery Program, Diru Creek Program, Clear Creek Program, Kalama Creek Program, George Adams Hatchery Program, Rick's Pond Hatchery Program, Hamma Hamma Hatchery Program, Dungeness/Hurd Creek Hatchery Program, Elwha Channel Hatchery Program, and the Skookum Creek Hatchery Spring-run Program. Under the final listing in 2005, the section 4(d) protections (and limits on them) apply to natural-origin and hatchery PS Chinook salmon with an intact adipose fin, but not to listed hatchery fish that have had their adipose fin removed.

Table 1. Expected 2017 Puget Sound Chinook salmon hatchery releases (WDFW 2016).

Subbasin	Artificial propagation program	Brood year	Run Timing	Clipped Adipose Fin	Intact Adipose Fin
Deschutes	Tumwater Falls	2016	Fall	3,800,000	-
Dungeness-Elwha	Dungeness	2016	Spring	-	50,000
	Elwha	2015	Fall	-	200,000
		2016	Fall	250,000	2,250,000
	Gray Wolf River	2016	Spring	-	50,000
	Hurd Creek	2015	Spring	-	50,000
	Upper Dungeness Pond	2016	Spring	-	50,000
Duwamish	Icy Creek	2015	Fall	300,000	-
	Soos Creek	2016	Fall	3,000,000	200,000
Hood Canal	Hood Canal Schools	2016	Fall	-	500
	Hoodsport	2015	Fall	120,000	-
		2016	Fall	2,800,000	-
Kitsap	Bernie Gobin	2015	Spring	40,000	-
		2016	Fall	-	200,000
			Summer	2,300,000	100,000
	Chambers Creek	2016	Fall	400,000	-
	Garrison	2016	Fall	450,000	-
	George Adams	2016	Fall	3,575,000	225,000
	Gorst Creek	2016	Fall	1,530,000	-
	Grovers Creek	2016	Fall	450,000	-
	Hupp Springs	2016	Spring	-	400,000
	Lummi Sea Ponds	2016	Fall	500,000	-
	Minter Creek	2016	Fall	1,250,000	-
Lake Washington	Friends of ISH	2016	Fall	-	1,425
	Issaquah	2016	Fall	2,000,000	-
Nisqually	Clear Creek	2016	Fall	3,300,000	200,000
	Kalama Creek	2016	Fall	600,000	-
Nooksack	Kendall Creek	2016	Spring	800,000	-

Subbasin	Artificial propagation program	Brood year	Run Timing	Clipped Adipose Fin	Intact Adipose Fin
	Skookum Creek	2016	Spring	-	1,000,000
Puyallup	Clarks Creek	2016	Fall	400,000	-
	Voights Creek	2016	Fall	1,600,000	-
	White River	2015	Spring	-	55,000
		2016	Spring	-	340,000
San Juan Islands	Friday Harbor ES	2016	Fall	-	225
	Glenwood Springs	2016	Fall	725,000	-
Skykomish	Wallace River	2015	Summer	500,000	-
		2016	Summer	800,000	200,000
Stillaguamish	Brenner	2016	Fall	-	45,000
	Whitehorse Pond	2016	Summer	220,000	-
Strait of Georgia	Samish	2016	Fall	3,800,000	200,000
Upper Skagit	Marblemount	2016	Spring	387,500	200,000
			Summer	200,000	-
Total Annual Release Number				**36,097,500**	**6,017,150**

Adult PS Chinook salmon typically return to freshwater from March through August and spawn from July through December. Early-timed Chinook salmon tend to enter freshwater as immature fish in the spring, migrate far upriver, and finally spawn in the late summer and early autumn. Late-timed Chinook salmon enter freshwater in the fall at an advanced stage of maturity, move rapidly to their spawning areas on the mainstem or lower tributaries of the rivers, and spawn within a few days or weeks of freshwater entry. Most PS Chinook salmon tend to mature at ages three and four, but the range is from two to six years.

Spawning females deposit between 2,000 and 5,500 eggs in a shallow nest, or redd, that they dig with their tail. Depending on water temperatures, the eggs hatch between 32 and 159 days after deposition. Alevins, newly hatched salmon with attached yolk sacs, remain in the gravel for another 14 to 21 days before emerging as fry. Juvenile Chinook salmon may migrate downstream to saltwater within 1 to 10 days and spend many months rearing in the estuary, or they may reside in freshwater for a full year, spending relatively little time in the estuary area, before migrating to sea. Most PS Chinook salmon leave the freshwater environment during their first year. Chinook salmon make extensive use of the protected estuary and nearshore habitats before migrating to the ocean.

Although some PS Chinook salmon spend their entire life in the Puget Sound, most migrate to the ocean and north along the Canadian coast. Return migration routes vary from year to year, with some fish migrating along the west coast of Vancouver Island and others through Johnstone Strait and the Strait of Georgia.

Spatial Structure and Diversity

The PS Chinook salmon ESU contains 31 "historically independent populations," of which nine are believed to be extinct (Ruckelshaus et al. 2006). The extinct populations were mostly composed of early-returning fish from the mid- and southern parts of the Puget Sound and in the Hood Canal/Strait of Juan de Fuca (Table 2).

Table 2. Historical populations of Chinook salmon in the Puget Sound (Ruckelshaus et al. 2006; NWFSC 2015).

Population	MPG	Status	Run Timing
NF Nooksack River	Strait of Georgia	Extant	Early
SF Nooksack River	Strait of Georgia	Extant	Early
Nooksack River late	-	*Extinct*	Late
Lower Skagit River	Whidbey Basin	Extant	Late
Upper Skagit River	Whidbey Basin	Extant	Late
Cascade River	Whidbey Basin	Extant	Early
Lower Sauk River	Whidbey Basin	Extant	Late
Upper Sauk River	Whidbey Basin	Extant	Early
Suiattle River	Whidbey Basin	Extant	Early
NF Stillaguamish River	Whidbey Basin	Extant	Late
SF Stillaguamish River	Whidbey Basin	Extant	Late
Stillaguamish River early	-	*Extinct*	Early
Skykomish River	Whidbey Basin	Extant	Late
Snoqualmie River	Whidbey Basin	Extant	Late
Snohomish River early	-	*Extinct*	Early
Sammamish River	Central and South Puget Sound	Extant	Late
Cedar River	Central and South Puget Sound	Extant	Late
Duwamish/Green River	Central and South Puget Sound	Extant	Late
Duwamish/Green River early	-	*Extinct*	Early
White River	Central and South Puget Sound	Extant	Early
Puyallup River	Central and South Puget Sound	Extant	Late
Puyallup River early	-	*Extinct*	Early
Nisqually	Central and South Puget Sound	Extant	Late
Nisqually River early	-	*Extinct*	Early
Skokomish River	Hood Canal	Extant	Late
Skokomish River early	Hood Canal	*Extinct*	Early
Mid-Hood Canal	Hood Canal	Extant	Late
Mid-Hood Canal early	Hood Canal	*Extinct*	Early
Dungeness River	Strait of Juan de Fuca	Extant	Late
Elwha River	Strait of Juan de Fuca	Extant	Late
Elwha River early	Strait of Juan de Fuca	*Extinct*	Early

Losing these nine historical populations reduced the species' spatial structure. In all cases, the extinct populations overlapped with extant populations, leaving the impression that the spatial structure had not changed. However, the two Chinook salmon run-types tend to spawn in different parts of the watershed (Myers et al. 1998). Early-timed Chinook salmon tend to migrate farther upriver and farther up into tributary streams, whereas, late-timed fish spawn in the mainstem or lower tributaries of the river. Therefore, losing one run timing could cause an underuse of available spawning habitat and reduce population distribution and spatial structure.

Chinook salmon population diversity can range in scale from genetic differences within and among populations to complex life-history traits. The loss of early-run populations is a leading factor affecting ESU diversity. As stated above, eight of the nine extinct populations were composed of early-returning fish (Table 2). Run-timing is a life-history trait considered to be an adaptation to variable environmental conditions. The early-run populations were an evolutionary legacy of the ESU, and the loss of these populations reduces the overall ESU's diversity.

Another major factor affecting PS Chinook salmon diversity is artificial propagation. In 1993, WDF et al. classified nearly half of the ESU populations as sustained, at least in part, by artificial propagation. Since the 1950s, hatcheries have released nearly two billion fish into Puget Sound tributaries. Most of these fish came from fall-run (late returning) adults from the Green River stock or stocks derived from Green River stock resulting in some PS Chinook salmon populations containing substantial hatchery-origin spawner numbers (first generation hatchery fish). By releasing so many hatchery-origin spawners, the use of a single stock could reduce the naturally spawning populations' genetic diversity and fitness. In 1991, a stock transfer policy (WDF 1991) was developed and implemented to foster local brood stocks by significantly reducing egg and juvenile transfers between watersheds. This policy mandates hatchery programs to use local brood stocks in rivers with extant indigenous stocks.

According to recent production estimates, Puget Sound hatcheries release over 42 million juvenile Chinook salmon each year (Table 1). Most hatchery fish production is for commercial harvest and sport fishing. However, tens of thousands of these fish escape harvest each year and return to spawn in Puget Sound tributaries. From 1990 through 2014, there has been a declining trend in the proportion of natural-origin spawners across the whole ESU (NWFSC 2015). For 2010-2014, more than 70% of the spawners are hatchery fish in eight of the 22 populations (Table 3). For the five MPGs, only the Whidbey Basin MPG had over half of their spawners be of natural-origin in the majority of the populations (NWFSC 2015).

Table 3. Five-year means of fraction wild for PS Chinook salmon by population (NWFSC 2015).

Population	Five-year means for fraction wild				
	1990-1994	1995-1999	2000-2004	2005-2009	2010-2014
Strait of Georgia MPG					
NF Nooksack River	0.53	0.29	0.07	0.18	0.16
SF Nooksack River	0.76	0.63	0.62	0.63	0.28
Strait of Juan de Fuca MPG					
Elwha River	0.65	0.41	0.54	0.34	0.15
Dungeness River	0.17	0.17	0.16	0.33	0.26
Hood Canal MPG					
Skokomish River	0.52	0.40	0.46	0.45	0.17
Mid-Hood Canal	0.79	0.82	0.79	0.61	0.29
Whidbey Basin MPG					
Skykomish River	0.73	0.46	0.55	0.72	0.73
Snoqualmie River	0.85	0.67	0.87	0.68	0.78
NF Stillaguamish River	0.75	0.65	0.80	0.57	0.59
SF Stillaguamish River	1.00	1.00	1.00	0.99	0.83
Upper Skagit River	0.96	0.98	0.96	0.94	0.96
Lower Skagit River	0.96	0.96	0.97	0.96	0.96
Upper Sauk River	0.96	0.96	0.96	0.96	0.96
Lower Sauk River	0.96	0.96	0.95	0.95	0.96
Suiattle River	0.98	0.98	0.98	0.97	0.98
Cascade River	0.98	0.98	0.98	0.98	0.98
Central / South Sound MPG					
Sammamish River	0.24	0.20	0.40	0.23	0.11
Cedar River	0.74	0.70	0.63	0.82	0.82
Green River	0.44	0.32	0.63	0.44	0.43
Puyallup River	0.84	0.70	0.70	0.40	0.57
White River	0.88	0.93	0.95	0.79	0.56
Nisqually River	0.78	0.80	0.68	0.31	0.30

Abundance and Productivity

Bledsoe et al. (1989) proposed an historical abundance of 690,000 PS Chinook salmon. However, this estimate is based upon the 1908 Puget Sound cannery pack, so it should be viewed cautiously since it probably included fish that originated in adjacent areas. Additionally, exploitation rate estimates used in run-size expansions are not based on precise data.

NMFS concluded in 1998 (Myers et al. 1998), 2005 (Good et al. 2005), 2011 (Ford 2011), and 2015 (NWFSC 2015) that the Puget Sound ESU was likely to become endangered in the foreseeable future. In the first status review, the Puget Sound Biological Review Team (BRT) estimated the total PS Chinook salmon run size[2] in the early 1990s to be approximately 240,000 Chinook salmon, with the vast majority as hatchery-origin. Based on current estimates, 67,000 of those fish were naturally produced Chinook salmon (Unpublished data, Norma Sands, NWFSC, March 5, 2010). ESU escapement (total spawners) increased to 47,686 (2000-2004), but has since declined to 40,411(2005-2009) and to 32,451 (2010-2014; Tables 4 and 5).

[2] Run size is calculated by combining harvest estimates and spawner estimates.

Table 4. Abundance–five-year geometric means for adult (age 3+) natural-origin and total spawners (natural- and hatchery-origin – in parenthesis) for the ESU with percent change between the most recent two 5-year periods shown on the far right column (NWFSC 2015).

Population	Geometric means					
	1990-1994	1995-1999	2000-2004	2005-2009	2010-2014	% Change
Strait of Georgia MPG						
NF Nooksack River	52 (102)	97 (476)	229 (3,476)	277 (1,675)	154 (1,167)	-44 (-30)
SF Nooksack River	126 (171)	133 (217)	235 (398)	244 (388)	88 (418)	-64 (8)
Strait of Juan de Fuca MPG						
Elwha River	420 (658)	274 (735)	357 (716)	193 (597)	164 (1,152)	-15 (93)
Dungeness River	20 (117)	18 (104)	71 (527)	162 (508)	119 (447)	-27 (-6)
Hood Canal MPG						
Skokomish River	506 (994)	478 (1,232)	479 (1,556)	500 (1,216)	256 (1,627)	-49 (34)
Mid-Hood Canal	93 (119)	152 (186)	169 (217)	47 (88)	75 (314)	60 (257)
Whidbey Basin MPG						
Skykomish River	1,658 (2,325)	1,494 (3,327)	2,606 (4,842)	2,388 (3,350)	1,693 (2,320)	-29 (-31)
Snoqualmie River	873 (1,035)	739 (1,187)	2,161 (2,480)	1,311 (1,965)	885 (1,143)	-32 (-42)
NF Stillaguamish River	553 (742)	603 (946)	967 (1,225)	550 (984)	574 (976)	4 (-1)
SF Stillaguamish River	150 (150)	241 (241)	219 (219)	101 (102)	71 (87)	-30 (-15)
Upper Skagit River	5,389 (5,599)	6,159 (6,267)	12,039 (12,484)	9,975 (10,611)	6,924 (7,194)	-31 (-32)
Lower Skagit River	1,417 (1,473)	1,001 (1,041)	2,765 (2,857)	2,118 (2,216)	1,391 (1,446)	-34 (-35)
Upper Sauk River	394 (409)	258 (268)	413 (428)	498 (518)	836 (867)	68 (67)
Lower Sauk River	399 (414)	414 (433)	812 (853)	546 (572)	413 (432)	-24 (-24)
Suiattle River	295 (302)	373 (382)	405 (415)	254 (261)	351 (360)	38 (38)
Cascade River	185 (189)	208 (213)	364 (371)	334 (341)	338 (345)	1 (1)
Central / South Sound MPG						
Sammamish River	52 (227)	32 (160)	385 (1,040)	289 (1,281)	160 (1,679)	-45 (31)
Cedar River	367 (509)	369 (541)	405 (643)	1,043 (1,275)	881 (1,075)	-16 (-16)
Green River	2,253 (5,331)	2,149 (7,272)	4,099 (6,624)	1,334 (3,187)	897 (2,168)	-33 (-32)
Puyallup River	2,143 (2,543)	1.611 (2,340)	1,171 (1,687)	795 (2,012)	598 (1,186)	-25 (-41)
White River	565 (645)	1,307 (1,415)	3,128 (3,309)	4,170 (5,301)	1,689 (3,471)	-59 (-35)
Nisqually River	630 (806)	596 (748)	891 (1,319)	587 (1,963)	701 (2,577)	19 (31)

In their population viability criteria assessment, the Puget Sound Technical Recovery Team (PSTRT) presented viable spawning abundances for 16 of the 22 populations (PSTRT 2002). For the 2010 status review (Ford 2011), viable spawning abundances for the remaining six populations were extrapolated based on a recovered productivity equal to the average for the 16 populations (recruits per spawner = 3.2). It is important to note that these are viability abundances assuming replacement only productivity – higher productivity would result in lower viable spawning abundances. For this reason, we use the low productivity planning range to evaluate the current abundance trends of PS Chinook salmon (Table 5).

Table 5. Average abundance estimates for PS Chinook salmon natural- and hatchery-origin spawners 2010-2014 (NWFSC 2015).

Population Name	Natural-origin Spawners[a]	Hatchery-origin Spawners[a]	% Hatchery Origin	Minimum Viability Abundance[b]	Expected Number of Outmigrants[c]
Strait of Georgia MPG					
NF Nooksack River	154	1,013	86.80%	16,000	93,360
SF Nooksack River	88	330	78.95%	9,100	33,440

Population Name	Natural-origin Spawners[a]	Hatchery-origin Spawners[a]	% Hatchery Origin	Minimum Viability Abundance[b]	Expected Number of Outmigrants[c]
Strait of Juan de Fuca MPG					
Elwha River	164	988	85.76%	15,100	92,160
Dungeness River	119	358	75.05%	4,700	38,160
Hood Canal MPG					
Skokomish River	256	1,371	84.27%	12,800	130,160
Mid-Hood Canal	75	239	76.11%	11,000	25,120
Whidbey Basin MPG					
Skykomish River	1,693	627	27.03%	17,000	185,600
Snoqualmie River	885	258	22.57%	17,000	91,440
NF Stillaguamish River	574	402	41.19%	17,000	78,080
SF Stillaguamish River	71	16	18.39%	15,000	6,960
Upper Skagit River	6,924	270	3.75%	17,000	575,520
Lower Skagit River	1,391	55	3.80%	16,000	115,680
Upper Sauk River	836	31	3.58%	3,000	69,360
Lower Sauk River	413	19	4.40%	5,600	34,560
Suiattle River	351	9	2.50%	600	28,800
Cascade River	338	7	2.03%	1,200	27,600
Central / South Sound MPG					
Sammamish River	160	1,519	90.47%	10,500	134,320
Cedar River	881	194	18.05%	11,500	86,000
Duwamish/Green River	897	1,271	58.63%	17,000	173,440
Puyallup River	598	588	49.58%	17,000	94,880
White River	1,689	1,782	51.34%	14,200	277,680
Nisqually River	701	1,876	72.80%	13,000	206,160
ESU Average	**19,258**	**13,223**	**40.71%**		**2,598,480**

[a] Five-year geometric mean of post-fishery spawners.
[b] Ford 2011
[c] Expected number of outmigrants=Total spawners*40% proportion of females*2,000 eggs per female*10% survival rate from egg to outmigrant

The average[3] abundance (2010-2014) for PS Chinook salmon populations is 32,481 adult spawners (19,258 natural-origin and 13,223 hatchery-origin spawners). Natural-origin spawners range from 71 (in the South Fork Stillaguamish River population) to 6,924 fish (in the Upper Skagit population). No populations are meeting minimum viability abundance targets, and only four of 22 populations average greater than 20% of the minimum viability abundance target for natural-origin spawner abundance (all of which are in the Skagit River watershed). The populations closest to planning targets (the Upper Skagit, Cascade, Upper Sauk, and Suiattle) need to increase substantially just to meet the minimum viability abundance target. The Skykomish population is the second most

[3] Average abundance calculations are the geometric mean. The geometric mean of a collection of positive data is defined as the nth root of the product of all the members of the data set, where n is the number of members. Salmonid abundance data tend to be skewed by the presence of outliers (observations considerably higher or lower than most of the data). For skewed data, the geometric mean is a more stable statistic than the arithmetic mean.

abundant population, but its natural-origin spawner abundance is only 10% of the minimum viability abundance target.

Juvenile PS Chinook salmon abundance estimates come from escapement data, the percentage of females in the population, and fecundity. Fecundity estimates for the ESU range from 2,000 to 5,500 eggs per female, and the proportion of female spawners in most populations is approximately 40% of escapement. By applying a conservative fecundity estimate (2,000 eggs/female) to the expected female escapement (both natural-origin and hatchery-origin spawners – 12,992 females), the ESU is estimated to produce approximately 26.0 million eggs annually. Smolt trap studies have researched egg to migrant juvenile Chinook salmon survival rates in the following Puget Sound tributaries: Skagit River, North Fork Stillaguamish River, South Fork Stillaguamish River, Bear Creek, Cedar River, and Green River (Beamer et al. 2000; Seiler et al. 2002, 2004, 2005; Volkhardt et al. 2005; Griffith et al. 2004). The average survival rate in these studies was 10%, which corresponds with those reported by Healey (1991). With an estimated survival rate of 10%, the ESU should produce roughly 2.60 million natural-origin outmigrants annually.

Juvenile listed hatchery PS Chinook salmon abundance estimates come from the annual hatchery production goals. Hatchery production varies annually due to several factors including funding, equipment failures, human error, disease, and adult spawner availability. Funding uncertainties and the inability to predict equipment failures, human error, and disease suggest that production averages from previous years is not a reliable indication of future production. For these reasons, abundance is assumed to equal production goals. The combined hatchery production goal for listed PS Chinook salmon from Table 1 is 42,114,650 adipose-fin-clipped and non-clipped juvenile Chinook salmon.

Fifteen-year trends in wild spawner abundance were calculated for each PS Chinook salmon population for two time series – 1990-2005 and 1999-2014 (Table 6). Trends were calculated from a linear regression applied to the smoothed wild spawner log abundance estimate (NWFSC 2015). For the 1990-2005 time series, trends were negative for only two of 22 populations. Recent trends (1999-2014), however, were negative for 17 of the 22 populations (NWFSC 2015).

Table 6. Fifteen year trends for PS Chinook salmon for two time series – 1990-2005 and 1999-2014 (NWFSC 2015).

	1990-2005		1999-2014	
Population	**Trend**	**95% CI**	**Trend**	**95% CI**
Strait of Georgia MPG				
NF Nooksack River	0.07	(0.04, 0.09)	0.04	(0, 0.07)
SF Nooksack River	0.03	(0, 0.06)	-0.06	(-0.10, -0.02)
Strait of Juan de Fuca MPG				
Elwha River	-0.02	(-0.06, 0.02)	-0.06	(-0.10, -0.03)
Dungeness River	0.14	(0.08, 0.19)	0.09	(0.03, 0.14)
Hood Canal MPG				
Skokomish River	0.02	(-0.01, 0.05)	-0.07	(-0.11, -0.02)
Mid-Hood Canal	0.03	(0, 0.07)	-0.07	(-0.11, -0.02)
Whidbey Basin MPG				
Skykomish River	0.03	(0, 0.06)	-0.02	(-0.04, 0.01)
Snoqualmie River	0.09	(0.05, 0.12)	-0.05	(-0.08, -0.03)
NF Stillaguamish River	0.04	(0.02, 0.06)	-0.04	(-0.06, -0.01)
SF Stillaguamish River	0.01	(-0.01, 0.03)	-0.10	(-0.12, -0.08)

Population	1990-2005		1999-2014	
	Trend	**95% CI**	**Trend**	**95% CI**
Upper Skagit River	0.07	(0.05, 0.09)	-0.03	(-0.06, 0)
Lower Skagit River	0.05	(0.02, 0.09)	-0.03	(-0.06, -0.01)
Upper Sauk River	0.01	(-0.02, 0.04)	0.06	(0.04, 0.08)
Lower Sauk River	0.05	(0.01, 0.08)	-0.04	(-0.07, -0.01)
Suiattle River	0.01	(-0.01, 0.03)	-0.01	(-0.04, 0.01)
Cascade River	0.06	(0.04, 0.08)	0.01	(-0.01, 0.03)
Central / South Sound MPG				
Sammamish River	0.17	(0.11, 0.23)	-0.02	(-0.06, 0.02)
Cedar River	0.03	(0, 0.06)	0.07	(0.05, 0.10)
Green River	0.02	(-0.02, 0.06)	-0.12	(-0.16, -0.09)
Puyallup River	-0.03	(-0.05, -0.02)	-0.06	(-0.08, -0.03)
White River	0.19	(0.17, 0.21)	-0.03	(-0.08, 0.01)
Nisqually River	0.05	(0.03, 0.06)	-0.01	(-0.05, 0.03)

Currently, for every natural-origin juvenile that migrates to Puget Sound 16 listed hatchery juveniles are released into Puget Sound watersheds. The hatchery fish are then targeted for fisheries and removed when they return to their release sites. However, some will stray and others will be missed. For Puget Sound, an average of 40% (range of 2-90%) of the naturally spawning Chinook salmon are first-generation hatchery fish with more than a third of all populations (9 of 22) having more hatchery-origin than natural-origin spawners (Table 5). Studies have documented that hatchery fish spawning in the wild have a lower success rate than naturally produced fish (McLean et al. 2004, Kostow et al. 2002, Berejikian et al. 2001, Reisenbichler and Rubin 1999).

Limiting Factors

Most of the gains in PS Chinook salmon natural-origin spawner abundance since the 1990s have been lost during the most recent 5-year period (2010-2014) (NWFSC 2015). In fact, 2014 abundance numbers were near the historic lows of the 1990s. In addition, the overall abundance is still only a fraction of historical levels. Several risk factors identified in the 2005 status review (Good et al. 2005) are still present, including high fractions of hatchery fish in many populations and widespread habitat loss and degradation. Additionally, there has been no recent improvement in the species' spatial structure or diversity. None of the extirpated populations has been re-established. However, many habitat and hatchery actions identified in the Puget Sound Chinook salmon recovery plan are expected to take years or decades to be implemented and produce significant improvements (NWFSC 2015). Concerning habitat, the following issues continue to impede PS Chinook salmon recovery throughout the fresh and marine waters of Puget Sound: untreated stormwater, contaminants, shoreline armoring, instream flows, impaired floodplain connectivity, and fish passage (NMFS 2016).

Status Summary

Across the ESU, most populations have declined in abundance over the past seven to 10 years (NWFSC 2015). Further, all PS Chinook salmon populations are well below the PSTRT planning ranges for recovery escapement levels and below the spawner-recruitment levels identified as consistent with recovery (Ford 2011; NWFSC 2015). Hatchery-origin spawners are present in high fractions in most populations outside of the Skagit River watershed with half of these non-Skagit watersheds seeing a decrease in the fraction of natural-origin spawners (NWFSC 2015). Overall, most populations have declined in abundance since the last two status reviews in 2005 and 2010; but the biological risk was determined to have not changed since the previous status reviews (NWFSC 2015).

2.2.2.2 Hood Canal Summer-run Chum Salmon

Description and Geographic Range

On June 28, 2005, NMFS listed HCS chum salmon—both natural-origin and some artificially-propagated fish—as a threatened species (70 FR 37160). The species comprises all naturally spawned populations of summer-run chum salmon in Hood Canal and its tributaries as well as populations in Olympic Peninsula rivers between Hood Canal and Dungeness Bay, Washington. Under the final listing in 2005, the section 4(d) protections (and limits on them) apply to natural-origin and hatchery-origin HCS chum salmon with an intact adipose fin, but not to listed hatchery fish that have had their adipose fin removed. Four artificial propagation programs were listed as part of the ESU (79 FR 20802; Table 7): Hamma Hamma Fish Hatchery Program, Lilliwaup Creek Fish Hatchery Program, Tahuya River Program; and Jimmycomelately Creek Fish Hatchery Program.

Table 7. Expected 2017 Hood Canal summer-run juvenile chum salmon hatchery releases (WDFW 2016).

Subbasin	Artificial propagation program	Brood year	Run Timing	Clipped Adipose Fin	Intact Adipose Fin
Hood Canal	LLTK - Lilliwaup	2016	Summer	-	150,000
Total Annual Release Number				**-**	**150,000**

Chum salmon in this ESU are summer-run fish. Juveniles, typically as fry, emerge from the gravel and outmigrate almost immediately to seawater. For their first few weeks, they reside in the top two to three centimeters of estuarine surface waters while staying extremely close to the shoreline (WDFW/PNPTT 2000). Subadults and adults forage in coastal and offshore waters of the North Pacific Ocean before returning to spawn in their natal streams. HCS chum salmon spawn from mid-September to mid-October (whereas fall-run chum salmon in the same geographic area spawn from November to December or January). Spawning typically occurs in the mainstems and lower river basins. Adults typically mature between the ages of three and five.

Spatial Structure and Diversity

The HCS chum salmon ESU has two populations, each containing multiple stocks or spawning aggregations (Table 8). In the Strait of Juan de Fuca population, state and tribal biologists assessing the species' status in the early 1990s identified small but persistent natural spawning aggregations in three streams (Salmon, Snow, and Jimmycomelately creeks). In the Dungeness River, spawning of unknown aggregations occurred. In Chimacum Creek, HCS chum salmon extirpation occurred in the mid-1980's.

Table 8. Historical populations, spawning aggregations, and the status of summer-run chum salmon in the Hood Canal ESU (Good et al. 2005, Sands et al. 2009; Ford 2011).

Population	Spawning Aggregations	Status	Supplementation/Reintroduction Program
Strait of Juan de Fuca	Dungeness River	Unknown	---
	Jimmycomelately Creek	Extant	Supplementation program began in 1999.
	Salmon Creek	Extant	Supplementation program began in 1992.
	Snow Creek	Extant	---
	Chimacum Creek	*Extinct*	Reintroduction program began in 1996; natural spawning reported starting in 1999.
Hood Canal	Big Quilcene River	Extant	Supplementation program began in 1992.
	Little Quilcene River	Extant	---
	Dosewallips River	Extant	---
	Duckabush River	Extant	---
	Hamma Hamma River	Extant	Supplementation program began in 1997.
	Lilliwaup Creek	Extant	---
	Big Beef Creek	*Extinct*	Reintroduction program began in 1996; returns reported starting in 2001
	Anderson Creek	*Extinct*	---
	Dewatto River	*Extinct*	Natural re-colonization occurring, but numbers remain low (<70).
	Tahuya River	*Extinct*	Reintroduction program began in 2000 with increased returns starting in 2006.
	Union River	Extant	---
	Skokomish River	*Extinct*	Spawning documented in recent years.
	Finch Creek	*Extinct*	---

In the Hood Canal population, spawning aggregations persisted in most of the major rivers draining from the Olympic Mountains into the western edge of the Canal, including Big and Little Quilcene Rivers, Dosewallips River, Duckabush River, Hamma Hamma River, and Lilliwaup Creek. On the eastern side of Hood Canal, persistent spawning was restricted to the Union River (Sands et al. 2009). Historical information and habitat characteristics of other streams indicate that summer chum salmon distribution was once more region-wide, especially in the eastern shore streams draining into Hood Canal. Based on river size and historical tribal fishing records, a major spawning aggregation once occurred in the Skokomish River before the construction of Cushman Dam in the 1920's. State and tribal biologists also identified recent extinctions in Big Beef Creek, Anderson Creek, Dewatto River, Tahuya River, and Finch Creek. Historically, additional streams such as Seabeck, Stavis, Big and Little Mission Creeks, and others probably supported summer chum salmon.

In 1992, state and tribal co-managers initiated an extensive rebuilding program for the HCS chum salmon (WDFW/PNPTT 2000 and 2001). Their recovery plan called for five supplementation and three reintroduction projects (Table 8). After individual projects' production level goals specified in the Summer Chum Salmon Conservation Initiative were met, supplementation or reintroduction programs were terminated on several streams (WDFW/PNPTT 2000 and 2001).

Spatial structure changes are the greatest concern for the ESU's diversity with HCS chum salmon aggregations being more isolated than they were historically (NMFS 2005b). In the past, most HCS chum salmon aggregations were 20-40 km apart with none greater than 80 km. Most extant summer chum salmon aggregations still occur within 20-40 km of each other, but some extinctions have led to a significant increase in spawning aggregations isolated by 80 km or more. Geographically, the extinctions occurred primarily in the northeastern Olympic Peninsula and northwestern Kitsap Peninsula (at the center of the ESU's geographic range), including all spawning aggregations within the Admiralty Inlet catchment, as well as the Skokomish and Tahuya Rivers. As geographic distances increase between spawning aggregations, they exchange fewer migrants. Such isolations impede the natural exchange of genetic information between spawning aggregations and populations.

Supplementation programs have been very successful in both increasing natural spawning abundance in six of eight extant streams (Salmon, Big Quilcene, Lilliwaup, Hamma Hamma, Jimmycomelately, and Union) and increasing spatial structure due to reintroducing spawning aggregations to three streams (Big Beef, Tahuya, and Chimacum creeks) (NWFSC 2015). The reintroductions have had mixed success, with Chimacum Creek being very successful, but natural-origin production has not yet been sustained in Big Beef Creek and Tahuya River (PNPTT and WDFW 2014). In general, habitat degradation is considered limiting to natural-origin production. Habitat preservation and restoration projects in individual watersheds have been implemented concurrently with supplementation programs and have aided in the ability to sustain natural-origin production (NWFSC 2015).

Abundance and Productivity

Historical HCS chum salmon abundance is mostly unknown. Harvest records indicate that chum salmon in the Puget Sound (including the HCS chum salmon ESU) were historically more numerous than Chinook salmon. During the years 1914-1919, four times as many chum salmon were harvested as Chinook salmon in the Puget Sound (WDF 1974). In 1968, spawning escapement records indicate that 45,000 adult HCS chum salmon returned to tributaries (WDF et al. 1993). During the early 1970s, adult chum salmon spawners dropped to about 20,000 annually (Ford 2011). By the 1980s, HCS chum salmon abundance began to decline ever more precipitously with several spawning aggregations extirpated during this period with seven spawning aggregations going extinct (Sands et al. 2009). Spawner abundances in both Hood Canal and Strait of Juan de Fuca populations were lowest throughout the 1990's but increased in the early 2000's (NWFSC 2015). Since the late 2000's, abundances have increased by 25% for the Hood Canal population and 53% for the Strait of Juan de Fuca population (Table 9).

Table 9. Abundance–five-year geometric means for adult natural-origin and total spawners (natural- and hatchery-origin – in parenthesis) for the ESU with percent change between the most recent two 5-year periods shown on the far right column (NWFSC 2015).

	Geometric means					
Population	**1990-1994**	**1995-1999**	**2000-2004**	**2005-2009**	**2010-2014**	**% Change**
Hood Canal MPG						
Strait of Juan de Fuca	386 (386)	629 (822)	2,190 (4,178)	4,020 (5,353)	6,169 (8,339)	53 (56)
Hood Canal	979 (979)	5,169 (7,223)	13,145 (18,928)	11,307 (13,605)	14,152 (15,553)	25 (14)

The current average run size of 23,034 adult spawners (20,855 natural-origin and 2,179 hatchery-origin spawners; Table 10) is largely the result of aggressive reintroduction and supplementation programs throughout the ESU. In the Strait of Juan de Fuca population, the annual natural-origin spawners returns for Jimmycomelately Creek dipped to a single fish in 1999 and again in 2002 (Unpublished data, Norma Sands, NWFSC, December 19, 2006). From 2010 to 2014, Jimmycomelately Creek averaged 1,670 natural-origin spawners. Salmon and Snow Creeks have improved substantially. Natural-origin spawner abundance was 130 fish in 1999, whereas the average for Salmon and Snow creeks were 2,499 and 476, respectively, for the 2010-2014 period.

Table 10. Abundance of natural-origin and hatchery-origin HCS chum salmon spawners in escapements 2010-2014 (unpublished data, Mindy Rowse, NWFSC, Apr 13, 2016).

Population Name	Natural-origin Spawners[a]	Hatchery-origin Spawners[a]	% Hatchery Origin	Expected Number of Outmigrants[c]
Strait of Juan de Fuca Population				
Jimmycomelately Creek	1,670	1,451	46.49%	456,407
Salmon Creek	2,499	-	0.00%	365,482
Snow Creek	476	1	0.21%	69,746
Chimacum Creek	1,381	-	0.00%	201,944
Population Average[d]	**6,026**	**1,452**	**19.42%**	**1,093,579**
Hood Canal Population				
Big Quilcene River	4,675	-	0.00%	683,769
Little Quilcene River	720	-	0.00%	105,327
Big Beef Creek	76	-	0.00%	11,054
Dosewallips River	2,263	3	0.13%	331,433
Duckabush River	3,989	10	0.26%	584,920
Hamma Hamma River	1,733	17	0.95%	255,873
Anderson Creek	-	-	-	-
Dewatto River	43	6	12.87%	7,247
Lilliwaup Creek	293	210	41.71%	73,518
Tahuya River	176	462	72.39%	93,236
Union River	861	19	2.16%	128,636
Population Average[d]	**14,829**	**727**	**4.67%**	**2,275,013**
ESU Average	**20,855**	**2,179**	**9.46%**	**3,368,592**

[a] Five-year geometric mean of post fishery natural-origin spawners (2010-2014).
[b] Five-year geometric mean of post fishery hatchery-origin spawners (2010-2014).
[c] Expected number of outmigrants=Total spawners*45% proportion of females*2,500 eggs per female*13% survival rate from egg to outmigrant.
[d] Averages are calculated as the geometric mean of the annual totals (2010-2014).

The Hood Canal populations have a similar success story. In 1989, only two summer chum salmon were found in spawning surveys conducted on the Big and Little Quilcene Rivers. Now, they have a combined average of 5,395 natural-origin spawners annually from 2010-2014. Hamma Hamma River returns averaged in the thousands between 1968 and 1979. But by 1989, there were an estimated 16 natural-origin spawners in the Hamma Hamma River. Recent estimates show an average of 1,733 natural-origin HCS chum salmon returning to the Hamma Hamma River annually.

The PSTRT defined interim planning ranges for population level abundance for both high productivity and low productivity (Table 10) (NMFS 2006). As the next section illustrates, productivity is low in both populations. Abundance in both populations is currently below the PSTRT planning targets for average natural-origin spawner abundance of 13,000 to 36,000 for the Strait of Juan de Fuca population and 25,000 to 85,000 for the Hood Canal population.

Escapement data, the percentage of females in the population, and fecundity can estimate juvenile HCS chum salmon abundance. ESU fecundity estimates average 2,500 eggs per female, and the proportion of female spawners is approximately 45% of escapement in most populations (WDFW/PNPTT 2000). By applying fecundity estimates to the expected escapement of females (both natural-origin and hatchery-origin spawners – 10,365 females), the ESU is estimated to produce approximately 25.9 million eggs annually. For HCS chum salmon, freshwater mortality rates are high with no more than 13% of the eggs expected to survive to the juvenile migrant stage (Quinn 2005). With an estimated survival rate of 13%, the ESU should produce roughly 3.37 million natural-origin outmigrants annually.

Linear regressions of smoothed log natural-origin spawner abundance were applied to both HCS chum salmon populations for two 15-year time series trend analyses (1990-2005 and 1999-2014) (Table 11) (NWFSC 2015). For both time series, trends were positive for both populations (NWFSC 2015).

Table 11. Fifteen year trends for HCS chum salmon for two time series – 1990-2005 and 1999-2014 (NWFSC 2015).

	1990-2005		1999-2014	
Population	**Trend**	**95% CI**	**Trend**	**95% CI**
Hood Canal MPG				
Strait of Juan de Fuca	0.17	(0.11, 0.23)	0.15	(0.08, 0.21)
Hood Canal	0.22	(0.17, 0.27)	0.07	(0.01, 0.13)

Annual hatchery production goals can estimate juvenile listed hatchery HCS chum salmon abundance. Hatchery production varies from year to year due to several factors including funding, equipment failures, human error, disease, and availability of adult spawners. Funding uncertainties and the inability to predict equipment failures, human error, and disease suggests that average production from past years is not a reliable indication of production in the coming years. For these reasons, production goals should equal abundance. The combined hatchery production goal for listed HCS chum salmon from Table 7 is 150,000 unmarked juvenile chum salmon.

Limiting Factors

While there is cause for optimism about this ESU's prospects, there is also cause for continued concern. Supplementation and reintroduction programs have increased natural-origin spawner numbers and distribution in both populations, but these hatchery supplementation programs have mostly ended with only one program continuing. The Hood Canal population has shown improvements since the early 1990's with abundance and productivity gains. With spatial structure, however, there is concern in east Hood Canal where spawning aggregations in Big Beef Creek and Tahuya River are about 60 km apart; thus an additional spawning aggregation would be needed in either Dewatto River or Anderson Creek (PNPTT and WDFW 2014; NWFSC 2015). Despite gains in habitat protection and restoration, concerns remain that given the pressures of population growth and existing land use management measures through local governments (i.e., shoreline management plans, critical area ordinances, and comprehensive plans) may be compromised or not enforced (NWFSC 2015). Overall, limiting factors include degraded estuarine and nearshore habitat, water quality, degraded floodplain connectivity and function, degraded channel structure and complexity, degraded riparian areas and large woody debris recruitment, degraded stream substrate, and degraded stream flow (NMFS 2016). Lastly, although abundances have increased for both populations, they are still well below what is targeted by the PSTRT for recovery.

Status Summary

Natural-origin spawner abundance has increased since their 1999 ESA-listing (64 FR 14508) and spawning abundance targets in both populations have been met in some years (NWFSC 2015). Productivity was quite low at the time of the last review (Ford 2011), though rates have increased in the last five years, and have been greater than replacement rates in the past two years for both populations. However, productivity of individual spawning aggregates shows only two of eight aggregates have viable performance. Spatial structure and diversity viability parameters for each population have increased and nearly meet the viability criteria. Despite substantive gains towards meeting viability criteria in the Hood Canal and Strait of Juan de Fuca summer chum salmon populations, the ESU still does not meet all of the recovery criteria for population viability at this time (NWFSC 2015).

2.2.2.3 Puget Sound Steelhead

Description and Geographic Range

On August 9, 1996, NMFS determined that the PS steelhead DPS did not warrant listing (61 FR 41541). In response to a petition received on September 13, 2004, NMFS updated the species' status review. On May 7, 2007, NMFS listed PS steelhead—both natural-origin and some artificially-propagated fish—as a threatened species (72 FR 26722). NMFS concluded that the PS steelhead DPS was likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. Six artificial propagation programs were listed as part of the DPS (79 FR 20802; Table 12), including: Green River Natural Program, White River Winter Steelhead Supplementation Program, Hood Canal Steelhead Supplementation Off-station Projects in the Dewatto, Skokomish, and Duckabush Rivers, and Lower Elwha Fish Hatchery Wild Steelhead Recovery Program. NMFS promulgated 4(d) protective regulations for PS steelhead on September 25, 2008 (73 FR 55451). The section 4(d) protections (and limits on them) apply to natural-origin and hatchery-origin PS steelhead with an intact adipose fin, but not to listed hatchery fish that have had their adipose fin removed.

Table 12. Expected 2017 Puget Sound steelhead listed hatchery releases (WDFW 2016).

Subbasin	Artificial propagation program	Brood year	Run Timing	Clipped Adipose Fin	Intact Adipose Fin
Dungeness/Elwha	Dungeness	2016	Winter	10,000	-
	Hurd Creek	2017	Winter	-	34,500
Duwamish/Green	Flaming Geyser	2016	Winter	-	15,000
	Icy Creek	2016	Summer	20,000	-
			Winter	-	23,000

Subbasin	Artificial propagation program	Brood year	Run Timing	Clipped Adipose Fin	Intact Adipose Fin
	Soos Creek	2016	Summer	30,000	-
Hood Canal	LLTK – Lilliwaup	2013	Winter	230	-
		2015	Winter	-	6,000
Puyallup	White River	2016	Winter	-	35,000
Total Annual Release Number				**60,230**	**113,500**

Steelhead are found in most of the larger accessible tributaries to Puget Sound, Hood Canal, and the eastern Strait of Juan de Fuca. Surveys of the Puget Sound (not including the Hood Canal) in 1929 and 1930 identified steelhead in every major basin except the Deschutes River (Hard et al. 2007). The DPS includes all naturally spawned anadromous winter-run and summer-run *O. mykiss* populations, in streams in the river basins of Puget Sound, Hood Canal, and the Strait of Juan de Fuca, Washington, bounded to the west by the Elwha River (inclusive) and to the north by the Nooksack River and Dakota Creek (inclusive). Hatchery steelhead are also distributed throughout the range of this DPS.

Of all the Pacific salmonids, *O. mykiss* probably exhibits the greatest life-history diversity. Resident *O. mykiss*, commonly called rainbow trout, complete their life cycle entirely in freshwater; whereas steelhead, the anadromous form of *O. mykiss*, reside in freshwater for their first one to three years before migrating to the ocean. Smoltification and seaward migration occur principally from April to mid-May (WDF et al. 1993). Though not well understood, smolts are believed to migrate quickly offshore (Hartt and Dell 1986). Steelhead then remain in the ocean for one to three years before returning to freshwater to spawn. In contrast with other Pacific salmonid species, steelhead are iteroparous, thus capable of repeat spawning. Among all West Coast steelhead populations, eight percent of spawning adults have spawned previously, with coastal populations having a higher repeat spawning incidence than inland populations (Busby et al. 1996).

Steelhead life-history type expression comes through the degree of sexual development when adults enter freshwater. Stream-maturing steelhead, also called summer-run steelhead, enter freshwater at an early maturation stage, usually from May to October. These summer-run steelhead migrate to headwater areas, hold for several months, and spawn in the spring. Ocean-maturing steelhead, also called winter-run steelhead, enter freshwater from December to April at an advanced maturation stage and spawn from March through June (Hard et al. 2007). While some temporal overlap in spawn timing between these forms exist, in basins where both winter- and summer-run steelhead are present, summer-run steelhead spawn farther upstream, often above a partially impassable barrier. In many cases, summer migration timing may have evolved to access areas above falls or cascades during low summer flows that are impassable during high winter flow months. However, relatively few basins in the Puget Sound DPS with the geomorphological and hydrological characteristics necessary to establish this summer-run life history exist. Thus, winter-run steelhead are predominant in Puget Sound.

Spatial Structure and Diversity

Although Puget Sound DPS steelhead populations include both summer- and winter-run life-history types, winter-run populations predominate. For the PS steelhead DPS, Myers et al. (2015) identified three Major Population Groups (MPGs) and 32 Demographically Independent Populations (DIPs) composed of 27 winter-run and nine summer-run steelhead stocks (Table 13). Summer-run stock statuses are mostly unknown; however, most appear to be small, averaging less than 200 spawners annually (Hard et al. 2007). Summer-run stocks are primarily concentrated in the northern Puget Sound and the Dungeness River (Myers et al. 2015).

Table 13. PS steelhead historical Demographically Independent Populations (DIPs), runs, and estimated capacities (Myers et al. 2015).

Demographically Independent Populations	Run(s)	Population Capacity
Central and South Puget Sound MPG		
Cedar River	Winter	5,949 – 11,899
N Lake Washington/Lake Sammamish	Winter	5,268 – 10,536
Green River	Winter	19,768 – 39,537
Puyallup/Carbon River	Winter	14,716 – 29,432
White River	Winter	17,490 – 34,981
Nisqually River	Winter	15,330 – 30,660
South Puget Sound Tributaries	Winter	9,854 – 19,709
East Kitsap Peninsula Tributaries	Winter	1,557 – 3,115
	TOTAL	**89,932 – 179,869**
Hood Canal and Strait of Juan de Fuca MPG		
East Hood Canal Tributaries	Winter	1,270 – 2,540
South Hood Canal Tributaries	Winter	2,985 – 5,970
Skokomish River	Winter	10,030 – 20,060
West Hood Canal Tributaries	Winter	3,608 – 7,217
Sequim/Discovery Bays Independent Tributaries	Winter	512 – 1,024
Dungeness River	Summer; Winter	2,465 – 4,930
Strait of Juan de Fuca Independent Tributaries	Winter	728 – 1,456
Elwha River	Winter	7,116 – 14,231
	TOTAL	**28,714 – 57,428**
North Cascades MPG		
Drayton Harbor Tributaries	Winter	2,426 – 4,852
Nooksack River	Winter	22,045 – 44,091
SF Nooksack River	Summer	1,137 – 2,273
Samish River and Bellingham Bay Tributaries	Winter	3,193 – 6,386
Skagit River	Summer; Winter	64,775 – 129,551
Nookachamps Creek	Winter	1,231 – 2,462
Baker River	Summer; Winter	5,028 – 10,056
Sauk River	Summer; Winter	23,230 – 46,460
Stillaguamish River	Winter	19,118 – 38,236
Deer Creek	Summer	1,572 – 3,144
Canyon Creek	Summer	121 - 243
Snohomish/Skykomish River	Winter	21,389 – 42,779
Pilchuck River	Winter	5,193 – 10,386
NF Skykomish River	Summer	663 – 1,325
Snoqualmie River	Winter	16,740 – 33,479
Tolt River	Summer	321 - 641
	TOTAL	**188,182 – 376,364**
	GRAND TOTAL	**306,828 – 613,661**

Probable steelhead extirpations include three summer-run stocks and one winter-run stock. For the Baker River summer-run DIP, Baker River dam construction blocked access to spawning areas. The current Elwha and Green summer-run steelhead stocks are descended from Skamania Hatchery stock, while historical summer-runs in these systems are thought to have been extirpated early in the 1900s. For the Chambers Creek winter-run steelhead stock, broodstock collection and selective breeding at the South Tacoma Hatchery may have been the cause (Hard et al. 2007).

As described above, the DPS is composed of both summer- and winter-run steelhead. The status of the summer-run DIPs was identified as a risk to DPS viability (NMFS 2005a). Summer-run steelhead DIPs, historically occurring throughout the Puget Sound but now concentrated in the northern region, are generally small and characterized as isolated populations adapted to streams with distinct attributes. The one summer-run DIP with abundance data (Tolt River) exhibits a negative trend in natural-origin run size. Most other DIPs are very small, with annual escapements below 50 fish.

Artificial propagation is a major factor affecting the genetic diversity of both summer- and winter-run steelhead in the Puget Sound DPS. Although offsite releases and releases of steelhead fry and parr have largely ceased in the DPS, annual hatchery steelhead smolt releases derived from non-local steelhead (Skamania summer-run steelhead) or domesticated steelhead originally found within the DPS (Chambers Creek winter-run steelhead) persist in most systems. And several of these releases are still composed of tens or hundreds of thousands of fish. This sustained hatchery management practice has increased the likelihood of interbreeding and ecological interaction between wild and hatchery fish—in spite of the apparent differences in average spawning time and its associated adverse fitness consequences for both summer- and winter-run steelhead. As NMFS (2005a) noted, even low levels (e.g., <5%) of gene flow per year from a non-DPS hatchery stock to a naturally spawning population can have a significant genetic impact after several generations. For 2016, 1.15 million hatchery steelhead are expected to be released throughout the range of the PS steelhead DPS (WDFW 2016).

Abundance and Productivity

Historical Puget Sound steelhead abundance is largely based on catch records. Catch records from 1889 to 1920 indicate that catch peaked at 163,796 steelhead in 1895. Using harvest rates of 30-50%, the estimated peak run size for Puget Sound would range from 327,592 to 545,987 fish. Myers et al. (2015) estimated historic PS steelhead abundance at 306,828 to 613,661 based upon geographic, hydrologic, and ecological characteristics (Table 13). In the 1980s, Light (1987) estimated the steelhead run size at approximately 100,000 winter-run and 20,000 summer-run steelhead. However, as many as 70% of the run were first generation hatchery fish (Hard et al. 2007). By the mid-1990s, Busby et al. (1996) estimated a total run of 45,000 (winter- and summer-run combined). Since then, DPS escapement (total spawners) has decreased to 17,363 (2000-2004), 15,926 (2005-2009), and 13,422 (2010-2014; Tables 14 and 15).

Table 14. Abundance–five-year geometric means for adult (age 3+) natural-origin and total spawners (natural- and hatchery-origin – in parenthesis) for the ESU with percent change between the most recent two 5-year periods shown on the far right column (NWFSC 2015).

Demographically Independent Populations	Geometric means					
	1990-1994	1995-1999	2000-2004	2005-2009	2010-2014	% Change
Central and South Puget Sound MPG						
Cedar River	(321)	(298)	(37)	(12)	(4)	(-67)
Green River	1,566 (1,730)	2,379 (2,505)	1,618 (1,693)	(716)	(552)	(-23)
Nisqually River	1,201 (1,208)	759 (759)	394 (413)	278 (375)	(442)	(18)
N. Lake WA/Lake Sammamish	321 (321)	298 (298)	37 (37)	12 (12)	-	-
Puyallup/Carbon River	1,156 (1,249)	1,003 (1,134)	428 (527)	315 (322)	(277)	(-14)
White River	696 (696)	519 (519)	466 (466)	225 (225)	531 (531)	136 (136)
Hood Canal and Strait of Juan de Fuca MPG						
Dungeness River	356 (356)	-	38 (38)	24 (25)	-	-
East Hood Canal Tribs.	110 (110)	176 (176)	202 (202)	62 (62)	60 (60)	-3 (-3)
Elwha River	206 (358)	127 (508)	(303)	-	(237)	-
Sequim/Discovery Bay Tribs	(30)	(69)	(63)	(17)	(19)	(12)
Skokomish River	385 (503)	359 (359)	205 (259)	351 (351)	(580)	(65)
South Hood Canl Tribs	89 (89)	111 (111)	103 (103)	113 (113)	64 (64)	-43 (-43)
Strait of Juan de Fuca Tribs	89 (89)	191 (191)	212 (212)	101 (101)	147 (147)	46 (46)
West Hood Canal Tribs	-	97 (97)	210 (210)	149 (174)	(74)	(-50)
North Cascades MPG						
Nooksack River	-	-	-	-	1,693 (1,745)	-
Pilchuck River	1,225 (1,225)	1,465 (1,465)	604 (604)	597 (597)	614 (614)	3 (3)
Samish River/ Bellingham Bay Tribs	316 (316)	717 (717)	852 (852)	534 (534)	846 (846)	58 (58)
Skagit River	7,189 (7,650)	7,656 (8,059)	5,424 (5,675)	4,767 (5,547)	(5,123)	(7)
Snohomish/Skykomish Rivers	6,654 (7,394)	6,382 (7,200)	3,230 (3,980)	4,589 (5,399)	(930)	(-83)
Snoqualmie River	1,831 (1,831)	2,056 (2,056)	1,020 (1,020)	944 (944)	680 (680)	-28 (-28)
Stillaguamish River	1,078 (1,078)	1,024 (1,166)	401 (550)	259 (327)	(392)	(20)
Tolt River	112 (112)	212 (212)	119 (119)	73 (73)	105 (105)	44 (44)

Steelhead are most abundant in the North Cascades MPG, with the Skagit and Nooksack rivers supporting the two largest winter-run steelhead DIPs (Table 15). The Snohomish/Snoqualmie DIP used to support the second largest DIP for the DPS, but this DIP has declined by 83% during the last five years (NWFSC 2015). Currently, neither the Central and South Puget Sound MPG nor the Hood Canal and Strait of Juan de Fuca MPG DIPs have averaged greater than 600 spawners annually.

Table 15. Abundance of PS steelhead spawner escapements (natural-origin and hatchery-production combined) from 2010-2014 (NWFSC 2015).

Demographically Independent Populations	Spawners	Expected Number of Outmigrants[b]
Central and South Puget Sound MPG		
Cedar River	4	455
Green River	552	62,790
Nisqually River	442	50,278
N. Lake WA/Lake Sammamish	-	-
Puyallup/Carbon River	277	31,509
White River	531	60,401
Hood Canal and Strait of Juan de Fuca MPG		
Dungeness River	-	-
East Hood Canal Tribs.	60	6,825
Elwha River	237	26,959
Sequim/Discovery Bay Tribs.	19	2,161
Skokomish River	580	65,975
South Hood Canal Tribs.	64	7,280
Strait of Juan de Fuca Tribs.	147	16,721
West Hood Canal Tribs.	74	8,418
North Cascades MPG		
Nooksack River	1,745	198,494
Pilchuck River	614	69,843
Samish River/ Bellingham Bay Tribs.	846	96,233
Skagit River	5,123	582,741
Snohomish/Skykomish Rivers	930	105,788
Snoqualmie River	680	77,350
Stillaguamish River	392	44,590
Tolt River	105	11,944
TOTAL	**13,422**	**1,526,753**

[a] Geometric mean of post fishery spawners.

[b] Expected number of outmigrants=Total spawners*50% proportion of females*3,500 eggs per female*6.5% survival rate from egg to outmigrant.

The average abundance (2010-2014) for the PS steelhead DPS is 13,422 adult spawners (natural-origin and hatchery-production combined). Juvenile PS steelhead abundance estimates is calculated from the escapement data (Table 15). For the species, fecundity estimates range from 3,500 to 12,000; and the male to female ratio averages 1:1 (Pauley et al. 1986). By applying a conservative fecundity estimate of 3,500 eggs to the expected escapement of females (6,711 females), 23.49 million eggs are expected to be produced annually. With an estimated survival rate of 6.5% (Ward and Slaney 1993), the DPS should produce roughly 1.53 million natural-origin outmigrants annually.

Linear regressions of smoothed log natural-origin spawner abundance were applied to PS steelhead DIPs for two 15-year time series trend analyses (1990-2005 and 1999-2014) (NWFSC 2015). For the 1990-2005 time series, trends were negative for 12 of 17 DIPs; and for the 1999-2014 time series, seven of eight DIPs had negative trends (Table 16). Only the Samish River/Bellingham Bay tributaries DIP had a positive trend for both time series (NWFSC 2015).

Table 16. Fifteen year trends for PS steelhead for two time series – 1990-2005 and 1999-2014 (NWFSC 2015).

Demographically Independent Populations	1990-2005		1999-2014	
	Trend	95% CI	Trend	95% CI
Central and South Puget Sound MPG				
Cedar River	-	-	-	-
Green River	-0.02	(-0.04, 0.01)	-	-
Nisqually River	-0.09	(-0.11, -0.07)	-	-
N. Lake WA/Lake Sammamish	-0.21	(-0.24, -0.18)	-	-
Puyallup/Carbon River	-0.09	(-0.11, -0.07)	-	-
White River	-0.04	(-0.06, -0.03)	-0.01	(-0.05, 0.02)
Hood Canal and Strait of Juan de Fuca MPG				
Dungeness River	-0.20	(-0.23, -0.17)	-	-
East Hood Canal Tribs.	0.00	(-0.02, 0.03)	-0.08	(-0.12, -0.04)
Elwha River	-	-	-	-
Sequim/Discovery Bay Tribs	-	-	-	-
Skokomish River	-0.03	(-0.05, -0.02)	-	-
South Hood Canal Tribs	0.01	(-0.01, 0.03)	-0.02	(-0.05, 0)
Strait of Juan de Fuca Tribs	0.04	(0.01, 0.07)	-0.02	(-0.06, 0.01)
West Hood Canal Tribs	-	-	-	-
North Cascades MPG				
Nooksack River	-	-	-	-
Pilchuck River	-0.04	(-0.06, -0.02)	-0.02	(-0.05, 0.01)
Samish River/Bellingham Bay Tribs	0.04	(0.02, 0.07)	0.02	(-0.01, 0.05)
Skagit River	-0.02	(-0.04, 0)	-	-
Snohomish/Skykomish Rivers	-0.05	(-0.08, -0.03)	-	-
Snoqualmie River	-0.03	(-0.06, -0.01)	-0.05	(-0.08, -0.02)
Stillaguamish River	-0.09	(-0.11, -0.06)	-	-
Tolt River	0.01	(-0.02, 0.04)	-0.02	(-0.06, 0.01)

Juvenile listed hatchery PS steelhead estimates come from the annual hatchery production goals. Hatchery production varies from year to year due to several factors including funding, equipment failures, human error, disease, and adult spawner availability. Funding uncertainties and the inability to predict equipment failures, human error, and disease suggests that average production from previous years is not a reliable estimate for future production. For these reasons, we will use production goals to estimate abundance. The combined production goal for listed PS steelhead hatchery stocks is 173,730 adipose-fin-clipped and non-clipped juveniles (Table 12).

Limiting Factors

Throughout the DPS, natural-origin steelhead production has shown, at best, a weak response to reduced harvest since the mid-1990s (Hard et al. 2007). Natural-origin production and productivity declines are most pervasive in the southern Puget Sound but occur throughout much of the DPS (NWFSC 2015). These trends primarily reflect patterns in winter-run steelhead—populations for which data are most plentiful. Patterns for most summer-run populations are unknown. Further, the Puget Sound Steelhead TRT identified freshwater habitat degradation and fragmentation with consequent effects on connectivity, as a primary limiting factor and threat facing the PS steelhead (Hard et al. 2007). Beyond that, the causes for the continued declines are somewhat unknown, but prominent causes include hatchery production, harvest management, and dam effects on habitat quality and quantity. Concerning habitat, the following issues continue to impede PS steelhead recovery throughout the fresh and marine waters of Puget Sound: untreated stormwater, contaminants, shoreline armoring, instream flows, impaired floodplain connectivity, and fish passage (NMFS 2016).

Status Summary

The Puget Sound Steelhead TRT recently concluded that the DPS was at very low viability, as were all three of its constituent MPGs, and many of its 32 DIPs (Hard et al. 2015). Over the past two to three years, there have been some minor increases in spawner abundance; but most of these improvements are small and abundance and productivity remain at levels of concern (NWFSC 2015). Furthermore, abundance trends remain predominantly negative. In addition, some aspects of diversity and spatial structure (i.e. natural spawning of hatchery fish, limited use of suitable habitat) are still likely to be limiting viability of most PS steelhead DIPs. Overall, the biological risk was determined to have not changed between the 2007 ESA listing, 2010 status review, and 2015 status review (NWFSC 2015).

2.2.2.4 Southern Eulachon

Description and Geographic Range

On March 16, 2010, NMFS listed the Southern DPS of eulachon (hereafter, “eulachon”) as a threatened species (75 FR 13012). This DPS encompasses all populations within the states of Washington, Oregon, and California and extends from the Skeena River in British Columbia south to the Mad River in Northern California (inclusive).

In May of 2011, the Committee on the Status for Endangered Wildlife in Canada (COSEWIC) released their assessment and status report for eulachon in Canada. COSEWIC divided the Canadian portion of the US designated Southern DPS into three designatable units (DUs) – Nass/Skeena Rivers population, Central Pacific Coast population, and Fraser River population (COSEWIC 2011a). DUs are discrete evolutionarily significant units, where “significant” means that the unit is important to the evolutionary legacy of the species as a whole and if lost would likely not be replaced through natural dispersion (COSEWIC 2009). Thus, DUs are biologically similar to ESU and DPS designations under the ESA. The Fraser River population (the closest Canadian population to the conterminous U.S.) was assessed as endangered by COSEWIC, and the listing decision for the Species at Risk Act (SARA) registry is currently scheduled for 2014 or later (COSEWIC 2011b).

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. Puget Sound lies between two of the larger eulachon spawning rivers (the Columbia and Fraser rivers) but lacks a regular eulachon run of its own (Gustafson et al. 2010). Within the conterminous U.S., most eulachon production originates in the Columbia River Basin and the major and most consistent spawning runs return to the Columbia River mainstem and Cowlitz River. Adult eulachon have been found at several Washington and Oregon coastal locations, and they were previously common in Oregon’s Umpqua River and the Klamath River in northern California. Runs occasionally occur in many other rivers and streams but often erratically, appearing in some years but not in others and only rarely in some river systems (Hay and McCarter 2000, Willson et al. 2006, Gustafson et al. 2010). Since 2005, eulachon in spawning condition have been observed nearly every year in the Elwha River by Lower Elwha Tribe Fishery Biologists (Lower Elwha Tribe, 2011). The Elwha is the only river in the United States' portion of Puget Sound and the Strait of Juan de Fuca that supports a consistent eulachon run.

Eulachon generally spawn in rivers fed by either glaciers or snowpack and that experience spring freshets. Because these freshets rapidly move eulachon eggs and larvae to estuaries, it is believed that eulachon imprint and home to an estuary into which several rivers drain rather than individual spawning rivers (Hay and McCarter 2000). From December to May, eulachon typically enter the Columbia River system with peak entry and spawning during February and March (Gustafson et al. 2010). They spawn in the lower Columbia River mainstem and multiple tributaries of the lower Columbia River.

Eulachon eggs, averaging 1 mm in size, are commonly found attached to sand or pea-sized gravel, though eggs have been found on a variety of substrates, including silt, gravel-to-cobble sized rock, and organic detritus (Smith and Saalfeld 1955, Langer et al. 1977, Lewis et al. 2002). Eggs found in areas of silt or organic debris reportedly suffer much higher mortality than those found in sand or gravel (Langer et al. 1977). Length of incubation ranges from about 28 days in 4°-5° C waters to 21-25 days in 8° C waters. Upon hatching, stream currents rapidly carry the newly hatched larvae, 4-8 mm in length, to the sea. Young larvae are first found in the estuaries of known spawning rivers and then disperse along the coast. After yolk sac depletion, eulachon larvae acquire characteristics to survive in oceanic conditions and move off into open marine environments as juveniles. Eulachon return to their spawning river at ages ranging from two to five years as a single age class. Prior to entering their spawning rivers, eulachon hold in brackish waters while their bodies undergo physiological changes in preparation for fresh water and to synchronize their runs. Eulachon then enter the rivers, move upstream, spawn, and die to complete their semelparous life cycle (COSEWIC 2011a).

Adult eulachon weigh an average of 40 g each and are 15 to 20 cm long with a maximum recorded length of 30 cm. They are an important link in the food chain between zooplankton and larger organisms. Small salmon, lingcod, white sturgeon, and other fish feed on small larvae near river mouths. As eulachon mature, a wide variety of predators consume them (Gustafson et al. 2010).

Spatial Structure and Diversity

There are no distinct differences among eulachon throughout the range of the southern DPS. However, the eulachon Biological Review Team (BRT) did separate the DPS into four subpopulations in order to rank threats they face. These are the Klamath River (including the Mad River and Redwood Creek), the Columbia River (including all of its tributaries), the Fraser River, and the BC coastal rivers (north of the Fraser River up to, and including, the Skeena River). Eulachon population structure has not been analyzed below the DPS level. The COSEWIC assessed eulachon populations in Canada and designated them with the following statuses: Nass/Skeena Rivers population (threatened), Central Pacific population (endangered), and Fraser River population (endangered) (COSEWIC 2011a).

Eulachon of the southern DPS are distinguished from eulachon occurring north of the DPS range by a number of factors including genetic characteristics. Significant microsatellite DNA variation in eulachon has been reported from the Columbia River to Cook Inlet, Alaska (Beacham et al. 2005). Within the range of the southern DPS, Beacham et al. (2005) found 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 diverging three to six times more from samples further to the north than they did from each other. Similar to the study of McLean et al. (1999), Beacham et al. (2005) found that genetic differentiation among populations was correlated with geographic distances. The authors also 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.

The BRT was concerned about risks to eulachon diversity due to its semelparity (spawn once and die) and data suggesting that Columbia and Fraser River spawning stocks may be limited to a single age class. These characteristics likely increase their vulnerability to environmental catastrophes and perturbations and provide less of a buffer against year-class failure than species such as herring that spawn repeatedly and have variable ages at maturity (Gustafson et al. 2010).

Abundance and Productivity

Eulachon are a short-lived, high-fecundity, high-mortality forage fish; and such species typically have extremely large population sizes. Fecundity estimates range from 7,000 to 60,000 eggs per female with egg to larva survival likely less than 1% (Gustafson et al. 2010). Among such marine species, high fecundity and mortality conditions may lead to random “sweepstake recruitment” events where only a small minority of spawning individuals contribute to subsequent generations (Hedgecock 1994).

Few direct estimates of eulachon abundance exist. Escapement counts and spawning stock biomass estimates are only available for a small number of systems. Catch statistics from commercial and First Nations fisheries are available for some systems in which no direct estimates of abundance are available. However, inferring population status or even trends from yearly catch statistic changes requires making certain assumptions that are difficult to corroborate (e.g., assuming that harvest effort and efficiency are similar from year to year, assuming a consistent relationship among the harvested and total stock portion, and certain statistical assumptions, such as random sampling). Unfortunately, these assumptions cannot be verified, few fishery-independent sources of eulachon abundance data exist, and in the United States, eulachon monitoring programs just started in 2011. However, the combination of catch records and anecdotal information indicates that there were large eulachon runs in the past and that eulachon populations have severely declined (Gustafson et al. 2010). As a result, eulachon numbers are at, or near, historically low levels throughout the range of the southern DPS.

Similar abundance declines have occurred in the Fraser and other coastal British Columbia rivers (Hay and McCarter 2000, Moody 2008). Over a three-generation time of 10 years (1999-2009), the overall Fraser River eulachon population biomass has declined by nearly 97% (Gustafson et al. 2010). In 1999, the biomass estimates were 418 metric tons[4]; and by 2010, had dropped to just 4

[4] The U.S. ton is equivalent to 2,000 pounds and the metric ton is equivalent to 2,204 pounds.

metric tons (Table 17). Abundance information is lacking for many coastal British Columbia subpopulations, but Gustafson et al. (2010) found that eulachon runs were universally larger in the past. Furthermore, the BRT was concerned that four out of seven coastal British Columbia subpopulations may be at risk of extirpation as a result of small population concerns such as Allee[5] effects and random genetic and demographic effects (Gustafson et al. 2010).

Table 17. Southern DPS eulachon spawning estimates for the lower Fraser River, British Columbia (data from http://www.pac.dfo-mpo.gc.ca/science/species-especes/pelagic-pelagique/herring-hareng/herspawn/pages/river1-eng.html).

Year	Biomass estimate (metric tons)	Estimated spawner population[a]
2006	29	725,000
2007	41	1,025,000
2008	10	250,000
2009	14	350,000
2010	4	100,000
2011	31	775,000
2012	120	3,000,000
2013	100	2,500,000
2014	66	1,650,000
2015	317	7,925,000
2011-2015[b]	**95.11**	**2,378,000**

[a] Estimated population numbers are calculated as 25,000 adults/metric ton (eulachon average 40g per adult).
[b] Five-year geometric mean of eulachon biomass estimates (2011-2015).

Under SARA, Canada designated the Fraser River population as endangered in May 2011 due to a 98% decline in spawning stock biomass over the previous 10 years (COSEWIC 2011a). From 2011 through 2015, the Fraser River eulachon spawner population estimate is 2,378,000 adults (Table 17).

The Columbia River and its tributaries support the largest known eulachon run. Although direct estimates of adult spawning stock abundance are limited, commercial fishery landing records begin in 1888 and continue as a nearly uninterrupted data set to 2010 (Gustafson et al. 2010). From about 1915 to 1992, historic commercial catch levels were typically more than 500 metric tons, occasionally exceeding 1,000 metric tons. In 1993, eulachon catch levels began to decline and averaged less than five metric tons from 2005-2008 (Gustafson et al. 2010). Persistent low eulachon returns and landings in the Columbia River from 1993 to 2000 prompted the states of Oregon and Washington to adopt a Joint State Eulachon Management Plan (WDFW and ODFW 2001). From 2011 through 2013, all recreational and commercial fisheries for eulachon were closed in Washington and Oregon; but the fisheries were reopened in 2014. Beginning in 2011, ODFW and Washington Department of Fish and Wildlife (WDFW) began eulachon biomass surveys similar to those conducted on the Fraser River. Five years of surveys have now been completed resulting in an

[5] The negative population growth observed at low population densities. Reproduction—finding a mate in particular—for migratory species can be increasingly difficult as the population density decreases.

estimate of 79,358,000 eulachon spawning adults for the Columbia River and its tributaries (Table 18).

Table 18. Southern DPS eulachon spawning estimates for the lower Columbia River and tributaries (Gustafson et al. 2016).

Year	Estimated biomass (metric tons)	Estimated number of spawners[a]
2011	1,500	36,800,000
2012	1,500	35,700,000
2013	4,400	107,700,000
2014	7,300	180,000,000
2015	5,000	123,582,000
2011-2015[b]	**3,248**	**79,358,000**

[a] Estimated spawner population numbers are calculated by estimating an assumed sex ratio of 1:1, a mean relative fecundity of 802.3 eggs per gram female bodyweight, an assumed egg to larval survival of 100%, and a mean fish weight of 40.6 g.

[b] Five-year geometric mean of mean eulachon biomass estimates (2011-2015).

In Northern California, no long-term eulachon monitoring programs exist. In the Klamath River, large eulachon spawning aggregations once regularly occurred but eulachon abundance has declined substantially (Fry 1979, Moyle et al. 1995, Larson and Belchik 1998, Hamilton et al. 2005). Recent reports from Yurok Tribal fisheries biologists mentioned only a few eulachon captured incidentally in other fisheries.

Beacham et al. (2005) reported that marine sampling by trawl showed that eulachon from different rivers mix during their 2 to 3 years of pre-spawning life in offshore marine waters, but not thoroughly. Their samples from southern British Columbia comprised a mix of fish from multiple rivers, but were dominated by fish from the Columbia and Fraser River populations. The combined estimate from the Columbia and Fraser rivers is 81.74 million eulachon.

Limiting Factors

Climate Change

Climate change impacts on ocean habitat are the most serious threat to persistence of the S eulachon (Gustafson et al. 2010), thus it will be discussed in greater detail in this section. Scientific evidence strongly suggests that global climate change is already altering marine ecosystems from the tropics to polar seas. Physical changes associated with warming include increases in ocean temperature, increased stratification of the water column, and changes in the intensity and timing of coastal upwelling. These changes will alter primary and secondary productivity and the structure of marine communities (ISAB 2007).

Although the precise changes in ocean conditions cannot be predicted they present a potentially severe threat to eulachon survival and recovery. Increases in ocean temperatures have already occurred and will likely continue to impact eulachon and their habitats. In the marine environment, eulachon rely upon cool or cold ocean regions and the pelagic invertebrate communities therein (Willson et al. 2006). Warming ocean temperatures will likely alter these communities, making it more difficult for eulachon and their larvae to locate or capture prey (Roemmich and McGowan 1995, Zamon and Welch 2005). Warmer waters could also allow for the northward expansion of eulachon predator and competitor ranges, increasing the already high predation pressure on the species (Rexstad and Pikitch 1986, McFarlane et al. 2000, Phillips et al. 2007).

Climate change along the entire Pacific Coast is expected to affect fresh water as well. Changes in hydrologic patterns may pose challenges to eulachon spawning because of decreased snowpack, increased peak flows, decreased base flow, changes in the timing and intensity of stream flows, and increased water temperatures (Morrison et al. 2002). In most rivers, eulachon typically spawn well before the spring freshet, near the seasonal flow minimum. This strategy typically results in egg hatch coinciding with peak spring river discharge. The expected alteration in stream flow timing may cause eulachon to spawn earlier or be flushed out of spawning rivers at an earlier date. Early emigration may result in a mismatch between entry of larval eulachon into the ocean and coastal upwelling, which could have a negative impact on marine survival of eulachon during this critical transition period (Gustafson et al. 2010).

Commercial and Recreational Harvest

In the past, commercial and recreational harvests likely contributed to eulachon decline. The best available information for catches comes from the Columbia River, where from 1938 to 1993 landings have averaged almost 2 million pounds per year (approximately 24.6 million fish), and have been as high as 5.7 million pounds in a single year (approximately 70 million fish) (Wydoski and Whitney 2003, Gustafson et al. 2010). Between 1994 and 2010, no catch exceeded one million pounds (approximately 12.3 million fish) annually and the median catch was approximately 43,000 pounds (approximately 529,000 fish), which amounts to a 97.7% reduction in catch (WDFW and ODFW 2001, JCRMS 2011). Catch from recreational eulachon fisheries was also high historically (Wydoski and Whitney 2003); and at its height in popularity, the fishery would draw thousands of participants annually. Currently, commercial and recreational harvest of eulachon is prohibited in both Washington and Oregon.

In British Columbia, the Fraser River supports the only commercial eulachon fishery that is within the range of the southern DPS. This fishery has been essentially closed since 1997, only opening briefly in 2002 and 2004 when only minor catches were landed (DFO 2008).

Shrimp Fishery Bycatch

Historically, bycatch of eulachon in the pink shrimp fishery along the U.S. and Canadian coasts has been very high (composing up to 28% of the total catch by weight; Hay and McCarter 2000, DFO 2008). Prior to the mandated use of bycatch-reduction devices (BRDs) in the pink shrimp fishery, 32–61% of the total catch in the pink shrimp fishery consisted of non-shrimp biomass, made up mostly of Pacific hake, various species of smelt including Pacific eulachon, yellowtail rockfish, sablefish, and lingcod (*Ophiodon elongatus*) (Hannah and Jones 2007). Reducing bycatch in this fishery has long been an active field of research (Hannah et al. 2003, Hannah and Jones 2007, Frimodig 2008) and great progress has been made in reducing bycatch. As of 2005, following required implementation of BRDs, the total bycatch by weight had been reduced to about 7.5% of the total catch and osmerid smelt bycatch was reduced to an estimated average of 0.73% of the total catch across all BRD types (Hannah and Jones 2007). Despite this reduction, bycatch of eulachon in these fisheries is still significant. The total estimated bycatch of eulachon in the Oregon and

California pink shrimp fisheries ranged from 217,841 fish in 2004 to 1,008,260 fish in 2010 (the most recent year that data is available; Al-Humaidhi et al. 2012).

Other Factors

Hydroelectric dams block access to historical eulachon spawning grounds and affect the quality of spawning substrates through flow management, altered delivery of coarse sediments, and siltation. Dredging activities during the eulachon spawning run may entrain and kill adult and larval fish and eggs. Eulachon carry high levels of pollutants – arsenic, lead, mercury, DDE, 9H-Fluorene, Phenanthrene (EPA 2002), and although it has not been demonstrated that high contaminant loads in eulachon have increased mortality or reduced reproductive success, such effects have been shown in other fish species (Kime 1995). The negative effects of these factors on the species and its habitat contributed to the determination to list the southern DPS of Pacific eulachon under the ESA.

Status Summary

Adult spawning abundance of the southern DPS of eulachon has clearly increased since the listing occurred in 2010 (Gustafson et al. 2015). The improvement in estimated abundance in the Columbia River, relative to the time of listing, reflects both changes in biological status and improved monitoring. The documentation of eulachon returning to the Naselle, Chehalis, Elwha, and Klamath rivers over the 2011–2015 also likely reflects both changes in biological status and improved monitoring. Although eulachon abundance in monitored populations has generally improved, especially in the 2013–2015 return years, recent poor ocean conditions and the likelihood that these conditions will persist into the near future suggest that population declines may be widespread in the upcoming return years. Therefore, it is too early to tell whether recent improvements in the southern DPS of eulachon will persist or whether a return to the severely depressed abundance years of the mid-late 1990s and late 2000s will reoccur (Gustafson et al. 2015).

2.2.3 Status of the Species' Critical Habitat

We review the status of designated critical habitat affected by the proposed action by examining the condition and trends of essential physical and biological features throughout the designated area. These features are essential to the conservation of the listed species because they support one or more of the species' life stages (e.g., sites with conditions that support spawning, rearing, migration, and foraging).

For salmon and steelhead, NMFS ranked watersheds within designated critical habitat at the scale of the fifth-field hydrologic unit code (HUC5) in terms of the conservation value they provide to each listed species they support[6]; the conservation rankings are high, medium, or low. To determine the conservation value of each watershed to species viability, NMFS' critical habitat analytical review teams (CHARTs; NOAA Fisheries 2005) evaluated the quantity and quality of habitat features (for example, spawning gravels, wood and water condition, side channels), the relationship of the area compared to other areas within the species' range, and the significance to the species of the population occupying that area. Thus, even a location that has poor quality of habitat could be

[6] The conservation value of a site depends upon "(1) the importance of the populations associated with a site to the ESU [or DPS] conservation, and (2) the contribution of that site to the conservation of the population through demonstrated or potential productivity of the area" (NOAA Fisheries 2005).

ranked with a high conservation value if it were essential due to factors such as limited availability (e.g., one of a very few spawning areas), a unique contribution of the population it served (e.g., a population at the extreme end of geographic distribution), or the fact that it serves another important role (e.g., obligate area for migration to upstream spawning areas).

2.2.3.1 Puget Sound Chinook Salmon

Critical habitat was designated for PS Chinook salmon on September 2, 2005, when NMFS published a final rule in the *Federal Register* (70 FR 52630). There are approximately 1,683 miles of stream habitats and 2,182 miles of nearshore marine habitats designated as critical habitat for PS Chinook salmon.

As part of the designation process, NMFS convened Critical Habitat Analytical Review Teams (CHART) to evaluate the current habitat status and identify habitat health threats. The Puget Sound CHART's assessment of habitat quality and identification of habitat threats is available on our website at: http://www.westcoast.fisheries.noaa.gov/publications/protected_species/salmon_steelhead/critical_habitat/chart_report/2005_chart_ps_chinook.pdf. In determining the areas eligible for critical habitat designation, the PS CHART identified the essential PBFs for species conservation. PS Chinook salmon PBFs are those sites and habitat components which support one or more life stages including freshwater spawning sites, freshwater rearing sites, freshwater migration corridors, and nearshore marine areas. Of the stream habitats designated as critical habitat, there are 926 miles of spawning/rearing sites, 215 miles of rearing/migration sites, and 542 miles of migration corridors. The 2,182 miles of designated nearshore marine habitats also contain rearing and migration PBFs. There are 61 watersheds within the range of this ESU. Twelve watersheds received a low rating, nine received a medium rating, and 40 received a high rating of conservation value to the ESU. Nineteen nearshore marine areas also received a rating of high conservation value.

PS Chinook salmon populations inhabit rivers and streams flowing into Puget Sound including the Straits of Juan De Fuca from the Elwha River, eastward. This includes rivers and streams flowing into Hood Canal, South Sound, North Sound, and the Strait of Georgia in Washington. This region experiences reduced rainfalls (50-120 cm) from the rainshadow effect of the Coast Mountains. The area is generally flat with high hills (600 m) at the southern margin of the ecoregion. Soils are composed of alluvial and lacustrine deposits. These deposits are glacial in origin north of Centralia, Washington. This area tends to have large groundwater resources, with groundwater from the bordering mountain ranges helping sustain river flows during drought periods. Peak river flow varies from December to June depending on the contribution of snowpack to surface runoff for each river system. Rivers tend to have sustained flows (five to eight months of flows at 50% of the peak or more), and low flows are generally 10-20% or more of the peak flows (Myers et al. 1998).

Douglas fir represents the primary subclimax forest species, with other coniferous species (lodgepole, western white, and ponderosa pines) locally abundant. Prairie, swamp, and oak, birch, or alder woodlands are also common. The land is heavily forested, and wood-cutting activities (including road building, etc.) contribute to soil erosion, river siltation, and river flow and temperature alteration. The region is heavily urbanized, and domestic and industrial wastes impact local water systems. Urban run-off and sewage treatment influence water quality west of the Cascade Mountains, with the exception of the Olympic Peninsula coastal and northern Puget Sound rivers. Glacial sediment also influences water quality, especially in the Skagit, North Fork Nooksack, Nisqually, and Puyallup/White River basins (Myers et al. 1998).

The PS CHART identified human activities that affect PBF quantity and quality. The major categories are (1) forestry; (2) grazing; (3) agriculture; (4) road building/maintenance; (5) channel modifications/diking; (6) urbanization; (7) sand and gravel mining; (8) dams; (9) irrigation impoundments and withdrawals; (10) river, estuary, and ocean traffic; and (11) wetland loss/removal. In addition to these, salmonid prey species harvest (e.g., herring, anchovy, and sardines) was found to affect nearshore marine PBFs. All of these activities affect PBFs by altering one or more of the following: stream hydrology, flow and water-level modifications, fish passage, geomorphology and sediment transport, temperature, dissolved oxygen, vegetation, soils, nutrients and chemicals, physical habitat structure, and stream/estuarine/marine biota and forage.

Habitat blockage and/or degradation occur throughout the PS Chinook salmon ESU range. In general, upper tributaries have been adversely affected by past forest practices, and lower tributaries and mainstem rivers have been degraded by agriculture and/or urbanization. Diking for flood control, draining and filling freshwater and estuarine wetlands, and sedimentation from timber harvests and urban development are cited as problems throughout the ESU (WDF et al. 1993). Blockages, water diversions, and shifts in flow regimes due to hydroelectric development and flood control projects are major habitat problems in several basins. Bishop and Morgan (1996) identified a variety of stream habitat limitations in the range of this species. These include: flow regime changes (all basins), sedimentation (all basins), high temperatures (Dungeness, Elwha, Green/Duwamish, Skagit, Snohomish, and Stillaguamish Rivers), streambed instability (most basins), estuarine loss (most basins), large woody debris loss (Elwha, Snohomish, and White Rivers), pool habitat loss (Nooksack, Snohomish, and Stillaguamish Rivers), and blockage or passage problems associated with dams or other structures (Cedar, Green/Duwamish, Snohomish, and White Rivers).

The Puget Sound Salmon Stock Review Group (PFMC 1997) extensively reviewed habitat conditions for several ESU stocks. They concluded that reductions in habitat quantity and quality have reduced PS Chinook salmon spawner numbers. Causes cited include tributary and mainstem habitat destruction, due to dams, and slough and side-channel habitat loss, due to diking, dredging, and hydromodification. They also noted habitat quality degradation due to land development activities.

2.2.3.2 Hood Canal Summer-run Chum Salmon

Critical habitat was designated for HCS chum salmon on September 2, 2005, when NMFS published a final rule in the *Federal Register* (70 FR 52630). There are approximately 79 miles of stream habitats and 377 miles of nearshore marine habitats designated as critical habitat for HCS chum salmon.

As part of the designation process, NMFS convened Critical Habitat Analytical Review Teams (CHART) to evaluate the current habitat status and identify habitat health threats. The Puget Sound CHART's assessment of habitat quality and identification of habitat threats is available on our website at
http://www.westcoast.fisheries.noaa.gov/publications/protected_species/salmon_steelhead/critical_h

abitat/chart_report/2005_chart_hc_chum.pdf. In determining the areas eligible for critical habitat designation, the PS CHART identified the PBFs essential for species conservation. PBFs for HCS chum salmon are those sites and habitat components that support one or more life stages including freshwater spawning sites, freshwater rearing sites, freshwater migration corridors, and nearshore marine areas. Designated critical habitat includes 34 miles of spawning/rearing sites, one mile of rearing/migration sites, 36 miles of migration corridors, and eight miles of unoccupied but essential habitat to ESU conservation. The 377 miles of designated nearshore marine habitats contain rearing and migration PBFs. There are 12 watersheds within the range of this ESU. Three watersheds received a medium rating and nine received a high rating of conservation value to the ESU. Five nearshore marine areas also received a rating of high conservation value.

The HCS chum salmon range from the Dungeness River (western boundary) clockwise around the Olympic Peninsula into and including Hood Canal. HCS chum salmon inhabit the Olympic Peninsula east of the Dungeness River including Discovery and Sequim Bays. Hood Canal is a 100-km-long, fjord-like, blind channel that extends to the west of Puget Sound. Beginning at the northern tip of the Kitsap Peninsula, the Canal runs southward along the eastern side of the Olympic Mountains, takes a sharp eastward turn at the hook-like Great Bend, and ends only a few kilometers from southern Puget Sound. The western shore is on the Olympic Peninsula, with river headwaters high in the Olympic Mountains. The eastern shore is on the Kitsap Peninsula, with rivers much gentler and without headwater snowpack. The Quilcene, Dosewallips, Duckabush, Hamma Hamma, and Skokomish Rivers on the western side of the Canal drain the eastern slope of the Olympic Mountains. These rivers tend to be steep, with cool water and high river flows even in summer. Big Beef Creek and the Dewatto, Tahuya, and Union Rivers drain the eastern shore of the Canal. They are smaller, lowland-type streams on the Kitsap Peninsula. The Kitsap Peninsula, part of a glacial drift plain that covers much of Puget Sound, consists of low rolling hills usually less than 154 m high. The streams have very low flow levels in late summer and early fall. The greater Hood Canal watershed is approximately 2,331 km^2.

The PS CHART identified human activities that affect PBF quantity and quality. The major categories are: (1) forestry; (2) agriculture; (3) road building/maintenance; (4) channel modifications/diking; (5) urbanization; (6) sand and gravel mining; (7) dams; (8) river, estuary, and ocean traffic; and (9) beaver removal. In addition to these, the harvest of salmonid prey species (e.g., herring, anchovy, and sardines) was found to affect nearshore marine PBFs. All of these activities affect PBFs by altering one or more of the following: stream hydrology, flow and water-level modifications, fish passage, geomorphology and sediment transport, temperature, dissolved oxygen, vegetation, soils, nutrients and chemicals, physical habitat structure, and stream/estuarine/marine biota and forage.

Stream channels and estuaries are, with few exceptions, moderately to highly degraded throughout the ESU. During the past 150 years, logging, road building, rural development, agriculture, water withdrawal, and channel manipulations (stream cleanout, dredging, and straightening) were common and widespread, especially within low gradient stream reaches utilized by summer chum salmon. Three quarters of the ESU’s watersheds contain simplified, degraded channels either completely lacking a forested riparian zone or surrounded by small diameter, deciduous-dominated forests. Most streams have degraded or reduced pool densities and large woody debris.

Over the past 150 years, development has occurred in nearly all estuaries within Hood Canal and the eastern Strait of Juan de Fuca. Degradation is severe in more than half of these estuaries with an additional 25% moderately degraded. Dikes, roads or causeways, remnant dikes or ditches, and fill are the primary causes of estuarine habitat degradation. In estuarine and nearshore areas, bulkheads, revetments, and impaired riparian corridors have reduced the amount of rearing habitat. Altered river and tidal dynamics have likely reduced estuarine food web productivity and, thus, the carrying capacity for chum salmon and other salmonids.

2.2.3.3 Puget Sound Steelhead

Critical habitat was designated for PS steelhead on February 24, 2016, when NMFS published a final rule in the Federal Register (81 FR 9252). There are approximately 2,031 miles of freshwater and estuarine habitat designated as critical habitat for PS steelhead.

As part of the designation process, NMFS convened a Puget Sound Critical Habitat Analytical Review Team (PS CHART) to evaluate the current habitat status and identify habitat health threats. The PS CHART's assessment of habitat quality and identification of habitat threats for PS steelhead is available on our website at: http://www.westcoast.fisheries.noaa.gov/protected_species/salmon_steelhead/salmon_and_steelhead_listings/steelhead/puget_sound/puget_sound_steelhead_proposed_critical_habitat_supporting_information.html. In determining the areas eligible for critical habitat designation, the PS CHART identified the essential PBFs for species conservation. PS steelhead PBFs are those sites and habitat components which support one or more life stages including freshwater spawning sites, freshwater rearing sites, freshwater migration corridors, estuarine areas, and nearshore marine areas. There are 18 subbasins containing 66 watersheds within the range of this DPS. Nine watersheds received a low rating, 16 received a medium rating, and 41 received a high rating of conservation value to the DPS. Additionally, one unoccupied area in the upper Elwha River watershed was identified as essential for the conservation of the species and is being designated as critical habitat.

PS steelhead populations inhabit rivers and streams flowing into Puget Sound including the Straits of Juan De Fuca from the Elwha River, eastward. The Puget Sound region is in the rain shadow of the Olympic Mountains and therefore is drier than the Olympic Peninsula; most of the Puget Sound region averages less than 160 cm of precipitation annually. Puget Sound rivers generally have high relief in the headwaters and extensive alluvial floodplains in the lowlands. The area is generally flat with high hills (600 m) at the southern margin of the ecoregion. Geology and topography are dominated by the effects of the Cordilleran Ice Sheet as evidenced by glacial deposits (alluvial and lacustrine deposits) and the regional geomorphology (Busby et al. 1996). This area tends to have large groundwater resources, with groundwater from the bordering mountain ranges helping sustain river flows during drought periods. Peak river flow varies from December to June depending on the snowpack to surface runoff contribution for each river system. Rivers tend to have sustained flows (five to eight months of flows at 50% of the peak or more), and low flows are generally 10-20% or more of the peak flows (Myers et al. 1998).

Douglas fir represents the primary subclimax forest species, with other coniferous species (lodgepole, western white, and ponderosa pines) locally abundant. Prairie, swamp, and oak, birch, or alder woodlands are also common. The land is heavily forested, and wood-cutting activities (including road building, etc.) contribute to soil erosion, river siltation, and river flow and temperature alteration. The region is heavily urbanized, and domestic and industrial wastes impact local water systems. Urban run-off and sewage treatment influence water quality west of the Cascade Mountains, with the exception of the Olympic Peninsula coastal and northern Puget Sound rivers. Glacial sediment also influences water quality, especially in the Skagit, North Fork Nooksack, Nisqually, and Puyallup/White River basins (Myers et al. 1998).

The PS CHART identified human activities that affect PBF quantity and quality. The major categories are (1) forestry; (2) grazing; (3) agriculture; (4) road building/maintenance; (5) channel modifications/diking; (6) urbanization; (7) sand and gravel mining; (8) mineral mining; (9) dams; (10) irrigation impoundments and withdrawals; (11) river, estuary, and ocean traffic; (12) wetland loss/removal; (13) beaver removal; and (14) exotic/invasive species introductions. In addition to these, salmonid prey species harvest (e.g., herring, anchovy, and sardines) was found to affect nearshore marine PBFs. All of these activities affect PBFs by altering one or more of the following: stream hydrology, flow and water-level modifications, fish passage, geomorphology and sediment transport, temperature, dissolved oxygen, vegetation, soils, nutrients and chemicals, physical habitat structure, and stream/estuarine/marine biota and forage.

Dams have dramatically affected steelhead habitat use in a number of Puget Sound subbasins. In addition to eliminating accessible habitat, dams affect habitat quality by changing river hydrology, temperature profiles, downstream gravel recruitment, and large woody debris movement. Dams have impeded upstream access to historical steelhead habitat in the following systems: Middle Fork Nooksack River, Baker River, Cedar River, Green River, White River, Nisqually River basin, and North Fork Skokomish River. Trap and haul programs have made passage above the dams on the Baker River and White River possible. A smolt collection facility has allowed downstream passage possible on the Baker River. On the White River, downstream migrants pass directly through the dams. Overall, passage efficiency is higher for larger (yearling) smolts (e.g., coho and sockeye salmon and steelhead) that migrate near the surface than for subyearling smolts (Chinook, chum, and pink salmon).

Urban development has dramatically altered many of the lower reaches of rivers and their tributaries in Puget Sound. Urbanization has destroyed historical land cover and exchanged it for large areas of imperious surface (buildings, roads, parking lots, etc.). Wetland and riparian habitat loss has dramatically changed urban stream hydrology by increasing flood frequency and peak flows during storm events while decreasing groundwater-driven summer flows. Agricultural land development has altered the historical land cover and directly impacted river morphology, since much of this development occurs in river floodplains. Dike construction, bank hardening, and channelization have reduced river braiding and sinuosity. Constricting a river, especially during high flow events, increases the likelihood of gravel scour and the dislocation of rearing juveniles.

Habitat blockage and/or degradation occur throughout the PS steelhead DPS range. In general, upper tributaries have been adversely affected by past forest practices, and lower tributaries and mainstem rivers have been degraded by agriculture and/or urbanization. Diking for flood control, draining and filling freshwater and estuarine wetlands, and sedimentation from timber harvests and urban development are cited as problems throughout the DPS (WDF et al. 1993). Blockages, water diversions, and shifts in flow regimes due to hydroelectric development and flood control projects are major habitat problems in several basins. Bishop and Morgan (1996) identified a variety of stream habitat limitations in the range of this species. These include: flow regime changes (all basins), sedimentation (all basins), high temperatures (Dungeness, Elwha, Green/Duwamish, Skagit, Snohomish, and Stillaguamish Rivers), streambed instability (most basins), estuarine loss (most basins), large woody debris loss (Elwha, Snohomish, and White Rivers), pool habitat loss (Nooksack, Snohomish, and Stillaguamish Rivers), and blockage or passage problems associated with dams or other structures (Cedar, Green/Duwamish, Snohomish, and White Rivers).

2.2.3.4 Southern Eulachon

Critical habitat was designated for S eulachon on October 20, 2011, when NMFS published a final rule in the *Federal Register* (76 FR 65324). NMFS designated 16 specific areas as critical habitat within the states of California, Oregon, and Washington. The designated areas are a combination of freshwater creeks and rivers and their associated estuaries, comprising approximately 335 miles of habitat; but no marine areas, including Puget Sound and the Strait of Juan de Fuca, were designated as critical habitat. Areas designated for critical habitat in Washington state include the Columbia River (from the mouth to Bonneville Dam), Grays River, Skamokawa Creek, Elochoman River, Cowlitz River, Toutle River, Kalama River, Lewis River, Quinault River, and Elwha River. The Tribal lands of Lower Elwha Tribe and Quinault Tribe are excluded from critical habitat designation.

As part of the designation process, NMFS evaluated the current status of the habitat and identified threats to habitat health. The assessment of habitat quality and identification of habitat threats is available on our website at http://www.westcoast.fisheries.noaa.gov/protected_species/eulachon/eulachon_critical_habitat.html . In determining what areas are eligible for critical habitat designation, the physical or biological features essential to the conservation of the southern DPS were analyzed as three major categories reflecting key life-history phases of eulachon. Freshwater spawning and incubation sites are essential for successful spawning and offspring production; essential environmental components include specific water flow, quality, and temperature conditions; spawning and incubation substrates; and migratory access. Freshwater and estuarine migration corridors, associated with spawning and incubation sites, are essential for allowing adult fish to swim upstream to reach spawning areas and allowing larval fish to proceed downstream and reach the ocean. Essential environment components include waters free of obstruction; specific water flow, quality, and temperature conditions (for supporting larval and adult mobility), and abundant prey items (for supporting larval feeding after the yolk sac depletion). Nearshore and offshore marine foraging habitat are essential for juvenile and adult survival; essential environmental components include water quality and available prey.

NMFS has identified numerous activities that may affect the physical and biological features essential to eulachon such that special management considerations or protection may be required. Major categories of such activities include: (1) dams and water diversions (i.e. Bonneville Dam, SRS structure – NF Toutle River); (2) dredging and disposal of dredged material (i.e. Cowlitz and Columbia rivers); (3) in-water construction or alterations; (4) pollution and runoff from point and non-point sources (i.e. agriculture, logging, urban); (5) tidal, wind, or wave energy projects; (6) port and shipping terminals; and (7) habitat restoration projects (i.e. salmon habitat restoration goals are different than those for eulachon). All of these activities may have an effect on one or more of the essential physical and biological features via their alteration of one or more of the following: stream hydrology; water level, flow, temperature and dissolved oxygen levels; erosion and sediment input/transport; physical habitat structure; vegetation; soils; nutrients and chemicals; fish passage; and estuarine/marine prey resources.

2.3 Action Area

"Action area" means all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR 402.02). For the purposes of this opinion, the action area includes all river reaches accessible to listed Chinook salmon, chum salmon, and steelhead in all sub-basins of Puget Sound. Additionally, the action area includes all marine waters off the West Coast of the continuous United States, including nearshore waters from the Mexican to Canadian borders and Puget Sound, accessible to listed Chinook salmon, chum salmon, coho salmon, sockeye salmon, steelhead, eulachon, green sturgeon, and rockfish. Where it is possible to narrow the range of the research, the effects analysis would take that limited geographic scope into account when determining the proposed actions' impacts on the species and their critical habitat.

In all cases, the proposed research activities would take place in individually very small sites. For example, the researchers might electrofish a few hundred feet of river, deploy a beach seine covering only a few hundred square feet of stream, or operate a screw trap in a few tens of square feet of habitat. Many of all the proposed actions would take place in designated critical habitat. More detailed habitat information (i.e., migration barriers, physical and biological habitat features, and special management considerations) for species considered in this opinion may be found in the Federal Register notices designating critical habitat for HCS chum salmon and PS Chinook salmon (70 FR 52630); S eulachon (76 FR 65324); and PS steelhead (81 FR 9252).

2.4 Environmental Baseline

The "environmental baseline" includes the past and present impacts of all Federal, state, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of state or private actions which are contemporaneous with the consultation in process (50 CFR 402.02). The environmental baseline for this opinion is therefore the result of the impacts that many activities (summarized below and in the species' status sections) have had on the various listed species' survival and recovery. The action area under consideration covers individual animals that could come from anywhere in the various listed species' entire ranges (see Section 2.3). As a result, the effects of these past activities on the species themselves (effects on abundance, productivity, etc.) cannot be tied to any particular population and are therefore displayed individually in the species status sections that precede this section (see Section 2.2). That is, for the majority of the work being contemplated here, the physical result of activities in the action area are indistinguishable from those effects described in the previous section on the species' rangewide status. In general, though, and with respect to the species' habitat, the environmental baseline is the culmination of these effects on the physical or biological features (PBFs) that are essential to the conservation of the species.

2.4.1 Summary for all Listed Species

2.4.1.1 Factors Limiting Recovery

The best scientific information presently available demonstrates that a multitude of factors, past and present, have contributed to the decline of west coast salmonids. NMFS' status reviews, Technical Recovery Team publications, and recovery plans for the listed species considered in this opinion identify several factors that have caused them to decline, as well as those that prevent them from recovering (many of which are the same). Very generally, these include habitat degradation and curtailment caused by human development and harvest and hatchery practices. NMFS' decision to list them identified a variety of factors that were limiting their recovery. None of these documents identifies scientific research as either a cause for decline or a factor preventing their recovery. See Table 19 for a summary of the major factors limiting recovery of the listed species considered in this opinion; more details can also be found in the individual discussions of the species' status.

Table 19. Major factors limiting recovery.

	PS Chinook salmon	HCS chum salmon	PS steelhead	S eulachon
Degraded floodplain and in-river channel structure	•		•	
Riparian area degradation and loss of in-river large woody debris	•	•	•	
Degraded tributaries/river habitat conditions		•		
Reduced access to spawning/rearing habitat			•	•
Degraded estuarine conditions and loss of estuarine habitat	•	•	•	
Excessive sediment in spawning gravels	•	•	•	
Degraded water quality	•		•	•
High water temperature	•		•	
Reduced streamflow in migration areas				
Predation on adults and juveniles		•		•
Chemical pollutants				•
Bycatch				•
Degradation of nearshore habitats	•			
Climate change	•	•	•	•

For detailed information on how various factors have degraded PBFs, please see any of the following: Busby et al. 1996, Good et al. 2005, Moyle et al. 2008, Gustafson et al. 2010, Ford 2011, NMFS 2016, NWFSC 2016, and sections 2.2.3.1-2.2.3.4.

Research Effects

Although not identified as a factor for decline or a threat preventing recovery, scientific research and monitoring activities have the potential to affect the species' survival and recovery by killing listed salmonids—whether intentionally or not. For the year 2017, NMFS has issued numerous research section 10(a)(1)(A) scientific research permits allowing lethal and non-lethal take of listed species, along with the state scientific research programs under ESA section 4(d) research. Table 20 displays the total take for the ongoing research authorized under ESA sections 4(d) and 10(a)(1)(A).

Table 20. Total authorized take and mortalities of ESA listed species for scientific research and monitoring as of December 2016.

Species	Life Stage	Origin[a]	Total Take	Percent of Abundance	Lethal Take	Percent of ESU/DPS killed
PS Chinook salmon[b]	Adult	LHAC	1,461	17.04606%	78	0.70332%
		LHIA	793		15	
		Natural	898	4.66300%	36	0.18694%
	Juvenile	LHAC	73,007	0.20397%	9,862	0.02755%
		LHIA	153,053	2.54361%	5,662	0.09410%
		Natural	345,625	13.30105%	6,887	0.26504%
HCS chum salmon	Adult	LHIA	0	0.00000%	0	0.00000%
		Natural	1,791	8.58787%	30	0.14385%
	Juvenile	LHIA	185	0.12333%	4	0.00267%
		Natural	708,387	21.02917%	4,549	0.13504%
PS steelhead[c]	Adult	LHAC	36	10.45299%	6	0.26822%
		LHIA	11		0	
		Natural	1,356		30	
	Juvenile	LHAC	4,900	2.95364%	115	0.06932%
		LHIA	2,830	3.58228%	30	0.03797%
		Natural	47,344	3.10096%	915	0.05993%
S eulachon[d]	Adult	Natural	35,543	0.04349%	32,888	0.04024%

[a] LHAC=Listed Hatchery Adipose Clipped, LHIA = Listed Hatchery Intact Adipose.
[b] Abundances for adult hatchery salmonids are LHAC and LHIA combined.
[c] Abundances for all adult PS steelhead are combined
[d] Abundances for juvenile listed eulachon are unknown

Actual take levels associated with these activities are almost certain to be a good deal lower than the allowed levels. There are several reasons for this. First, the juvenile abundance estimates are deliberately designed to generate a conservative picture of abundance. Second, it is important to remember that estimates of lethal take for most of the proposed studies are purposefully inflated to account for potential accidental deaths and it is therefore very likely that fewer juveniles would be killed by the research than stated. In fact, for the vast majority of scientific research permits, history has shown that researchers generally take far fewer salmonids than the allotted number of salmonids every year (14.16% of requested take and 12.66% of requested mortalities were used in ID, OR, and WA Section 10a1A permits from 2008 to 2015). Third, for salmonids, many of the fish that may be affected would be in the smolt stage, but others definitely would not be. These latter would simply be described as "juveniles," which means they may actually be yearlings, parr, or even fry: life stages represented by multiple spawning years and many more individuals than reach the smolt stage—perhaps as much as an order of magnitude more. Therefore, the already small percentages were derived by (a) conservatively estimating the actual number of juveniles, (b) overestimating the number of fish likely to be killed, and (c) treating each dead juvenile fish as part of the same year class. Thus, the actual numbers of juvenile salmonids the research is likely to kill are undoubtedly smaller than the stated figures—probably something on the order of one seventh of the values given in the tables.

2.5 Effects of the Proposed Actions on the Species and Their Designated Critical Habitat

Under the ESA, "effects of the action" means the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline (50 CFR 402.02). Indirect effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur.

2.5.1 Effects on the Species

As discussed further below, the proposed research activities will have no measurable effects on the habitat of listed salmonids or eulachon. The actions are therefore not likely to measurably affect any of the listed species by reducing their habitat's ability to contribute to their survival and recovery.

The primary effect of the proposed research will be on the listed species in the form of capturing and handling the fish. Harassment caused by capturing, handling, and releasing fish generally leads to stress and other sub-lethal effects, but the fish do sometimes die from such treatment.

The following subsections describe the types of activities being proposed. Each is described in terms broad enough to apply to the entire Tribal Plan (2017-2021). The activities would be carried out by trained professionals using established protocols. The effects of the activities are well documented and discussed in detail below. No researcher would receive authorization unless the activities (e.g., electrofishing) incorporate NMFS' uniform, pre-established set of mitigation measures. These measures are described in Section 1.3 of this opinion. They are incorporated (where relevant) into the Tribal Plan (2017-2021) as part of the conditions to which a researcher must adhere.

Capture/handling

Any physical handling or disturbance is known to be stressful to fish (Sharpe et al. 1998). The primary contributing factors to stress and death from handling are excessive doses of anesthetic, differences in water temperatures (between the river and wherever the fish are held), dissolved oxygen conditions, the amount of time that fish are held out of the water, and physical trauma. Stress on salmonids increases rapidly from handling if the water temperature exceeds 18ºC or dissolved oxygen is below saturation. Fish that are transferred to holding tanks can experience trauma if care is not taken in the transfer process, and fish can experience stress and injury from overcrowding in traps if the traps are not emptied regularly. Decreased survival of fish can result when stress levels are high because stress can be immediately debilitating and may also increase the potential for vulnerability to subsequent challenges (Sharpe et al. 1998). Debris buildup at traps can also kill or injure fish if the traps are not monitored and cleared regularly. The conditions identified earlier in subsection 1.3 contain measures that mitigate the factors that commonly lead to stress and trauma from handling, and thus minimize the harmful effects of capturing and handling fish. When these measures are followed, fish typically recover fairly rapidly from handling.

Electrofishing

Electrofishing is a process by which an electrical current is passed through water containing fish in order to stun them—thus making them easy to capture. It can cause a suite of effects ranging from simply disturbing the fish to actually killing them. The amount of unintentional mortality attributable to electrofishing varies widely depending on the equipment used, the settings on the equipment, and the expertise of the technician. Electrofishing can have severe effects on adult salmonids. Spinal injuries in adult salmonids from forced muscle contraction have been documented. Sharber and Carothers (1988) reported that electrofishing killed 50 percent of the adult rainbow trout in their study.

Most of the studies on the effects of electrofishing on fish have been conducted on adult fish greater than 300 mm in length (Dalbey et al. 1996). The relatively few studies that have been conducted on juvenile salmonids indicate that spinal injury rates are substantially lower than they are for large fish. Smaller fish are subjected to a lower voltage gradient than larger fish (Sharber and Carothers 1988) and may therefore be subject to lower injury rates (e.g., Hollender and Carline 1994, Dalbey et al. 1996, Thompson et al. 1997). McMichael et al. (1998) found a 5.1% injury rate for juvenile Middle Columbia River steelhead captured by electrofishing in the Yakima River subbasin. The incidence and severity of electrofishing damage is partly related to the type of equipment used and the waveform produced (Sharber and Carothers 1988, McMichael 1993, Dalbey et al. 1996; Dwyer and White 1997). Continuous direct current (DC) or low-frequency (30 Hz) pulsed DC have been recommended for electrofishing (Fredenberg 1992; Snyder 1992 and 1995; Dalbey et al. 1996) because lower rates of spinal injury, particularly in salmonids, occur with these waveforms (Fredenberg 1992, McMichael 1993, Sharber et al. 1994, Dalbey et al. 1996). Only a few recent studies have examined the long-term effects of electrofishing on salmonid survival and growth (Dalbey et al. 1996, Ainslie et al. 1998). These studies indicate that although some of the fish suffer spinal injury, few die as a result. However, severely injured fish grow at slower rates and sometimes they show no growth at all (Dalbey et al. 1996).

NMFS' electrofishing guidelines (NMFS 2000) will be followed in all electrofishing surveys. The guidelines require that field crews be trained in observing animals for signs of stress and shown how to adjust electrofishing equipment to minimize that stress. All areas are visually searched for fish before electrofishing may begin. Electrofishing is not done in the vicinity of redds or spawning adults. All electrofishing equipment operators are trained by qualified personnel to be familiar with equipment handling, settings, maintenance, and safety. Operators work in pairs to increase both the number of fish that may be seen and the ability to identify individual fish without having to net them. Working in pairs also allows the researcher to net fish before they are subjected to higher electrical fields. Only DC units are used, and the equipment is regularly maintained to ensure proper operating condition. Voltage, pulse width, and rate are kept at minimal levels and water conductivity is tested at the start of every electrofishing session so those minimal levels can be determined. Due to the low settings used, shocked fish normally revive instantaneously. Fish requiring revivification receive immediate, adequate care. In all cases, electrofishing is used only when other survey methods are not feasible.

The preceding discussion focused on the effects of using a backpack unit for electrofishing and the ways those effects would be mitigated. In larger streams and rivers, however, electrofishing units are sometimes mounted on boats or rafts. These units often use more current than backpack electrofishing equipment because they need to cover larger (and deeper) areas and, as a result, can have a greater impact on fish. In addition, the environmental conditions in larger, more turbid streams can limit researchers' ability to minimize impacts on fish. That is, in areas of lower visibility it can be difficult for researchers to detect the presence of adults and thereby take steps to avoid them. Because of its greater potential to harm fish, and because NMFS has not published appropriate guidelines, boat electrofishing has not been given a general authorization under NMFS' ESA section 4(d) rules. In any case, all researchers intending to use boat electrofishing would use all means at their disposal to ensure that a minimum number of fish are harmed.

Gastric Lavage

Knowledge of the food and feeding habits of fish are important in the study of aquatic ecosystems. However, in the past, food habit studies required researchers to kill fish for stomach removal and examination. Consequently, several methods have been developed to remove stomach contents without injuring the fish. Most techniques use a rigid or semi-rigid tube to inject water into the stomach to flush out the contents.

Few assessments have been conducted regarding the mortality rates associated with nonlethal methods of examining fish stomach contents (Kamler and Pope 2001). However, Strange and Kennedy (1981) assessed the survival of salmonids subjected to stomach flushing and found no difference between stomach-flushed fish and control fish that were held for three to five days. In addition, when Light et al. (1983) flushed the stomachs of electrofished and anesthetized brook trout, survival was 100% for the entire observation period. In contrast, Meehan and Miller (1978) determined the survival rate of electrofished, anesthetized, and stomach flushed wild and hatchery coho salmon over a 30-day period to be 87% and 84% respectively.

Hook and Line

Fish that are caught and released alive as part of a research project may still die as a result of injuries or stress they experience during capture and handling. The likelihood of killing a fish varies widely, based on a number of factors including the gear type used, the species, the water conditions, and the care with which the fish is released.

The available information assessing hook and release mortality of adult steelhead suggests that hook and release mortality is low. Hooton (1987) found catch and release mortality of adult winter steelhead to average 3.4% (127 mortalities of 3,715 steelhead caught) when using barbed and barbless hooks, bait, and artificial lures. Among 336 steelhead captured on various combinations of popular terminal gear in the Keogh River, the mortality of the combined sample was 5.1%. Natural bait had slightly higher mortality (5.6%) than did artificial lures (3.8%), and barbed hooks (7.3%) had higher mortality than barbless hooks (2.9%). Hooton (1987) concluded that catching and releasing adult steelhead was an effective mechanism for maintaining angling opportunity without negatively impacting stock recruitment. Reingold (1975) showed that adult steelhead hooked, played to exhaustion, and then released returned to their target spawning stream at the same rate as steelhead not hooked and played to exhaustion. Pettit (1977) found that egg viability of hatchery steelhead was not negatively affected by catch-and-release of pre-spawning adult female steelhead. Bruesewitz (1995) found, on average, fewer than 13% of harvested summer and winter steelhead in

Washington streams were hooked in critical areas (tongue, esophagus, gills, eye). The highest percentage (17.8%) of critical area hookings occurred when using bait and treble hooks in winter steelhead fisheries.

The referenced studies were conducted when water temperatures were relatively cool, and primarily involve winter-run steelhead. Data on summer-run steelhead and warmer water conditions are less abundant (Cramer et al. 1997). Catch and release mortality of steelhead is likely to be higher if the activity occurs during warm water conditions. In a study conducted on the catch and release mortality of steelhead in a California river, Taylor and Barnhart (1999) reported over 80% of the observed mortalities occurred at stream temperatures greater than 21 degrees C. Catch and release mortality during periods of elevated water temperature are likely to result in post-release mortality rates greater than reported by Hooton (1987) because of warmer water and that fact that summer fish have an extended freshwater residence that makes them more likely to be caught. As a result, NOAA Fisheries expects steelhead hook and release mortality to be in the lower range discussed above.

Juvenile steelhead occupy many waters that are also occupied by resident trout species and it is not possible to visually separate juvenile steelhead from similarly-sized, stream-resident, rainbow trout. Because juvenile steelhead and stream-resident rainbow trout are the same species, are similar in size, and have the same food habits and habitat preferences, it is reasonable to assume that catch-and-release mortality studies on stream-resident trout are similar for juvenile steelhead. Where angling for trout is permitted, catch-and-release fishing with prohibition of use of natural or synthetic bait reduces juvenile steelhead mortality more than any other angling regulatory change. Many studies have shown trout mortality to be higher when using bait than when angling with artificial lures and/or flies (Taylor and White 1992; Schill and Scarpella 1995; Mongillo 1984; Wydoski 1977; Schisler and Bergersen 1996). Wydoski (1977) showed the average mortality of trout, when using bait, to be more than four times greater than the mortality associated with using artificial lures and flies. Taylor and White (1992) showed average mortality of trout to be 31.4% when using bait versus 4.9 and 3.8% for lures and flies, respectively. Schisler and Bergersen (1996) reported average mortality of trout caught on passively fished bait to be higher (32%) than mortality from actively fished bait (21%). Mortality of fish caught on artificial flies was only 3.9%. In the compendium of studies reviewed by Mongillo (1984), mortality of trout caught and released using artificial lures and single barbless hooks was often reported at less than 2%.

Most studies have found little difference (or inconclusive results) in the mortality of juvenile steelhead associated with using barbed versus barbless hooks, single versus treble hooks, and different hook sizes (Schill and Scarpella 1995; Taylor and White 1992; Mongillo 1984). However, some investigators believe that the use of barbless hooks reduces handling time and stress on hooked fish and adds to survival after release (Wydoski 1977). In summary, catch-and-release mortality of juvenile steelhead is generally less than 10% and approaches 0% when researchers are restricted to use of artificial flies and lures. As a result, all steelhead sampling via angling must be carried out using barbless artificial flies and lures.

Only a few reports are available that provide empirical evidence showing what the catch and release mortality is for Chinook salmon in freshwater. The ODFW has conducted studies of hooking mortality incidental to the recreational fishery for Chinook salmon in the Willamette River. A study of the recreational fishery estimates a per-capture hook-and-release mortality for wild spring

Chinook in Willamette River fisheries of 8.6% (Schroeder et al. 2000), which is similar to a mortality of 7.6% reported by Bendock and Alexandersdottir (1993) in the Kenai River, Alaska.

A second study on hooking mortality in the Willamette River, Oregon, involved a carefully controlled experimental fishery, and mortality was estimated at 12.2% (Lindsay et al. 2004). In hooking mortality studies, hooking location and gear type is important in determining the mortality of released fish. Fish hooked in the jaw or tongue suffered lower mortality (2.3 and 17.8% in Lindsay et al. (2004) compared to fish hooked in the gills or esophagus (81.6 and 67.3%). A large portion of the mortality in the Lindsay et al. (2004) study was related to deep hooking by anglers using prawns or sand shrimp for bait on two-hook terminal tackle. Other baits and lures produced higher rates of jaw hooking than shrimp, and therefore produced lower hooking mortality estimates. The Alaska study reported very low incidence of deep hooking by anglers using lures and bait while fishing for salmon.

Based on the available data, the U.S. v. Oregon Technical Advisory Committee has adopted a 10% rate in order to make conservative estimates of incidental mortality in fisheries (TAC 2008). Nonetheless, given the fact that no ESA section 10 permit or 4(d) authorization may “operate to the disadvantage of the species,” we allow no more than a three percent mortality rate for any listed species collected via angling, and all such activities must employ barbless artificial lures and flies.

Observing/Harassing

For some parts of the proposed studies, listed fish would be observed in-water (e.g., by snorkel surveys or from the banks). Direct observation is the least disruptive method for determining a species’ presence/absence and estimating their relative numbers. Its effects are also generally the shortest-lived and least harmful of the research activities discussed in this section because a cautious observer can effectively obtain data while only slightly disrupting the fishes’ behavior. Fry and juveniles frightened by the turbulence and sound created by observers are likely to seek temporary refuge in deeper water or behind or under rocks or vegetation. In extreme cases, some individuals may leave a particular pool or habitat type and then return when observers leave the area. At times the research involves observing adult fish—which are more sensitive to disturbance. During some of the research activities discussed below, redds may be visually inspected, but per NMFS’ pre-established mitigation measures (included in state fisheries agency submittals), would not be walked on. Harassment is the primary form of take associated with these observation activities, and few if any injuries (and no deaths) are expected to occur—particularly in cases where the researchers observe from the stream banks rather than in the water. Because these effects are so small, there is little a researcher can do to mitigate them except to avoid disturbing sediments, gravels, and, to the extent possible, the fish themselves, and allow any disturbed fish the time they need to reach cover.

Sacrifice

In some instances, it is necessary to kill a captured fish in order to gather whatever data a study is designed to produce. In such cases, determining the effect is straightforward: the sacrificed fish, if juveniles, are killed; if the fish are adults, the effect depends upon whether they are killed before or after they have a chance to spawn. If they are killed after they spawn, there is very little overall effect. Essentially, it amounts to removing the nutrients their bodies would have provided to the spawning grounds. If they are killed before they spawn, not only are they removed from the DPS/ESU, but so are all their potential progeny. Thus, killing pre-spawning adults has the greatest potential to affect the listed species. Because of this, NMFS rarely allows it to happen. And, in almost every instance where it is allowed, the adults are stripped of sperm and eggs so their progeny can be raised in a controlled environment such as a hatchery—thereby mitigating the potential harm posed by sacrificing the adults.

Screw trapping

Smolt, rotary screw (and other out-migration) traps, are generally used to obtain information on natural population abundance and productivity. On average, they achieve a sample efficiency of four to 20% of the emigrating population from a river or stream--depending on river size. Although under some conditions traps may achieve a higher efficiency for a relatively short period of time (NMFS 2003). Based on years of sampling at hundreds of locations under hundreds of scientific research authorizations, we would expect the mortality rates for fish captured at rotary screw type traps to be one percent or less.

The trapping, capturing, or collecting and handling of juvenile fish using traps is likely to cause some stress on listed fish. However, fish typically recover rapidly from handling procedures. The primary factors that contribute to stress and mortality from handling are excessive doses of anesthetic, differences in water temperature, dissolved oxygen conditions, the amount of time that fish are held out of water, and physical trauma. Stress on salmonids increases rapidly from handling if the water temperature exceeds 64.4 degrees F (18 degrees C) or if dissolved oxygen is below saturation. Additionally, stress can occur if there are more than a few degrees difference in water temperature between the stream/river and the holding tank.

The potential for unexpected injuries or mortalities among listed fish is reduced in a number of ways. These can be found in the individual study protocols and in the conditions stated earlier. In general, screw traps are checked at least daily and usually fish are handled in the morning. This ensures that the water temperature is at its daily minimum when fish are handled. Also, fish may not be handled if the water temperature exceeds 69.8 degrees Fahrenheit (21 degrees C). Great care must be taken when transferring fish from the trap to holding areas and the most benign methods available are used—often this means using sanctuary nets when transferring fish to holding containers to avoid potential injuries. The investigators' hands must be wet before and during fish handling. Appropriate anesthetics must be used to calm fish subjected to collection of biological data. Captured fish must be allowed to fully recover before being released back into the stream and will be released only in slow water areas. And often, several other stringent criteria are applied on a case-by case basis: safety protocols vary by river velocity and trap placement, the number of times the traps are checked varies by water and air temperatures, the number of people working at a given site varies by the number of outmigrants expected, etc. All of these protocols and more are used to make sure the mortality rates stay at one percent or lower.

Tagging/Marking

Techniques such as Passive Integrated Transponder (PIT) tagging, coded wire tagging, fin-clipping, and the use of radio transmitters are common to many scientific research efforts using listed species.

All sampling, handling, and tagging procedures have an inherent potential to stress, injure, or even kill the marked fish. This section discusses each of the marking processes and its associated risks.

A PIT tag is an electronic device that relays signals to a radio receiver; it allows salmonids to be identified whenever they pass a location containing such a receiver (e.g., any of several dams) without researchers having to handle the fish again. The tag is inserted into the body cavity of the fish just in front of the pelvic girdle. The tagging procedure requires that the fish be captured and extensively handled; therefore, any researchers engaged in such activities will follow the conditions listed previously in this Opinion to ensure that the operations take place in the safest possible manner. In general, the tagging operations will take place where there is cold water of high quality, a carefully controlled environment for administering anesthesia, sanitary conditions, quality control checking, and a carefully regulated holding environment where the fish can be allowed to recover from the operation.

PIT tags have very little effect on growth, mortality, or behavior. The few reported studies of PIT tags have shown no effect on growth or survival (Prentice et al. 1987; Jenkins and Smith 1990; Prentice et al. 1990). For example, in a study between the tailraces of Lower Granite and McNary Dams (225 km), Hockersmith et al. (2000) concluded that the performance of yearling chinook salmon was not adversely affected by gastrically- or surgically implanted sham radio tags or PIT-tags. Additional studies have shown that growth rates among PIT-tagged Snake River juvenile fall chinook salmon in 1992 (Rondorf and Miller 1994) were similar to growth rates for salmon that were not tagged (Conner et al. 2001). Prentice and Park (1984) also found that PIT-tagging did not substantially affect survival in juvenile salmonids.

Coded wire tags (CWTs) are made of magnetized, stainless-steel wire. They bear distinctive notches that can be coded for such data as species, brood year, hatchery of origin, and so forth (Nielsen 1992). The tags are intended to remain within the animal indefinitely, consequently making them ideal for long-term, population-level assessments of Pacific Northwest salmon. The tag is injected into the nasal cartilage of a salmon and therefore causes little direct tissue damage (Bergman et al. 1968; Bordner et al. 1990). The conditions under which CWTs may be inserted are similar to those required for applying PIT-tags.

A major advantage to using CWTs is the fact that they have a negligible effect on the biological condition or response of tagged salmon; however, if the tag is placed too deeply in the snout of a fish, it may kill the fish, reduce its growth, or damage olfactory tissue (Fletcher et al. 1987; Peltz and Miller 1990). This latter effect can create problems for species like salmon because they use olfactory clues to guide their spawning migrations (Morrison and Zajac 1987).

In order for researchers to be able to determine later (after the initial tagging) which fish possess CWTs, it is necessary to mark the fish externally—usually by clipping the adipose fin—when the CWT is implanted (see text below for information on fin clipping). One major disadvantage to recovering data from CWTs is that the fish must be killed in order for the tag to be removed. However, this is not a significant problem because researchers generally recover CWTs from salmon that have been taken during the course of commercial and recreational harvest (and are therefore already dead).

The other primary method for tagging fish is to implant them with acoustic tags, radio tags, or archival loggers. There are two main ways to accomplish this and they differ in both their characteristics and consequences. First, a tag can be inserted into a fish's stomach by pushing it past the esophagus with a plunger. Stomach insertion does not cause a wound and does not interfere with swimming. This technique is benign when salmon are in the portion of their spawning migrations during which they do not feed (Nielsen 1992). In addition, for short-term studies, stomach tags allow faster post-tagging recovery and interfere less with normal behavior than do tags attached in other ways.

The second method for implanting tags is to place them within the body cavities of (usually juvenile) salmonids. These tags do not interfere with feeding or movement. However, the tagging procedure is difficult, requiring considerable experience and care (Nielsen 1992). Because the tag is placed within the body cavity, it is possible to injure a fish's internal organs. Infections of the sutured incision and the body cavity itself are also possible, especially if the tag and incision are not treated with antibiotics.

Fish with internal tags often die at higher rates than fish tagged by other means because tagging is a complicated and stressful process. Mortality is both acute (occurring during or soon after tagging) and delayed (occurring long after the fish have been released into the environment). Acute mortality is caused by trauma induced during capture, tagging, and release. It can be reduced by handling fish as gently as possible. Delayed mortality occurs if the tag or the tagging procedure harms the animal in direct or subtle ways. Tags may cause wounds that do not heal properly, may make swimming more difficult, or may make tagged animals more vulnerable to predation (Howe and Hoyt 1982; Matthews and Reavis 1990; Moring 1990). Tagging may also reduce fish growth by increasing the energetic costs of swimming and maintaining balance. As with the other forms of tagging and marking, researchers will keep the harm caused by tagging to a minimum by following the conditions in the Tribal Plan (2017-2021) as well as any other NMFS requested requirements.

Tissue Sampling / Marking

Tissue sampling techniques such as fin-clipping are common to many scientific research efforts using listed species. All sampling, handling, and clipping procedures have an inherent potential to stress, injure, or even kill the fish. This section discusses tissue sampling processes and its associated risks.

Fin clipping is the process of removing part or all of one or more fins to obtain non-lethal tissue samples and alter a fish's appearance (and thus make it identifiable). When entire fins are removed, it is expected that they will never grow back. Alternatively, a permanent mark can be made when only a part of the fin is removed or the end of a fin or a few fin rays are clipped. Although researchers have used all fins for marking at one time or another, the current preference is to clip the adipose, pelvic, or pectoral fins. Marks can also be made by punching holes or cutting notches in fins, severing individual fin rays (Welch and Mills 1981). Many studies have examined the effects of fin clips on fish growth, survival, and behavior. The results of these studies are somewhat varied; however, it can be said that fin clips do not generally alter fish growth. Studies comparing the growth of clipped and unclipped fish generally have shown no differences between them (e.g., Brynildson and Brynildson 1967). Moreover, wounds caused by fin clipping usually heal quickly—especially those caused by partial clips.

Mortality among fin-clipped fish is also variable. Some immediate mortality may occur during the marking process, especially if fish have been handled extensively for other purposes (e.g., stomach sampling). Delayed mortality depends, at least in part, on fish size; small fishes have often been found to be susceptible to it and Coble (1967) suggested that fish shorter than 90 mm are at particular risk. The degree of mortality among individual fishes also depends on which fin is clipped. Studies show that adipose- and pelvic-fin-clipped coho salmon fingerlings have a 100% recovery rate (Stolte 1973). Recovery rates are generally recognized as being higher for adipose- and pelvic-fin-clipped fish in comparison to those that are clipped on the pectoral, dorsal, and anal fins (Nicola and Cordone 1973). Clipping the adipose and pelvic fins probably kills fewer fish because these fins are not as important as other fins for movement or balance (McNeil and Crossman 1979). Mortality is generally higher when the major median and pectoral fins are clipped. Mears and Hatch (1976) showed that clipping more than one fin may increase delayed mortality, but other studies have been less conclusive.

Regardless, any time researchers clip or remove fins, it is necessary that the fish be handled. Therefore, the same safe and sanitary conditions required for tissue sampling operations also apply to tagging and marking activities.

2.5.2 Species-specific Effects of the Action

In previous sections, we estimated the annual abundance of adult and juvenile listed salmonids and eulachon. Since there are no measurable habitat effects, the analysis will consist primarily of examining directly measurable impacts on abundance. Abundance effects stand on their own and can be tied directly to productivity effects and less directly to structure and diversity effects. The effect of the action is measured in terms of its impact on the relevant species' total abundance by origin (Natural) and production [Listed Hatchery Adipose Clip (LHAC) and Listed Hatchery Intact Adipose (LHIA)]. Table 21 displays the estimated annual abundance of the listed species.

Table 21. Estimated annual abundance of ESA listed fish.

Species	Origin[a]	Abundance	
		Adult	Juvenile
PS Chinook salmon	LHAC	13,223[b]	36,097,500
	LHIA		6,017,150
	Natural	19,258	2,598,480
HCS chum salmon	LHIA	2,179	150,000
	Natural	20,855	3,368,592
PS steelhead	LHAC	13,422[c]	60,230
	LHIA		113,500
	Natural		1,526,753
S eulachon[d]	Natural	81,740,000	-

a LHAC=Listed Hatchery Adipose Clipped, LHIA = Listed Hatchery Intact Adipose.
b Abundances for adult hatchery salmonids are LHAC and LHIA combined.
c Abundances for all adult PS steelhead are combined
d Abundances for juvenile listed eulachon are unknown

2.5.2.1 Puget Sound Chinook Salmon

The specific projects and related take estimates are described in detail in the Tribal Plan (2017-2021) (NWIFC 2016) and the 39 associated projects submitted on the NOAA APPS website. Those records are incorporated in full herein. The NWIFC would conduct, oversee, or coordinate 34 projects that could take listed PS Chinook salmon. Most of the captured juvenile fish would be variously marked, tagged, or tissue sampled and released, whereas most of the adult fish would be briefly handled and released. However, any fish handling carries an inherent potential for causing or promoting stress, disease, injury, or death of the specimen. We have summarized the total proposed take in Table 22.

Table 22. Summary of proposed take and mortalities of PS Chinook salmon for the Tribal Plan (2017-2021).

Life Stage	Origin[a]	Take Action	Requested Take	Requested Mortalities
Adult	LHAC	Capture/Mark, Tag, Sample Tissue/Release Live Animal	360	15
	LHIA	Capture/Mark, Tag, Sample Tissue/Release Live Animal	18	2
	Natural	Capture/Mark, Tag, Sample Tissue/Release Live Animal	140	5
Juvenile	LHAC	Capture/Handle/Release Fish	58,045	446
		Capture/Mark, Tag, Sample Tissue/Release Live Animal	12,065	21
		Intentional (Directed) Mortality	765	765
	LHIA	Capture/Handle/Release Fish	4,365	20
		Capture/Mark, Tag, Sample Tissue/Release Live Animal	800	12
		Intentional (Directed) Mortality	120	120
	Natural	Capture/Handle/Release Fish	105,640	830
		Capture/Mark, Tag, Sample Tissue/Release Live Animal	3,250	28
		Intentional (Directed) Mortality	980	980
		Observe/Harass	10	0

[a] LHAC=Listed Hatchery Adipose Clipped, LHIA=Listed Hatchery Intact Adipose

Researchers, when submitting their applications, estimated the number of juvenile and adult PS Chinook salmon that may be handled and killed during the year. Additionally, to account for the dynamic and potentially increasing scope of research that may annually affect listed PS Chinook salmon, we increased the requested fish handling and lethal take numbers in this evaluation by 10%. Although it is difficult to anticipate how much more research may be requested, NMFS believes this 10% buffer would be sufficient to include any changes or additions. Table 23 compares the total requested take, plus the 10% buffer, to the species' estimated abundance.

Table 23. Total requested take and mortalities, plus the 10% buffer, compared to the estimated abundance of PS Chinook salmon for the Tribal Plan (2017-2021).

Life Stage	Origin	Total requested take plus 10%	Percent of ESU handled[b]	Total requested mortalities plus 10%	Percent of ESU killed[b]
Adult	LHAC	396	3.1445%	17	0.1414%
	LHIA	20		2	
	Natural	154	0.7997%	6	0.0286%
Juvenile	LHAC	77,963	0.2178%	1,355	0.0038%
	LHIA	5,814	0.0966%	167	0.0028%
	Natural	120,868	4.6515%	2,022	0.0778%

[a] LHAC=Listed Hatchery Adipose Clipped, LHIA=Listed Hatchery Intact Adipose
[b] Abundance estimates for adult hatchery salmonids are LHAC and LHIA combined

Eight projects have requested to intentionally kill juvenile natural-origin PS Chinook salmon. The purposes of the lethal take is to analyze otoliths (six projects; two of which will also analyze stomach contents), pathogen presence (one project; internal tissue analysis), and tissue toxicology (one project; internal tissue analysis). Otolith analysis allows researchers to measure residence time in freshwater, migration in and out of the tidally-influenced estuary, and entry and residence in nearshore marine waters (NWIFC 2016). This detailed life history provides essential information about survival rates of juvenile fish that utilize different habitat types and the carrying capacity of those habitats. Further, analyzing the chemical content of the otolith growth increments may provide even more information about the origin and life history of salmon. For pathogen and toxicology analysis, examination of the internal tissues of sacrificed salmon may help provide important information about the impact and presence of pathogens and toxins in the environment and their effect upon listed salmonids. The researchers will concentrate their lethal take on fish that appear to be stressed, likely to die, or are already dead at the time of capture. There is no request to intentionally kill adult PS Chinook salmon.

Because the majority of the fish that would be captured are expected to recover with no ill effects (only 1.74% of the take are requested mortalities), the true effects of the proposed action are best seen in the context of the fish that are likely to be killed. To determine the effects of these losses, Table 23 compares the numbers of fish that may be killed to the total abundance numbers expected for the ESU. At the ESU level, the authorized activities may kill at most 0.078% of natural-origin juvenile and 0.029% natural-origin PS Chinook salmon. Therefore, the research would be a very small impact on the species' abundance, a likely similar impact on their productivity, and no measureable effect on their spatial structure or diversity. And it is possible that the impacts could be even smaller than those laid out above. During research activities from 2010 through 2015, only 68.86% of the requested take and 26.82% of the requested mortalities for natural-origin PS Chinook salmon were used.

An effect of the research that cannot be quantified is how it would help benefit and conserve the species. Projects within the Tribal Plan (2017-2021) are split into three different groups: (1) Smolt Production Studies, (2) Life-History Studies, and (3) Habitat Restoration Monitoring. Smolt production studies provide outmigrant smolt abundances from river systems, which provide population productivity and survivorship estimates. This data yields valuable insight on the annual variability in freshwater survival, while enabling the quantification of relationships among various factors influencing survivorship and the timing of events in the freshwater phase and smolt production (e.g. flow, peak flow, water temperature). Life-history studies describe the life history and ecology of juvenile salmonids in freshwater, estuarine, and nearshore marine areas, while quantifying the relationship between habitat availability or quality and growth and survival. These studies assess habitat availability or quality and carrying capacity by describing the fundamental aspects of juvenile life history (e.g. residence time, growth and survival in freshwater, estuarine, and nearshore marine habitats). These investigations are primarily designed to develop and test hypotheses about habitat limiting factors that inform and prioritize habitat restoration efforts. Habitat restoration monitoring studies the distribution and abundance of juvenile and adult salmon in the vicinity of restored or newly accessible habitat in order to assess the effectiveness of habitat restoration efforts. We expect these research actions to generate lasting benefits to conservation of the listed fish, though we are not relying on any particular benefit in making our conclusion in section 2.8.

2.5.2.2 Hood Canal summer-run chum salmon

The specific projects and related take estimates are described in detail in the Tribal Plan (2017-2021) (NWIFC 2016) and the 39 associated projects submitted on the NOAA APPS website. Those records are incorporated in full herein. The NWIFC would conduct, oversee, or coordinate four projects that could take listed HCS chum salmon. Most of the captured juvenile fish would be variously marked, tagged, or tissue sampled and released. However, any fish handling carries an inherent potential for causing or promoting stress, disease, injury, or death of the specimen. We have summarized the total proposed take in Table 24.

Table 24. Summary of proposed take and mortalities of HCS chum salmon for the Tribal Plan (2017-2021).

Life Stage	Origin	Take Action	Requested Take	Requested Mortalities
Juvenile	Natural	Capture/Handle/Release Fish	1,240	13
		Capture/Mark, Tag, Sample Tissue/Release Live Animal	100	1

Researchers, when submitting their applications, estimated the number of juvenile and adult HCS chum salmon that may be handled and killed during the year. Additionally, to account for the dynamic and potentially increasing scope of research that may annually affect listed HCS chum salmon, we increased the requested fish handling and lethal take numbers in this evaluation by 10%. Although it is difficult to anticipate how much more research may be requested, NMFS believes this 10% buffer would be sufficient to include any changes or additions. Table 25 compares the total requested take, plus the 10% buffer, to the species' estimated abundance.

Table 25. Total requested take and mortalities, plus the 10% buffer, compared to the estimated abundance of HCS chum salmon for the Tribal Plan (2017-2021).

Life Stage	Origin	Total requested take plus 10%	Percent of ESU handled	Total requested mortalities plus 10%	Percent of ESU killed
Juvenile	Natural	1,474	0.0438%	15	0.0005%

None of the projects have requested to intentionally kill juvenile or adult natural-origin HCS chum salmon.

Because the majority of the fish that would be captured are expected to recover with no ill effects (only 1.045% of the take are requested mortalities), the true effects of the proposed action are best seen in the context of the fish that are likely to be killed. To determine the effects of these losses, Table 25 compares the numbers of fish that may be killed to the total abundance numbers expected for the ESU. At the ESU level, the authorized activities may kill at most 0.0005% of natural-origin juvenile HCS chum salmon. Therefore, the research would be a very small impact on the species' abundance, a likely similar impact on their productivity, and no measureable effect on their spatial structure or diversity. And it is possible that the impacts could be even smaller than those laid out above. During research activities from 2010 through 2015, only 40.34% of the requested take and 1.74% of the requested mortalities for natural-origin HCS chum salmon were used.

An effect of the research that cannot be quantified is how it would help benefit and conserve the species. Projects within the Tribal Plan (2017-2021) are split into two different groups: (1) Life-History Studies and (2) Habitat Restoration Monitoring. Life-history studies describe the life history and ecology of juvenile salmonids in freshwater, estuarine, and nearshore marine areas, while quantifying the relationship between habitat availability or quality and growth and survival. These studies assess habitat availability or quality and carrying capacity by describing the fundamental aspects of juvenile life history (e.g. residence time, growth and survival in freshwater, estuarine, and nearshore marine habitats). These investigations are primarily designed to develop and test hypotheses about habitat limiting factors that inform and prioritize habitat restoration efforts. Habitat restoration monitoring studies the distribution and abundance of juvenile and adult salmon in the vicinity of restored or newly accessible habitat in order to assess the effectiveness of habitat restoration efforts. We expect these research actions to generate lasting benefits to conservation of the listed fish, though we are not relying on any particular benefit in making our conclusion in section 2.8.

2.5.2.3 Puget Sound steelhead

The specific projects and related take estimates are described in detail in the Tribal Plan (2017-2021) (NWIFC 2016) and the 39 associated projects submitted on the NOAA APPS website. Those records are incorporated in full herein. The NWIFC would conduct, oversee, or coordinate 32 projects that could take listed PS steelhead. Most of the captured juvenile fish would be variously marked, tagged, or tissue sampled and released, whereas most of the adult fish would be briefly handled and released. However, any fish handling carries an inherent potential for causing or promoting stress, disease, injury, or death of the specimen. We have summarized the total proposed take in Table 26.

Table 26. Summary of proposed take and mortalities of PS steelhead for the Tribal Plan (2017-2021).

Life Stage	Origin[a]	Take Action	Requested Take	Requested Mortalities
Adult	Natural	Capture/Mark, Tag, Sample Tissue/Release Live Animal	181	3
Juvenile	LHIA	Capture/Handle/Release Fish	90	4
	Natural	Capture/Handle/Release Fish	6,307	87
		Capture/Mark, Tag, Sample Tissue/Release Live Animal	15,714	220
		Intentional (Directed) Mortality	40	40
		Observe/Harass	10	0

[a] LHIA=Listed Hatchery Intact Adipose

Researchers, when submitting their applications, estimated the number of juvenile and adult PS steelhead that may be handled and killed during the year. Additionally, to account for the dynamic and potentially increasing scope of research that may annually affect listed PS steelhead, we increased the requested fish handling and lethal take numbers in this evaluation by 10%. Although it is difficult to anticipate how much more research may be requested, NMFS believes this 10% buffer would be sufficient to include any changes or additions. Table 27 compares the total requested take, plus the 10% buffer, to the species' estimated abundance.

Table 27. Total requested take and mortalities, plus the 10% buffer, compared to the estimated abundance of PS steelhead for the Tribal Plan (2017-2021).

Life Stage	Origin	Total requested take plus 10%	Percent of ESU handled[b]	Total requested mortalities plus 10%	Percent of ESU killed[b]
Adult	Natural	199	1.4834%	3	0.0246%
Juvenile	LHIA	99	0.12532%	4	0.0056%
	Natural	24,278	1.59018%	382	0.0250%

[a] LHIA=Listed Hatchery Intact Adipose
[b] Abundance estimates for adult steelhead are natural-origin, LHAC (Listed Hatchery Adipose Clipped), and LHIA combined

One project has requested to intentionally kill juvenile natural-origin PS steelhead to analyze their otoliths and internal tissues. Otolith analysis allows researchers to measure residence time in freshwater, migration in and out of the tidally-influenced estuary, and entry and residence in nearshore marine waters (NWIFC 2016). This detailed life history provides essential information about survival rates of juvenile fish that utilize different habitat types and the carrying capacity of those habitats. Further, analyzing the chemical content of the otolith growth increments may provide even more information about the origin and life history of salmon. There is no request to intentionally kill adult PS steelhead.

Because the majority of the fish that would be captured are expected to recover with no ill effects (only 1.584% of the take are requested mortalities), the true effects of the proposed action are best seen in the context of the fish that are likely to be killed. To determine the effects of these losses, Table 27 compares the numbers of fish that may be killed to the total abundance numbers expected for the ESU. At the ESU level, the authorized activities may kill at most 0.025% of natural-origin juvenile and adult PS steelhead. Therefore, the research would be a very small impact on the species' abundance, a likely similar impact on their productivity, and no measureable effect on their spatial structure or diversity. And it is possible that the impacts could be even smaller than those laid out above. During research activities from 2010 through 2015, only 55.25% of the requested take and 23.97% of the requested mortalities for natural-origin PS steelhead were used.

An effect of the research that cannot be quantified is how it would help benefit and conserve the species. Projects within the Tribal Plan (2017-2021) are split into three different groups: (1) Smolt Production Studies, (2) Life-History Studies, and (3) Habitat Restoration Monitoring. Smolt production studies provide outmigrant smolt abundances from river systems, which provide population productivity and survivorship estimates. This data yields valuable insight on the annual variability in freshwater survival, while enabling the quantification of relationships among various factors influencing survivorship and the timing of events in the freshwater phase and smolt production (e.g. flow, peak flow, water temperature). Life-history studies describe the life history and ecology of juvenile salmonids in freshwater, estuarine, and nearshore marine areas, while quantifying the relationship between habitat availability or quality and growth and survival. These studies assess habitat availability or quality and carrying capacity by describing the fundamental aspects of juvenile life history (e.g. residence time, growth and survival in freshwater, estuarine, and nearshore marine habitats). These investigations are primarily designed to develop and test hypotheses about habitat limiting factors that inform and prioritize habitat restoration efforts. Habitat restoration monitoring studies the distribution and abundance of juvenile and adult salmon in the vicinity of restored or newly accessible habitat in order to assess the effectiveness of habitat restoration efforts. We expect these research actions to generate lasting benefits to conservation of the listed fish, though we are not relying on any particular benefit in making our conclusion in section 2.8.

2.5.2.4 Southern eulachon

The specific projects and related take estimates are described in detail in the Tribal Plan (2017-2021) (NWIFC 2016) and the 39 associated projects submitted on the NOAA APPS website. Those records are incorporated in full herein. The NWIFC would conduct, oversee, or coordinate three projects that could take listed S eulachon. Most of the adult fish would be briefly handled and released. However, any fish handling carries an inherent potential for causing or promoting stress, disease, injury, or death of the specimen. We have summarized the total proposed take in Table 28.

Table 28. Summary of proposed take and mortalities of S eulachon for the Tribal Plan (2017-2021).

Life Stage	Origin[a]	Take Action	Requested Take	Requested Mortalities
Adult	Natural	Capture/Handle/Release Fish	225	3

Researchers, when submitting their applications, estimated the number of juvenile and adult S eulachon that may be handled and killed during the year. Additionally, to account for the dynamic and potentially increasing scope of research that may annually affect listed S eulachon, we increased the requested fish handling and lethal take numbers in this evaluation by 10%. Although it is difficult to anticipate how much more research may be requested, NMFS believes this 10% buffer would be sufficient to include any changes or additions. Table 29 compares the total requested take, plus the 10% buffer, to the species' estimated abundance.

Table 29. Total requested take and mortalities, plus the 10% buffer, compared to the estimated abundance of S eulachon for the Tribal Plan (2017-2021).

Life Stage	Origin	Total requested take plus 10%	Percent of ESU handled	Total requested mortalities plus 10%	Percent of ESU killed
Adult	Natural	248	0.0003%	3	<0.0001%

None of the projects have requested to intentionally kill juvenile or adult natural-origin S eulachon.

Because the majority of the fish that would be captured are expected to recover with no ill effects (only 1.333% of the take are requested mortalities), the true effects of the proposed action are best seen in the context of the fish that are likely to be killed. To determine the effects of these losses, Table 29 compares the numbers of fish that may be killed to the total abundance numbers expected for the ESU. At the ESU level, the authorized activities may kill at most less than 0.0001% of adult S eulachon. Therefore, the research would be a very small impact on the species' abundance, a likely similar impact on their productivity, and no measureable effect on their spatial structure or diversity. And it is possible that the impacts could be even smaller than those laid out above.

An effect of the research that cannot be quantified is how it would help benefit and conserve the species. None of these projects are directly researching eulachon; all take and mortalities would be indirect to the proposed tribal research. However, captured eulachon do provide important distribution and abundance information to help understand their recovery progress. We expect these research actions to generate lasting benefits to conservation of the listed fish, though we are not relying on any particular benefit in making our conclusion in section 2.8.

2.5.3 Effects on Critical Habitat

Full descriptions of effects of the proposed activities are found in the previous section. In general, the activities would be (1) electrofishing, (2) capturing fish with angling equipment, traps, and nets of various types, (3) collecting biological samples from live fish, and (4) collecting deceased fish for biological sampling. All of these techniques are minimally intrusive in terms of their effect on habitat because they would involve very little, if any, disturbance of streambeds or adjacent riparian zones. None of the activities will measurably affect any habitat PBF listed earlier. Moreover, the proposed activities are all of short duration. Therefore, we conclude that the proposed activities are not likely to have an adverse impact on any designated critical habitat.

2.6 Cumulative Effects

"Cumulative effects" are those effects of future state or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 CFR 402.02). Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

Some continuing non-Federal activities are reasonably certain to contribute to climate effects within the action area. However, it is difficult if not impossible to distinguish between the action area's future environmental conditions caused by global climate change that are properly part of the environmental baseline vs. cumulative effects. Therefore, all relevant future climate-related environmental conditions in the action area are described in the environmental baseline (Section 2.3).

Future state, tribal, and local government actions will likely be in the form of legislation, administrative rules, or policy initiatives. Government and private actions may include changes in land and water uses, including ownership and intensity, any of which could impact listed species or their habitat. Government actions are subject to political, legislative, and fiscal uncertainties. These realities, added to the geographic scope of the action area which encompasses numerous government entities exercising various authorities, make any analysis of cumulative effects difficult and speculative. For more information on the various efforts being made at the local, tribal, state, and national levels to conserve PS Chinook salmon and other listed salmonids, see any of the recent status reviews, listing *Federal Register* notices, and recovery planning documents, as well as recent consultations on issuance of section 10(a)(1)(A) research permits, the Puget Sound Salmon Recovery Plan (SSDC 2007), and NMFS (2006).

Because the action area falls within navigable waters, the vast majority of future actions in the region will undergo section 7 consultation with one or more of the Federal entities with regulatory jurisdiction over water quality, flood management, navigation, or hydroelectric generation. It is possible, though very unlikely, that at some point in the future, state or tribal managers may undertake a purely non-Federal harvest or hatchery action that would not need to undergo section 7 consultation. However, we do not know of any such activity that is reasonably certain to occur in the action area, so it is not necessary to discuss any in this section. In almost all instances, proponents of future actions will need government funding or authorization to carry out a project that may affect salmon or its habitat; and therefore, the effects such a project may have on salmon and steelhead will be analyzed when the need arises.

In developing this biological opinion, we considered several efforts being made at the local, tribal, state, and national levels to conserve listed salmonids—primarily final recovery and efforts laid out in the Status review updates for Pacific salmon and steelhead listed under the Endangered Species Act (NMFS 2016). The result of that review was that salmon take—particularly associated with research, monitoring, and habitat restoration—is likely to continue to increase in the region for the foreseeable future. However, as noted above, all actions falling in those categories would also have to undergo consultation (like that in this opinion) before they are allowed to proceed.

Non-Federal actions are likely to continue affecting listed species. The cumulative effects in the action area are difficult to analyze because of this opinion's geographic scope, the different resource authorities in the action area, the uncertainties associated with government and private actions, and the changing economies of the region. Whether these effects will increase or decrease is a matter of speculation; however, based on the trends identified in the baseline, the adverse cumulative effects are likely to increase. From 1960 through 2013, the population in Puget Sound has increased from 2.85 to 6.88 million people with 66% of the population living in urban areas (Source: http://www.ofm.wa.gov/). During this population boom, urban land development has eliminated hydrologically mature forest and undisturbed soils resulting in significant change to stream channels (altered stream flow patterns, channel erosion) which eventually results in habitat simplification (Booth et al. 2002). Combining this population growth with over a century of resource extraction (logging, mining, etc.), Puget Sound's hydrology has been greatly changed and has created a different environment than what Puget Sound salmonids evolved in (Cuo et al. 2009). Scholz et al. (2011) has documented adult coho salmon mortality rates of 60-100% for the past decade in urban central Puget Sound streams that are high in metals and petroleum hydrocarbons especially after stormwater runoff. In addition, marine water quality factors (e.g. climate change, pollution) are likely to continue to be degraded by various human activities that will not undergo consultation. Although state, tribal, and local governments have developed plans and initiatives to benefit listed fish, they must be applied and sustained in a comprehensive way before NMFS can consider them "reasonably foreseeable" in its analysis of cumulative effects. Thus, the most likely cumulative effect is that the habitat in the action area is likely to continue to be degraded with respect to its ability to support the listed salmonids.

2.7 Integration and Synthesis

The Integration and Synthesis section is the final step in our assessment of the risk posed to species and critical habitat as a result of implementing the proposed action. In this section, we add the effects of the action (Section 2.5) to the environmental baseline (Section 2.4) and the cumulative effects (Section 2.6), taking into account the status of the species and critical habitat (Section 2.2), to formulate the agency's biological opinion as to whether the proposed action is likely to: (1) Reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing its numbers, reproduction, or distribution; or (2) appreciably diminishes the value of designated or proposed critical habitat for the conservation of the species.

These assessments are made in full consideration of the status of the species and critical habitat (Section 2.2). They are also made in consideration of the other scientific research and monitoring that has been authorized through 4(d) and Section 10(a)(1)(A) permits and may affect the various listed species. The reasons we integrate the proposed take of the Tribal Plan (2017-2021) considered here with the take from other research authorizations are that they are similar in nature, and we have good information on what the effects are. Thus, it is possible to determine the overall effect of all research in the region on the species considered here. The following three tables, therefore, (a) combine the proposed take for the Tribal Plan (2017-2021) considered in this opinion for all components of each species (Table 30), (b) add the take proposed by the researchers in this opinion to the take that has already been authorized in the region (Table 31), and then (c) compare those totals to the estimated annual abundance of each species under consideration (Table 32).

Table 30. Total requested take for the research and percentages of the ESA listed species for the Tribal Plan (2017-2021) covered in this Biological Opinion.

Species	Life Stage	Origin[a]	Total Take	Percent of Abundance	Lethal Take	Percent of ESU/DPS killed
PS Chinook salmon[b]	Adult	LHAC	396	3.14452%	17	0.141420%
		LHIA	20		2	
		Natural	154	0.79967%	6	0.028560%
	Juvenile	LHAC	77,963	0.21782%	1,355	0.003786%
		LHIA	5,814	0.09662%	167	0.002779%
		Natural	120,868	4.65149%	2,022	0.077807%
HCS chum salmon	Adult	LHIA	0	0.00000%	0	0.000000%
		Natural	0	0.00000%	0	0.000000%
	Juvenile	LHIA	0	0.00000%	0	0.000000%
		Natural	1,474	0.04376%	15	0.000457%
PS steelhead[c]	Adult	LHAC	0	1.48339%	0	0.024586%
		LHIA	0		0	
		Natural	199		3	
	Juvenile	LHAC	0	0.00000%	0	0.000000%
		LHIA	99	0.12532%	4	0.005570%
		Natural	24,278	1.59018%	382	0.025001%
S eulachon	Adult	Natural	248	0.00030%	3	0.000004%

[a] LHAC=Listed Hatchery Adipose Clipped, LHIA = Listed Hatchery Intact Adipose.
[b] Abundances for adult hatchery salmonids are LHAC and LHIA combined.
[c] Abundances for all adult PS steelhead are combined

Table 31. Total expected take of the ESA listed species for scientific research and monitoring already approved as of December 2016.

Species	Life Stage	Origin[a]	Total Take	Percent of Abundance	Lethal Take	Percent of ESU/DPS killed
PS Chinook salmon[b]	Adult	LHAC	1,461	17.04606%	78	0.70332%
		LHIA	793		15	
		Natural	898	4.66300%	36	0.18694%
	Juvenile	LHAC	73,007	0.20397%	9,862	0.02755%
		LHIA	153,053	2.54361%	5,662	0.09410%
		Natural	345,625	13.30105%	6,887	0.26504%
HCS chum salmon	Adult	LHIA	0	0.00000%	0	0.00000%
		Natural	1,791	8.58787%	30	0.14385%
	Juvenile	LHIA	185	0.12333%	4	0.00267%
		Natural	708,387	21.02917%	4,549	0.13504%
PS steelhead[c]	Adult	LHAC	36	10.45299%	6	0.26822%
		LHIA	11		0	
		Natural	1,356		30	
	Juvenile	LHAC	4,900	2.95364%	115	0.06932%
		LHIA	2,830	3.58228%	30	0.03797%
		Natural	47,344	3.10096%	915	0.05993%
S eulachon	Adult	Natural	35,543	0.04349%	32,888	0.04024%

[a] LHAC=Listed Hatchery Adipose Clipped, LHIA = Listed Hatchery Intact Adipose.
[b] Abundances for adult hatchery salmonids are LHAC and LHIA combined.
[c] Abundances for all adult PS steelhead are combined

Table 32. Total expected take of the ESA listed species for scientific research and monitoring already approved as of December 2016 plus the Tribal Plan (2017-2021) research covered in this Biological Opinion.

Species	Life Stage	Origin[a]	Total Take	Percent of Abundance	Lethal Take	Percent of ESU/DPS killed
PS Chinook salmon[b]	Adult	LHAC	1,857	20.19058%	95	0.84474%
		LHIA	813		17	
		Natural	1,052	5.46266%	42	0.21549%
	Juvenile	LHAC	150,970	0.42179%	11,217	0.03134%
		LHIA	158,867	2.64023%	5,829	0.09688%
		Natural	466,493	17.95253%	8,909	0.34285%
HCS chum salmon	Adult	LHIA	0	0.00000%	0	0.00000%
		Natural	1,791	8.58787%	30	0.14385%
	Juvenile	LHIA	185	0.12333%	4	0.00267%
		Natural	709,861	21.07293%	4,564	0.13550%
PS steelhead[c]	Adult	LHAC	36	11.93637%	6	0.29280%
		LHIA	11		0	
		Natural	1,555		33	
	Juvenile	LHAC	4,900	2.95364%	115	0.06932%
		LHIA	2,929	3.70759%	34	0.04354%
		Natural	71,622	4.69114%	1,297	0.08493%
S eulachon	Adult	Natural	35,791	0.04379%	32,891	0.04024%

[a] LHAC=Listed Hatchery Adipose Clipped, LHIA = Listed Hatchery Intact Adipose.
[b] Abundances for adult hatchery salmonids are LHAC and LHIA combined.
[c] Abundances for all adult PS steelhead are combined

Salmonids

For juvenile salmonids, the total amount of estimated natural-origin, lethal take for the proposed research would be 2,022 PS Chinook salmon, 15 HCS chum salmon, and 382 PS steelhead. Compared with the previous Tribal Plan, this represents a change of +230 PS Chinook salmon (+12.9%), -321 HCS chum salmon (-95.5%), and -79 PS steelhead (-17.1%) natural-origin juveniles. This is the maximum amount of lethal take contemplated in this biological opinion; if the Tribal Plan (2017-2021) is authorized and exercised, a lesser amount of take is expected to actually occur. Overall, these numbers represent very small fractions of the expected natural-origin abundances and may kill at most 0.0778% of any natural-origin listed component (PS Chinook salmon) (Table 30).

For adult salmonids, the total amount of estimated natural-origin, lethal take for the proposed research would be six PS Chinook salmon and three PS steelhead (no adult take of HCS chum salmon was requested for either Tribal Plan) annually. Compared with the previous Tribal Plan, this represents no change for PS Chinook salmon and +1 individual for PS steelhead natural-origin adults. This is the maximum amount of lethal take contemplated in this biological opinion; if the Tribal Plan (2017-2021) is authorized and exercised, a lesser amount of take is expected to actually occur. Overall, these numbers represent very small fractions of the expected natural-origin abundances and may kill at most 0.0286% of any natural-origin listed component (PS Chinook salmon) (Table 30).

When combined with scientific research and monitoring permits already approved (Section 10 (a)(1)(A) and state 4(d) permits) (Table 31), the total take and mortalities are low (Table 32). For example, approximately 17.95% of juvenile natural origin, PS Chinook salmon would be taken. However, and as noted previously, the majority of salmonids handled subsequently recover shortly after handling with no long-term ill effects. For natural-origin PS Chinook salmon juvenile take, only 1.91% of the requested take is authorized as lethal take (8,909 of 466,493); thus, we estimate that a maximum of 0.343% of natural-origin PS Chinook salmon juvenile take for the ESU would be killed. And for the vast majority of scientific research permits, history has shown that researchers generally take far fewer salmonids than the allotted number of salmonids every year (14.16% of requested take and 12.66% of requested mortalities were used in ID, OR, and WA Section 10a1A permits from 2008 to 2015). Thus, the activities contemplated in this opinion would add only very small fractions to those already low numbers.

Thus, as Tables 30-32 demonstrate, all the mortalities, even taken together, represent very small fractions of the various species' abundances. Our conclusion is based on these conservative assumptions. Nonetheless, and for a number of reasons, the displayed percentages are in reality almost certainly much smaller than even the small figures stated. First, the juvenile abundance estimates are deliberately designed to generate a conservative picture of abundance. Second, it is important to remember that estimates of lethal take for most of the proposed studies are purposefully inflated to account for potential accidental deaths; and it is, therefore, very likely that fewer juveniles would be killed by the research than stated. As mentioned in the previous paragraph, only one-seventh of the authorized take and one-eighth of the authorized mortalities has been used from 2008 through 2015. Third, for salmonids, many of the fish that may be affected would be in the smolt stage, but others definitely would not be. These latter would simply be described as "juveniles," which means they may actually be yearlings, parr, or even fry: life stages represented by multiple spawning years and many more individuals than reach the smolt stage—perhaps as much as an order of magnitude more. Therefore, the already small percentages were derived by (a) conservatively estimating the actual number of juveniles, (b) overestimating the number of fish likely to be killed, and (c) treating each dead juvenile fish as part of the same year class. Thus, the actual numbers of juvenile salmonids the research is likely to kill are undoubtedly smaller than the stated figures—probably something on the order of one seventh of the values given in the tables.

Eulachon

For listed eulachon, all the mortalities, even taken together, represent very small fractions of the various species' abundances. Since no directed mortality is requested for the Tribal Plan (2017-2021) within this Opinion, it is important to remember that lethal take estimates exist only to account for potential accidental deaths.

For the listed S eulachon, the total amount of estimated lethal take for the proposed research would be three adult eulachon. This is the maximum amount of lethal take contemplated in this biological opinion; if the Tribal Plan (2017-2021) is authorized and exercised, a lesser amount of take is expected to actually occur. Overall, these numbers represent very small fractions of the abundances for eulachon (<0.0001%) (Table 30). For the vast majority of scientific research permits, history has shown that researchers generally take fewer eulachon than the allotted number of eulachon every year (37.73% of requested take and 38.36% of requested mortalities were used in OR and WA Section 10a1A permits from 2009 to 2015).

For all of these species, it is very likely that fewer fish would be killed by the research than stated. In fact, for the vast majority of scientific research permits, history has shown that researchers generally take far fewer than the allotted number of fish every year. As a result, the detrimental effect of the research activities contemplated in this opinion—even when they are added to the effects already contemplated in the region—are expected to be minimal. Because these effects are so small, the actions would have only a slight negative effect on the species' abundance and productivity. And because that slight impact is in most cases distributed throughout the entire listing units, it would be so attenuated as to have no appreciable effect on spatial structure or diversity. Moreover, as described in the Tribal Plan (2017-2021), all the research actions are expected to generate lasting benefits for the listed fish.

Critical Habitat

As noted earlier, we do not expect the individual actions to have any appreciable effect on any listed species' critical habitat. This is true for all the Tribal Plan (2017-2021) actions in combination as well: the actions' short duration, minimal intrusion, and overall lack of measureable effect signify that even when taken together they would have no discernible impact on critical habitat.

Summary

As noted in the sections on species status, no listed species currently has all its biological requirements being met. Their status is such that there must be a substantial improvement in the environmental conditions of their habitat and other factors affecting their survival if they are to begin to approach recovery. While the proposed research activities would in fact have some negative effect on each of the species' abundance, in all cases, this effect would be miniscule, the activity has not been identified as a threat, and the benefit from the research must be taken into account. In addition, while the future impacts of cumulative effects are uncertain at this time, they are likely to continue to be negative. Nonetheless, in no case would the proposed actions exacerbate any of the negative cumulative effects discussed (habitat alterations, etc.); and in all cases, the research may eventually help to limit adverse effects by increasing our knowledge about the species' requirements, habitat use, and abundance. The effects of climate change are also likely to continue to be negative. However, given the proposed actions' short time frames and limited areas, those negative effects, while somewhat unpredictable, are too small to be effectively gauged as an additional increment of harm over the time span considered in this analysis. Moreover, the actions would in no way contribute to climate change (even locally), and in any case the proposed actions would actually help monitor the effects of climate change by noting stream temperatures, flows, marine conditions, etc. So while we can expect both cumulative effects and climate change to continue their negative trends, it is unlikely that any of the proposed actions would have any additive impact to the pathways by which those effects are realized (e.g., a slight reduction in salmonid abundance would have no effect on increasing stream temperatures or continuing land development).

To this picture, it is necessary to add the increment of effect represented by the proposed actions. Our analysis shows that the proposed research activities would have slight negative effects on each species' abundance and productivity (and probably some negative effects on diversity and structure—ones that are so small that we cannot even measure them at this point). However, those abundance and productivity reductions are so small as to have no more than a negligible effect on the species' survival and recovery. In all cases, even the worst possible effect on abundance would be small fractions of one percent, the activity has never been identified as a threat, and the research is designed to benefit the species' survival in the long term.

For more than a decade, research and monitoring activities conducted on anadromous salmonids in the Pacific Northwest have provided resource managers with a wealth of important and useful information regarding anadromous fish populations. For example, juvenile fish trapping efforts have enabled the production of population inventories, PIT-tagging efforts have increased the knowledge of anadromous fish migration timing and survival, and fish passage studies have provided an enhanced understanding of how fish behave and survive when moving past dams and through reservoirs. By issuing research authorizations—including these being contemplated in this opinion—NMFS has allowed information to be acquired that has enhanced resource managers' abilities to make more effective and responsible decisions to sustain anadromous salmonid populations, mitigate adverse impacts on endangered and threatened salmon and steelhead, and implement recovery efforts. The resulting information continues to improve our knowledge of the respective species' life histories, specific biological requirements, genetic make-up, migration timing, responses to human activities (positive and negative), and survival in the rivers and ocean. And that information, as a whole, is critical to the species' survival.

Therefore, we expect the detrimental effects on the species are expected to be minimal and those impacts would only be seen in terms of slight reductions in abundance and productivity. And because these reductions are so slight, the actions—even in combination—would have no appreciable effect on the species' diversity or distribution. Moreover, the actions are expected to provide lasting benefits for the listed fish (albeit unquantifiable at this time), and all habitat effects would be negligible.

2.8 Conclusion

After reviewing and analyzing the current status of the listed species and critical habitat, the environmental baseline within the action area, the effects of the proposed action, any effects of interrelated and interdependent activities, and cumulative effects, it is NMFS' biological opinion that the proposed actions are not likely to jeopardize the continued existence of Puget Sound Chinook salmon, Hood Canal summer-run chum salmon, Puget Sound steelhead, and southern eulachon or destroy or adversely modify its designated critical habitat.

2.9 Incidental Take Statement

Section 9 of the ESA and Federal regulations pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. "Harm" is further defined by regulation to include significant habitat modification or degradation that actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including breeding, spawning, rearing, migrating, feeding, or sheltering (50 CFR 222.102). "Incidental take" is defined by regulation as takings that result from, but are not the purpose of, carrying out an otherwise lawful activity conducted by the Federal agency or applicant (50 CFR 402.02). Section 7(b)(4) and section 7(o)(2) provide that taking that is incidental to an otherwise lawful agency action is not considered to be prohibited taking under the ESA if that action is performed in compliance with the terms and conditions of this ITS.

In this instance, and for the actions considered in this opinion, there is no incidental take at all. The reason for this is that all the take contemplated in this document would be carried out under the Tribal Plan (2017-2021) which allows the researchers to directly take the animals in question. The actions are considered to be direct take rather than incidental take because in every case their actual purpose is to take the animals while carrying out a lawfully permitted activity. Thus, the take cannot be considered "incidental" under the definition given above. Nonetheless, one of the purposes of an incidental take statement is to lay out the amount or extent of take beyond which individuals carrying out an action cannot go without being in possible violation of section 9 of the ESA. That purpose is fulfilled here by the amounts of direct take laid out in the effects section above (2.5) and summarized in the integration and synthesis section (2.7; Table 30). Those amounts—displayed in the Tribal Plan's (2017-2021) effects analysis—constitute hard limits on both the amount and extent of take the researchers would be allowed in a given year. This concept is also reflected in the reinitiation clause just below.

2.10 Reinitiation of Consultation

This concludes formal consultation for "Evaluation and Recommended Determination of a Tribal Resource Management Plan Submitted for Consideration Under the Endangered Species Act's Tribal Plan Limit [50 CFR 223.204] for the Period January 1, 2017 – December 31, 2021."

As 50 CFR 402.16 states, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained or is authorized by law and if: (1) The amount or extent of incidental taking specified in the ITS is exceeded, (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion, (3) the agency action is subsequently modified in a manner that causes an effect on the listed species or critical habitat that was not considered in this opinion, or (4) a new species is listed or critical habitat designated that may be affected by the action.

In the context of this opinion, there is no incidental take anticipated and the reinitiation trigger set out in (1) is not applicable. If any of the direct take amounts specified in this opinion's effects analysis section (2.5) are exceeded, reinitiation of formal consultation will be required because the regulatory reinitiation triggers set out in (2) and/or (3) will have been met.

2.11 "Not Likely to Adversely Affect" Determination

NMFS' concurrence with a determination that an action "is not likely to adversely affect" listed species or critical habitat is based on our finding that the effects are expected to be discountable, insignificant, or completely beneficial. Insignificant effects relate to the size of the impact and should never reach the scale where take occurs; discountable effects are those that are extremely unlikely to occur; and beneficial effects are contemporaneous positive effects without any adverse effects to the species or critical habitat.

Southern Resident Killer Whales Determination

The Southern Resident (SR) killer whale DPS composed of J, K, and L pods was listed as endangered under the ESA on November 18, 2005 (70 FR 69903). The final rule listing SR killer whales as endangered identified several potential factors that may have caused their decline or may be limiting recovery. These are: quantity and quality of prey, toxic chemicals which accumulate in top predators, and disturbance from sound and vessel traffic. The rule also identified oil spills as a potential risk factor for this species. The final recovery plan includes more information on these potential threats to SR killer whales (NMFS 2008a).

NMFS published the final rule designating critical habitat for SR killer whales on November 29, 2006 (71 FR 69054). Critical habitat includes approximately 2,560 square miles of inland waters including Puget Sound, but does not include areas with water less than 20 feet deep relative to extreme high water. The physical or biological features (PBFs) of SR killer whale critical habitat are: (1) water quality to support growth and development; (2) prey species of sufficient quantity, quality, and availability to support individual growth, reproduction and development, as well as overall population growth; and (3) passage conditions to allow for migration, resting, and foraging.

SR killer whales spend considerable time in the Georgia Basin from late spring to early autumn, with concentrated activity in the inland waters of Washington State around the San Juan Islands, and then move south into Puget Sound in early autumn. Pods make frequent trips to the outer coast during this season. In the winter and early spring, SR killer whales move into the coastal waters along the outer coast from Southeast Alaska south to central California (NMFS 2008a, Hilborn et al. 2012). Half of the research activities included in the proposed actions would occur in freshwater areas where SR killer whales do not occur; and therefore, the proposed action may only indirectly affect SR killer whales by reducing their prey. The remainder of the research would occur in the critical habitat of SR killer whales (i.e. Puget Sound, Pacific Ocean) but direct interactions among the vessels and their capture equipment would be of an extremely low likelihood, therefore the potential for effects is discountable. This opinion would not authorize marine mammal take, nor has such take ever been observed in the past when similar activities were conducted in the action area. As a whole, the proposed action would only have discountable effects on marine mammals.

SR killer whales consume a variety of fish and one species of squid, but salmon, and Chinook salmon in particular, are their primary prey (review in NMFS 2008a). Ongoing and past diet studies of SR killer whales conduct sampling during spring, summer and fall months in inland waters of Washington State and British Columbia (i.e., Ford and Ellis 2006; Hanson et al. 2010; ongoing research by NWFSC). Genetic analysis of these samples indicate that when SR killer whales are in inland waters from May to September, they consume Chinook salmon stocks that originate from regions including the Fraser River (including Upper Fraser, Mid Fraser, Lower Fraser, N. Thompson, S. Thompson and Lower Thompson), Puget Sound (N. and S. Puget Sound), the Central BC Coast, W. and E. Vancouver Island, and Central Valley California (Hanson et al. 2010). Other research and analysis provides additional information on the age of prey consumed (Hanson unpubl. data, as summarized in Ward et al. unpubl. report), confirming that SR killer whales predominantly consume larger (i.e. older) Chinook salmon when in inland waters (May through September).

The proposed actions may affect SR killer whales indirectly by reducing availability of their primary prey, Chinook salmon. As described in the effects analysis for salmonids, up to 2,022 juvenile and six adult Chinook salmon may be killed during proposed research activities.

Take of juvenile salmonids could affect prey availability to the whales in future years throughout their range, including designated critical habitat in inland waters of Washington. For the Puget Sound, average smolt to adult survival of both naturally produced and hatchery Chinook is 1%. If one percent of the 2,022 juvenile Chinook salmon taken by research activities were to survive to adulthood, this would translate to the effective loss of 20 adult Chinook salmon per year across a 3-5 year period after the research activities occurred (i.e., by the time these juveniles would have grown to be adults and available prey of killer whales). This constitutes an increase of two adult equivalent Chinook salmon from the previous Tribal Plan. Additionally, these take estimates are likely an overestimate of the actual number of Chinook salmon that would be taken during research activities, and thus the actual reduction in prey available to the whales is likely smaller than the stated figure.

Given the total quantity of prey available to SR killer whales throughout their range, this reduction in prey is extremely small, and although measurable is not anticipated to be different than zero by multiple decimal places (based on NMFS previous analysis of the effects of salmon harvest on SR killer whales; e.g., NMFS 2008b). Because the reduction is so small, there is also a very low probability that any of the juvenile Chinook salmon killed by the research activities would have later (in 3-5 years' time) been intercepted by the killer whales across inland waters of their range in the absence of the research activities. Therefore, the anticipated take of salmonids associated with the proposed actions would result in an insignificant reduction in adult equivalent prey resources for SR killer whales.

Future loss of Chinook salmon from Chinook salmon ESU populations could affect the prey PBF of designated critical habitat. As described above, however, considering the estimate of up to 26 adult equivalent Chinook salmon that could be taken by the proposed actions, and the total amount of prey available in the critical habitat, the reduction would be insignificant and would not affect the conservation value of the critical habitat. Proposed research activities would have discountable effects on the water quality or passage PBFs for SR killer whales.

Therefore, NMFS finds that potential adverse effects of the proposed research on SR killer whales are discountable or insignificant and determines that the proposed action may affect, but is not likely to adversely affect SR killer whales or their critical habitat.

3. MAGNUSON-STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT ESSENTIAL FISH HABITAT CONSULTATION

Section 305(b) of the MSA directs Federal agencies to consult with NMFS on all actions or proposed actions that may adversely affect EFH. The MSA (section 3) defines EFH as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.” Adverse effect means any impact that reduces quality or quantity of EFH, and may include direct or indirect physical, chemical, or biological alteration of the waters or substrate and loss of (or injury to) benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality or quantity of EFH. Adverse effects on EFH may result from actions occurring within EFH or outside of it and may include site-specific or EFH-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810). Section 305(b) also requires NMFS to recommend measures that can be taken by the action agency to conserve EFH.

This analysis is based, in part, on the EFH assessment provided by the NMFS and descriptions of EFH for Pacific Coast salmon (PFMC 2014) contained in the fishery management plans developed by the Pacific Fishery Management Council (PFMC) and approved by the Secretary of Commerce.

3.1 Essential Fish Habitat Affected by the Project

In the estuarine and marine areas, salmon EFH extends from the nearshore and tidal submerged environments within state territorial waters out to the full extent of the exclusive economic zone (370.4 km) offshore of Washington, Oregon, and California north of Point Conception. The EFH identified within the action areas are identified in the Pacific coast salmon fishery management plan (PFMC 2014). Freshwater EFH for Pacific salmon includes all those streams, lakes, ponds, wetlands, and other water bodies currently, or historically accessible to salmon in Washington, Oregon, Idaho, and California, except areas upstream of certain impassable man-made barriers (as identified by the PFMC), and longstanding, naturally-impassable barriers (i.e., natural waterfalls in existence for several hundred years).

3.2 Adverse Effects on Essential Fish Habitat

As the Biological Opinion above describes, the proposed research actions are not likely, singly or in combination, to adversely affect the habitat upon which Pacific salmon, groundfish, and coastal pelagic species, depend. All the actions are of limited duration, minimally intrusive, and are entirely discountable in terms of their effects, short-or long-term, on any habitat parameter important to the fish.

3.3 Essential Fish Habitat Conservation Recommendations

No adverse effects upon EFH are expected; therefore, no EFH conservation recommendations are necessary.

3.4 Statutory Response Requirement

As required by section 305(b)(4)(B) of the MSA, the Federal agency must provide a detailed response in writing to NMFS within 30 days after receiving an EFH Conservation Recommendation from NMFS. Given that there are no conservation recommendations, there is no statutory response requirement.

3.5 Supplemental Consultation

The Action Agency must reinitiate EFH consultation with NMFS if the proposed action is substantially revised in a way that may adversely affect EFH, or if new information becomes available that affects the basis for NMFS' EFH Conservation Recommendations [50 CFR 600.920(l)].

4. DATA QUALITY ACT DOCUMENTATION AND PRE-DISSEMINATION REVIEW

The Data Quality Act (DQA) specifies three components contributing to the quality of a document. They are utility, integrity, and objectivity. This section of the opinion addresses these DQA components, documents compliance with the DQA, and certifies that this opinion has undergone pre-dissemination review.

4.1 Utility

Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable, and beneficial to the intended users. The intended users of this opinion are the applicants and funding/action agencies listed on the first page. This opinion will be posted on the Public Consultation Tracking System website (https://pcts.nmfs.noaa.gov/pcts-web/homepage.pcts). The format and naming adheres to conventional standards for style

This ESA section 7 consultation on the issuance of the Tribal Plan (2017-2021) concluded that the actions will not jeopardize the continued existence of any species. Therefore, the funding/action agencies may carry out the research actions and NMFS may permit them. Pursuant to the MSA, NMFS determined that no conservation recommendations were needed to conserve EFH.

4.2 Integrity

This consultation was completed on a computer system managed by NMFS in accordance with relevant information technology security policies and standards set out in Appendix III, 'Security of Automated Information Resources,' Office of Management and Budget Circular A-130; the Computer Security Act; and the Government Information Security Reform Act.

4.3 Objectivity

Information Product Category: Natural Resource Plan

Standards: This consultation and supporting documents are clear, concise, complete, and unbiased; and were developed using commonly accepted scientific research methods. They adhere to published standards including the NMFS ESA Consultation Handbook, ESA regulations, 50 CFR 402.01 et seq., and the MSA implementing regulations regarding EFH, 50 CFR 600.

Best Available Information: This consultation and supporting documents use the best available information, as referenced in the References section. The analyses in this contain more background on information sources and quality.

Referencing: All supporting materials, information, data and analyses are properly referenced, consistent with standard scientific referencing style.

Review Process: This consultation was drafted by NMFS staff with training in ESA, and reviewed in accordance with West Coast Region ESA quality control and assurance processes.

5. REFERENCES

5.1 Federal Register Notices

November 20, 1991 (56 FR 58612). Notice of Policy: Policy on Applying the Definition of Species Under the Endangered Species Act to Pacific Salmon.

August 9, 1996 (61 FR 41541). Proposed Rule: Endangered and Threatened Species: Proposed Endangered Status for Five ESUs of Steelhead and Proposed Threatened Status for Five ESUs of Steelhead in Washington, Oregon, Idaho, and California.

March 25, 1999 (64 FR 14508). Final Rule: Endangered and Threatened Species: Threatened Status for Two ESUs of Chum Salmon in Washington and Oregon.

June 28, 2005 (70 FR 37160). Endangered and Threatened Species: Final Listing Determinations for 16 ESUs of West Coast Salmon, and Final 4(d) Protective Regulations for Threatened Salmonid ESUs.

September 2, 2005 (70 FR 52630). Final Rule: Endangered and Threatened Species: Designated Critical Habitat: Designation of Critical Habitat for 12 Evolutionarily Significant Units of West Coast Salmon and Steelhead in Washington, Oregon, and Idaho.

November 18, 2005 (70 FR 69903). Final Rule: Endangered and Threatened Wildlife and Plants: Endangered Status for Southern Resident Killer Whales.

January 5, 2006 (71 FR 834). Final Rule: Endangered and Threatened Species: Final Listing Determinations for 10 Distinct Population Segments of West Coast Steelhead.

November 29, 2006 (71 FR 69054). Final Rule: Endangered and Threatened Species; Designation of Critical Habitat for Southern Resident Killer Whale.

May 11, 2007 (72 FR 26722). Final Rule: Endangered and Threatened Species: Final Listing Determination for Puget Sound Steelhead.

September 25, 2008 (73 FR 55451). Final Rule: Endangered and Threatened Species: Final Protective Regulations for Threatened Puget Sound Steelhead.

March 18, 2010 (75 FR 13012). Final Rule: Endangered and Threatened Wildlife and Plants: Threatened Status for Southern Distinct Population Segment of Eulachon.

October 20, 2011 (76 FR 65324). Final Rule: Endangered and Threatened Species; Designation of Critical Habitat for the Southern Distinct Population Segment of Eulachon.

April 14, 2014 (79 FR 20802). Final Rule: Endangered and Threatened Wildlife; Final Rule To Revise the Code of Federal Regulations for Species Under the Jurisdiction of the National Marine Fisheries Service.

February 11, 2016 (81 FR 7214). Final Rule: Interagency Cooperation—Endangered Species Act of 1973, as Amended; Definition of Destruction or Adverse Modification of Critical Habitat.

February 11, 2016 (81 FR 7414). Final Rule: Listing Endangered and Threatened Species and Designating Critical Habitat; Implementing Changes to the Regulations for Designating Critical Habitat.

February 24. 2016 (81 FR 9252). Final Rule: Endangered and Threatened Species; Designation of Critical Habitat for Lower Columbia River Coho Salmon and Puget Sound Steelhead.

November XX, 2016 (81 FR XXXXX). Notice: Endangered and Threatened Species; Take of Anadromous Fish

5.2 Literature Cited

Abdul-Aziz, O. I., N. J. Mantua, and K. W. Myers. 2011. Potential climate change impacts on thermal habitats of Pacific salmon (*Oncorhynchus spp.*) in the North Pacific Ocean and adjacent seas. Can. J. Fish. Aquat. Sci. 68:1660-1680.

Ainslie, B. J., J. R. Post, and A. J. Paul. 1998. Effects of pulsed and continuous DC electrofishing on juvenile rainbow trout. North American Journal of Fisheries Management: Vol. 18, No. 4, pp. 905–918.

Al-Humaidhi, A. W., M. A. Bellman , J. Jannot, and J. Majewski. 2012. Observed and estimated total bycatch of green sturgeon and Pacific eulachon in 2002-2010 U.S. west coast fisheries. West Coast Groundfish Observer Program. National Marine Fisheries Service, NWFSC, 2725 Montlake Blvd E., Seattle, WA 98112.

Beacham, T. D., D. E. Hay, and K. D. Le. 2005. Population structure and stock identification of eulachon (*Thaleichthys pacificus*), an anadromous smelt, in the Pacific Northwest. Mar. Biotechnol. 7:363–372.

Beamer, E. M., R. E. McClure, and B. A. Hayman. 2000. Fiscal Year 1999 Skagit River Chinook Restoration Research. Skagit System Cooperative.

Beechie, T., E. Buhle, M. Ruckelshaus, A. Fullerton, and L. Holsinger. 2006. Hydrologic regime and the conservation of salmon life history diversity. Biological Conservation. 130:560-572.

Bendock, T. and M. Alexandersdottir. 1993. Hooking mortality of Chinook salmon released in the Kenai River, Alaska. North American Journal of Fisheries Management 13:540-549.

Berejikian, B. A., E. P. Tezak, and S. L. Schroder. 2001. Reproductive behavior and breeding success of captively reared Chinook salmon. North American Journal of Fisheries Management. 21:255-260.

Bergman, P. K., K. B. Jefferts, H. F. Fiscus, and R. C. Hager. 1968. A preliminary evaluation of an implanted, coded wire fish tag. Washington Department of Fisheries, Fisheries Research Papers 3(1):63-84.

Bishop, S. and A. Morgan (eds). 1996. Critical habitat issues by basin for natural Chinook salmon stocks in the coastal and Puget Sound areas of Washington state. Northwest Indian Fisheries Commission, Olympia, WA, 105 pp.

Bledsoe, L. J., D. A. Somerton, and C. M. Lynde. 1989. The Puget Sound runs of salmon: An examination of the changes in run size since 1896. *In* C. D. Levings, L. B. Holtby, and M. A. Henderson (editors), Proceedings of the National Workshop on Effects of Habitat Alteration on Salmonid Stocks, May 6-8, 1987, Nanaimo, B.C., p. 50-61. Can. Spec. Publ. Fish. Aquat. Sci. 105.

Bond, N.A., M.F. Cronin, H. Freeland, and N. Mantua. 2015. Causes and impacts of the 2014 warm anomaly in the NE Pacific. Geophysical Research Letters. 42:3414-3420.

Booth, D. B., D. Hartley, and R. Jackson. 2002. Forest cover, impervious-surface area, and the mitigation of stormwater impacts. J Amer Water Res Assoc. 38(3):835-845.

Bordner, C. E., S. I. Doroshov, D. E. Hinton, R. E. Pipkin, R. B. Fridley, and F. Haw. 1990. Evaluation of marking techniques for juvenile and adult white sturgeons reared in captivity. American Fisheries Society Symposium 7:293-303.

Bruesewitz, S. L. 1995. Hook placement in steelhead. Technical Report No. AF95-01. Washington Department of Fish and Wildlife, Olympia.

Brynildson, O. M. and C. L. Brynildson. 1967. The effect of pectoral and ventral fin removal on survival and growth of wild brown trout in a Wisconsin stream. Transactions of the American Fisheries Society 96:353-355.

Busby, P. J., T. C. Wainwright, G. J. Bryant, L. J. Lierheimer, R. S. Waples, F. W. Waknitz, and I. V. Lagomarsino. 1996. Status review of West Coast steelhead from Washington, Idaho, Oregon, and California. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-NWFSC-27.

Coble, D. W. 1967. Effects of fin-clipping on mortality and growth of yellow perch with a review of similar investigations. Journal of Wildlife Management 31:173-180.

Conner, W. P., H. L. Burge, and R. Waitt. 2001. Snake River fall Chinook salmon early life history, condition, and growth as affected by dams. Unpublished report prepared by the U.S. Fish and Wildlife Service and University of Idaho, Moscow, ID. 4 p.

COSEWIC (Committee on the Status for Endangered Wildlife in Canada). 2009. Guidelines for recognizing designatable units. Approved by COSEWIC in November 2009. Available at: http://www.cosewic.gc.ca/eng/sct2/sct2_5_e.cfm

COSEWIC. 2011a. COSEWIC assessment and status report on the eulachon, Cass/Skeena Rivers population, Central Pacific Coast population and the Fraser River population *Thaleichthys pacificus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xv + 88 pp.

COSEWIC. 2011b. Eulachon Species at Risk Act (SARA) Process backgrounder. Available at: http://fnfisheriescouncil.ca/index.php/more-info/search-documents/doc_download/875-eulachonsarabackgrounderannex

Cramer, S. P., C. F. Willis, S. C. Vigg, J. T. Hawksworth, R. Montagne, D. Cramer, F. Shrier, C. Phillips, J. Welty, and K. Reininga. 1997. Synthesis and analysis of the Lower Columbia River Steelhead Initiative. Special Report. S.P. Cramer and Associates, Gresham, Oregon.

Crozier, L.G. and R.W. Zabel. 2006. Climate impacts at multiple scales: evidence for differential population responses in juvenile Chinook salmon. Journal of Animal Ecology. 75:1100-1109.

Crozier, L., R.W. Zabel, S. Achord, and E.E. Hockersmith. 2010. Interacting effects of density and temperature on body size in multiple populations of Chinook salmon. Journal of Animal Ecology. 79:342-349.

Cuo, L., D. P. Lettenmaier, M. Alberti, and J. E. Richey. 2009. Effects of a century of land cover and climate change on the hydrology of the Puget Sound basin. Hydrol. Process. 23:907-933.

Dalbey, S. R., T. E. McMahon, and W. Fredenberg. 1996. Effect of electrofishing pulse shape and electrofishing-induced spinal injury to long-term growth and survival of wild rainbow trout. North American Journal of Fisheries Management. 16:560-569.

DFO (Dept. Fisheries and Oceans Canada). 2008. Fraser River eulachon (*Thaleichthys pacificus*): 2007 population assessment and harvest recommendations for 2008. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2007/048.

Dwyer, W. P. and R. G. White. 1997. Effect of electroshock on juvenile Arctic grayling and Yellowstone cutthroat trout growth 100 days after treatment. North American Journal of Fisheries Management. 17:174-177.

EPA. 2002. Columbia River Basin fish contaminant survey 1996–1998. EPA 910-R-02-006, Environmental Protection Agency, Region 10, Seattle, WA. Online at: http://yosemite.epa.gov/r10/oea.nsf/0703bc6b0c5525b088256bdc0076fc44/c3a9164ed269353788256c09005d36b7/$FILE/Fish%20Study.PDF

Fletcher, D. H., F. Haw, and P. K. Bergman. 1987. Retention of coded-wire tags implanted into cheek musculature of largemouth bass. North American Journal of Fisheries Management 7:436-439.

Ford, J. K. B. and G. M. Ellis. 2006. Selective foraging by fish-eating killer whales *Orcinus* orca in British Columbia. Marine Ecology Progress Series. 316:185-199.

Ford, M. J. (ed.). 2011. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest. U.S. Depart. of Commer., NOAA Tech. Memo. NOAA-TM-NWFSC-113, 281 pp.

Fredenberg, W. A. 1992. Evaluation of electrofishing-induced spinal injuries resulting from field electrofishing surveys in Montana. Montana Department of Fish, Wildlife and Parks, Helena.

Frimodig, A. 2008. Informational report: Bycatch reduction devices used in the pink shrimp trawl fishery. Rep. to California Fish and Game Commission. California Dept. Fish and Game, Marine Region, State Fisheries Evaluation Project.

Fry, D. H., Jr. 1979. Anadromous fishes of California. Calif. Dept. Fish & Game, Sacramento, CA.

Good, T. P., R. S. Waples, and P. Adams (editors). 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC-66, 598 pp.

Griffith, J., M. Alexandersdottir, R. Rogers, J. Drotts, and P. Stevenson. 2004. 2003 annual Stillaguamish smolt report. Stillaguamish Tribe of Indians.

Gustafson, R. G., M. J. Ford, D. Teel, and J. S. Drake. 2010. Status review of eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-105, 360 pp.

Gustafson, R., Y.-W. Lee, E. Ward, K. Somers, V. Tuttle, and J. Jannot. 2016. Status review update of eulachon (*Thaleichthys pacificus*) listed under the Endangered Species Act: southern distinct population segment. 25 March 2016 Report to National Marine Fisheries Service – West Coast Region from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112.

Hamilton, J. B., G. L. Curtis, S. M. Snedaker, and D. K. White. 2005. Distribution of anadromous fishes in the Upper Klamath River watershed prior to hydropower dams – A synthesis of the historical evidence. Fisheries. 30(4):10-20.

Hannah, R. W., S. A. Jones, and K. M. Matteson. 2003. Observations of fish and shrimp behavior in ocean shrimp (*Pandalus jordani*) trawls. ODFW Information Rep. 2003-03. Oregon Dept. fish and Wildlife, Marine Resources Program, Newport.

Hannah, R. W. and S. A. Jones. 2007. Effectiveness of bycatch reduction devices (BRDs) in the ocean shrimp (*Pandalus jordani*) trawl fishery. Fish. Res. 85:217–225.

Hanson, M. B., K. L. Ayres, R. W. Baird, K. C. Balcomb, K. Balcomb-Bartok, J. R. Candy, C. K. Emmons, J. K. B. Ford, M. J. Ford, B. Gisborne, J. Hempelmann-Halos, G. S. Schorr, J. G. Sneva, D. M. Van Doornik, and S. K. Wasser. 2010. Species and stock identification of prey consumed by endangered southern resident killer whales in their summer range. Endangered Species Research. 11:69–82.

Hard, J. J., J. M. Myers, M. J. Ford, R. G. Cope, G. R. Pess, R. S. Waples, G. A. Winans, B. A. Berejikian, F. W. Waknitz, P. B. Adams. P. A. Bisson, D. E. Campton, and R. R. Reisenbichler. 2007. Status review of Puget Sound steelhead (*Oncorhynchus mykiss*). U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-81, 117 pp.

Hard, J. J., J. M. Myers, E. J. Connor, R. A. Hayman, R. G. Kope, G. Lucchetti, A. R. Marshall, G. R. Pess, and B. E. Thompson. 2015. Viability criteria for steelhead within the Puget Sound distinct population segment. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-129.

Hartt, A. C. and M. B. Dell. 1986. Early oceanic migrations and growth of juvenile Pacific salmon and steelhead trout. International North Pacific Fisheries Commission, Bulletin Number 46, 105 pp.

Hay, D. E., and P. B. McCarter. 2000. Status of the eulachon *Thaleichthys pacificus* in Canada. Department of Fisheries and Oceans Canada, Canadian Stock Assessment Secretariat, Research Document 2000-145. Ottawa, Ontario.

Healey, M. C. 1991. The life history of Chinook salmon (*Oncorhynchus tshawytscha*). *In* C. Groot and L. Margolis (eds), Life history of Pacific salmon, p. 311-393. Univ. BC Press, Vancouver, BC.

Healey, M. 2011. The cumulative impacts of climate change on Fraser River sockeye salmon (*Oncorhynchus nerka*) and implications for management. Canadian Journal of Fisheries and Aquatic Sciences. 68:718-737.

Hedgecock, D. 1994. Does variance in reproductive success limit effective population sizes of marine organisms? In A.R. Beaumont (ed.), Genetics and Evolution of Aquatic Organisms, p. 122–134. Chapman & Hall, London.

Hilborn, R., S. P. Cox, F. M. D. Gulland, D. G. Hankin, N. T. Hobbs, D. E. Schindler, and A. W. Trites. 2012. The effects of salmon fisheries on Southern Resident Killer Whales: Final report of the Independent Science Panel. Prepared with the assistance of D. R. Marmorek and A. W. Hall, ESSA Technologies Ltd., Vancouver, B.C. for National Marine Fisheries Service (Seattle. WA) and Fisheries and Oceans Canada (Vancouver, B.C.). xv + 61 pp. + Appendices.

Hockersmith, E. E., W. D. Muir, and others. 2000. Comparative performance of sham radiotagged and PIT-tagged juvenile salmon. Report to U.S. Army Corps of Engineers, Contract W66Qkz91521282, 25 p.

Hollender, B. A. and R. F. Carline. 1994. Injury to wild brook trout by backpack electrofishing. North American Journal of Fisheries Management. 14:643-649.

Hooton, R. S. 1987. Catch and release as a management strategy for steelhead in British Columbia. *In* R. Barnhart and T. Roelofs, editors. Proceedings of Catch and Release Fishing: a Decade of Experience, a National Sport Fishing Symposium. Humboldt State University, Arcata, California.

Howe, N. R. and P. R. Hoyt. 1982. Mortality of juvenile brown shrimp *Penaeus aztecus* associated with streamer tags. Transactions of the American Fisheries Society 111:317-325.

IPCC (Intergovernmental Panel on Climate Change). 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. Available from: http://www.climatechange2013.org/ Cambridge, United Kingdom and New York, NY, USA.

ISAB (Independent Scientific Advisory Board). 2007. Climate change impacts on Columbia River Basin fish and wildlife. ISAB Climate Change Report, ISAB 2007-2, Northwest Power and Conservation Council, Portland, Oregon.

JCRMS (Joint Columbia River Management Staff). 2011. 2011 joint staff report concerning stock status and fisheries for sturgeon and smelt. Oregon Department of Fish and Wildlife and Washington Department of Fish and Wildlife.

Jenkins, W. E. and T. I. J. Smith. 1990. Use of PIT tags to individually identify striped bass and red drum brood stocks. American Fisheries Society Symposium 7:341-345.

Johnson, O. W., W. S. Grant, R. G. Kope, K. Neely, F. W. Waknitz, R. S. Waples. 1997. Status review of chum salmon from Washington, Idaho, Oregon, and California. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-32, 280 p.

Kamler, J.F. and K.L. Pope. 2001. Nonlethal Methods of Examining Fish Stomach Contents. Reviews in Fisheries Science 9(1):1-11.

Kime, D. E. 1995. The effects of pollution on reproduction in fish. Rev. Fish Biol. Fisheries. 5:52-96.

Klos, P.Z., T.E. Link, and T.J. Abatzoglou. 2014. Extent of the rain-snow transition zone in the western U.S. under historic and projected climate. Geophysical Research Letters. 41:4560-4568.

Kostow, K. E., A. R. Marshall, and S. R. Phelps. 2002. Naturally spawning hatchery steelhead contribute to smolt production but experience low reproductive success. Transactions of the American Fisheries Society. 132:780-790.

Langer, O. E., B. G. Shepherd, and P. R. Vroom. 1977. Biology of the Nass River eulachon 1977. Department of Fisheries and Environment Tech. Rep. Series PAC/T-77-10. 56 pp.

Larson, Z. S. and M. R. Belchik. 1998. A preliminary status review of eulachon and Pacific lamprey in the Klamath River Basin. Yurok Tribal Fisheries Program, Klamath, CA.

Lewis, A. F. J., McGurk, M. D., and Galesloot, M. G. 2002. Alcan's Kemano River eulachon (*Thaleichthys pacificus*) monitoring program 1988–1998. Consultant's report prepared by Ecofish Research Ltd. for Alcan Primary Metal Ltd., Kitimat, BC, xxiv + 136 pp.

Light, R.W., P.H. Adler, and D.E. Arnold. 1983. Evaluation of Gastric Lavage for Stomach Analyses. North American Journal of Fisheries Management. 3:81-85.

Light, J. T. 1987. Coastwide abundance of North American steelhead trout. (Document submitted to the annual meeting of the Int. North Pac. Fish Comm., 1987) Fisheries Research Institute Report FRI-UW_8710. Univ. Washington, Seattle, 18 pp.

Lindsay, R. B., R. K. Schroeder, and K. R. Kenaston. 2004. Hooking mortality by anatomical location and its use in estimating mortality of spring Chinook salmon caught and released in a river sport fishery. North American Journal of Fisheries Management 24:367-378.

Matthews, K. R. and R. H. Reavis. 1990. Underwater tagging and visual recapture as a technique for studying movement patterns of rockfish. American Fisheries Society Symposium. 7:168-172.

McElhany, P., M. H. Ruckelshaus, M. J. Ford, T. C. Wainwright, and E. P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. U.S. Dept. Commer., NOAA Tech. Memo NMFS-NWFSC-42. 156pp.

McFarlane, G. A., J. R. King, and R. J. Beamish. 2000. Have there been recent changes in climate? Ask the fish. Progr. Oceanogr. 47:147–169.

McMichael, G. A. 1993. Examination of electrofishing injury and short-term mortality in hatchery rainbow trout. North American Journal of Fisheries Management 13:229-233.

McMichael, G. A., L. Fritts, and T. N. Pearsons. 1998. Electrofishing injury to stream salmonids; injury assessment at the sample, reach, and stream scales. North American Journal of Fisheries Management. 18:894-904.

McLean, J. E., D. E. Hay, and E. B. Taylor. 1999. Marine population structure in an anadromous fish: Life history influences patterns of mitochondrial DNA variation in the eulachon, *Thaleichthys pacificus*. Mol. Ecol. 8:S143–S158.

McLean, J. E., P. Bentzen, and T. P. Quinn. 2004. Differential reproductive success of sympatric, naturally spawning hatchery and wild steelhead, *Oncorhynchus mykiss.* Environmental Biology of Fishes. 69:359-369.

McNeil, F. I. and E. J. Crossman. 1979. Fin clips in the evaluation of stocking programs for muskellunge (*Esox masquinongy*). Transactions of the American Fisheries Society. 108:335-343.

Mears, H. C. and R. W. Hatch. 1976. Overwinter survival of fingerling brook trout with single and multiple fin clips. Transactions of the American Fisheries Society 105: 669-674.

Meehan, W.R. and R.A. Miller. 1978. Stomach flushing: effectiveness and influence on survival and condition of juvenile salmonids. J. Fish. Res. Board Can. 35:1359-1363.

Melillo, J.M., T.C Richmond, and G.W. Yohe. 2014. Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program.

Mongillo, P. E. 1984. A summary of salmonid hooking mortality. Washington Department of Game, Olympia.

Moody, M. F. 2008. Eulachon past and present. Master of Science thesis. University of British Columbia, Vancouver. 307pp.

Moring, J. R. 1990. Marking and tagging intertidal fishes: review of techniques. American Fisheries Society Symposium. 7:109-116.

Morrison, J. and D. Zajac. 1987. Histologic effect of coded wire tagging in chum salmon. North American Journal of Fisheries Management. 7:439-441.

Morrison, J., M. Quick, and M. G. G. Foreman. 2002. Climate change in the Fraser River watershed: Flow and temperature predictions. J. Hydrol. 263:230–244.

Moyle, P. B., R. M. Yoshiyama, J. E. Williams, and E. D. Wikramanayake. 1995. Eulachon *In* Fish species of special concern in California, Second Edition, p. 123-127. California Department of Fish & Game, Inland Fisheries Division, Rancho Cordova, CA.

Moyle, P. B., J. A. Israel, and S. E. Purdy. 2008. Salmon, steelhead, and trout in California – status of an emblematic fauna. UC Davis Center for Watershed Sciences. Davis, CA. 316 pp.

Myers, J. M., R. G. Kope, G. J. Bryant, D. Teel, L. J. Lierheimer, T. C. Wainwright, W. S. Grant, F. W. Waknitz, K. Neely, S. T. Lindley, and R. S. Waples. 1998. Status review of Chinook salmon from Washington, Idaho, Oregon, and California. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC-35, 443 pp.

Myers, J. M., J. J. Hard, E. J. Connor, R. A. Hayman, R. G. Kope, G. Lucchetti, A. R. Marshall, G. R. Pess, and B. E. Thompson. 2015. Identifying historical populations of steelhead within the Puget Sound distinct population segment. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-128.

Nicola, S. J. and A. J. Cordone. 1973. Effects of fin removal on survival and growth of rainbow trout (*Salmo gairdneri*) in a natural environment. Transactions of the American Fisheries Society. 102(4):753-759.

Nielsen, L. A. 1992. Methods of marking fish and shellfish. American Fisheries Society Special Publication 23. Bethesda, Maryland 1992, 208p.

NMFS. 2000. Guidelines for electrofishing waters containing salmonids listed under the Endangered Species Act, June 2000. Available at: http://www.westcoast.fisheries.noaa.gov/publications/reference_documents/esa_refs/section4d/electro2000.pdf

NMFS (National Marine Fisheries Service). 2003. Endangered Species Act - Section 7 Consultation Biological Opinion and Magnuson-Stevens Act Essential Fish Habitat Consultation on: 1) Issuance of an incidental take statement (ITS) to the USFWS; 2) Issuance of an ITS to the BPA and the Confederated Tribes and Bands of the Yakama Nation (Yakama Nation); and 3) Issuance of permit 1347 jointly to the Washington Department of Fish and Wildlife (WDFW), the Public Utility District No. 1 of Chelan County (Chelan PUD), and the Public Utility District No. 1 of Douglas County (Douglas PUD). NMFS, Portland, Oregon.

NMFS. 2005a. Status review update for Puget Sound steelhead. July 2005. NW Fisheries Science Center, U.S. Dept. Commerce, NMFS, Seattle, WA.

NMFS. 2005b. Final assessment of NOAA Fisheries' critical habitat analytical review teams for 12 Evolutionarily Significant Units of West Coast salmon and Steelhead. August 2005.

NMFS. 2006. Final supplement to the Puget Sound Salmon Recovery Plan. Available at: http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/puget_sound/chinook/ps-supplement.pdf

NMFS. 2008a. Recovery plan for Southern Resident Killer Whales (*Orcinus orca*). National Marine Fisheries Service, Northwest Region, Seattle, Washington.

NMFS. 2008b. ESA Section 7(a)(2) Consultation Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation on the approval of revised regimes under the Pacific Salmon Treaty and the Deferral of Management to Alaska of certain fisheries Included in those Regimes. NMFS, Northwest Region. December 22. 373 pp.

NMFS. 2016. 2016 5-Year Review: Summary & Evaluation of Puget Sound Chinook, Hood Canal Summer-run Chum, and Puget Sound Steelhead - DRAFT. NMFS, West Coast Region. 76 pp.

NOAA Fisheries. 2005. Critical habitat analytical review teams for 12 evolutionarily significant units of west coast salmon and steelhead. Protected Resources Division, Portland, Oregon. August. 27 pp.

NWFSC (Northwest Fisheries Science Center). 2015. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest. December 21, 2015. 357 pp.

NWIFC (Northwest Indian Fisheries Commission). 2016. Puget Sound Tribal Salmon Research Plan – October 2016. 24 pp. + appendix.

Pauley, G. B., B. M. Bortz, and M. F. Shepard. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest) -- steelhead trout. U.S. Fish Wildl. Serv. Biol. Rep. 82(11.62). U.S. Army Corps of Engineers, TR EL-82-4. 24 pp.

Peltz, L. and J. Miller. 1990. Performance of half-length coded wire tags in a pink salmon hatchery marking program. American Fisheries Society Symposium 7:244-252.

Pettit, S. W. 1977. Comparative reproductive success of caught-and-released and unplayed hatchery female steelhead trout (*Salmo gairdneri*) from the Clearwater River, Idaho. Transactions of American Fisheries Society. 106(5):431-435.

Phillips, A. J., S. Ralston, R. D. Brodeur, T. D. Auth, R. L. Emmett, C. Johnson, and V. G. Wespestad. 2007. Recent pre-recruit Pacific hake (*Merluccius productus*) occurrences in the northern California Current suggest a northward expansion of their spawning area. Calif. Coop. Ocean. Fish. Investig. Rep. 48:215–229.

PFMC (Pacific Fishery Management Council). 1997. Review of the 1996 ocean salmon fisheries. (Available from Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 200, Portland, OR 97220.)

PFMC. 2014. Appendix A to the Pacific Coast Salmon Fishery Management Plan, as modified by Amendment 18. Identification and description of essential fish habitat, adverse impacts, and recommended conservation measures for salmon. 227 pp.

PNPTT and WDFW. 2014. Five-year review of the Summer Chum salmon Conservation Initiative for the period 2005 through 2013: Supplemental Report No. 8, Summer Chum Salmon Conservation Initiative -- An implementation plan to recover summer chum salmon in the Hood Canal and Strait of Juan de Fuca region. September 2014. Wash. Dept. Fish and Wildlife. Olympia, WA. 237 pp., including appendices.

Prentice, E. F. and D. L. Park. 1984. A study to determine the biological feasibility of a new fish tagging system. Annual Report of Research, 1983-1984. Project 83-19, Contract DEA179-83BP11982.

Prentice, E. F., T. A. Flagg, and C. S. McCutcheon. 1987. A study to determine the biological feasibility of a new fish tagging system, 1986-1987. Bonneville Power Administration, Portland, Oregon.

Prentice, E. F., T. A. Flagg, and C. S. McCutcheon. 1990. Feasibility of using implantable passive integrated transponder (PIT) tags in salmonids. American Fisheries Society Symposium 7: 317-322.

PSTRT (Puget Sound Technical Recovery Team). 2002. Planning ranges and preliminary guidelines for the delisting and recovery of the Puget Sound Chinook salmon evolutionarily significant unit.

Quinn, T. P. 2005. The Behavior and Ecology of Pacific Salmon and Trout. Published by University of Washington Press. 2005. 378 pp.

Reingold, M. 1975. Effects of displacing, hooking, and releasing on migrating adult steelhead trout. Transactions of the American Fisheries Society. 104(3):458-460.

Reisenbichler, R. R. and S. P. Rubin. 1999. Genetic changes from artificial propagation of Pacific salmon affect the productivity and viability of supplemented populations. ICES Journal of Marine Science. 56:459-466.

Rexstad, E. A. and E. K. Pikitch. 1986. Stomach contents and food consumption estimates of Pacific hake, *Merluccius productus*. Fish. Bull. 84:947–956.

Roemmich, D. and J. McGowan. 1995. Climatic warming and the decline of zooplankton in the California Current. Science. 267:1324–1326.

Rondorf, D. W. and W. H. Miller. 1994. Identification of the spawning, rearing and migratory requirements of fall Chinook salmon in the Columbia River Basin. Prepared for the U.S. Dept. of Energy, Portland, OR. 219 p.

Ruckelshaus, M. H., K. P. Currens, W. H. Graeber, R. R. Fuerstenberg, K. Rawson, N. J. Sands, and J. B. Scott. 2006. Independent populations of Chinook salmon in Puget Sound. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC-78, 125 pp.

Rykaczewski, R. R., J. P. Dunne, W. J. Sydeman, M. Garcia-Reyes, B. A. Black, and S. J. Bograd. 2015. Poleward displacement of coastal upwelling-favorable winds in the ocean's eastern boundary currents through the 21st century. Geophysical Research Letters. 42:6424-6431.

Salathe, E. P., A. F. Hamlet, C. F. Mass, S. Y. Lee, M. Stumbaugh, and R. Steed. 2014. Estimates of Twenty-First-Century Flood Risk in the Pacific Northwest Based on Regional Climate Model Simulations. Journal of Hydrometeorology. 15:1881-1899.

Sands, N. J., K. Rawson, K. P. Currens, W. H. Graeber, M. H. Ruckelshaus, R. R. Fuerstenberg, and J. B. Scott. 2009. Determination of independent populations and viability criteria for the

Hood Canal summer chum salmon evolutionarily significant unit. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-101, 58 p.

Sawaske, S.R. and D.L. Freyberg. 2014. An analysis of trends in baseflow recession and low-flows in rain-dominated coastal streams of the pacific coast. Journal of Hydrology. 519:599-610.

Schill, D. J., and R. L. Scarpella. 1995. Wild trout regulation studies. Annual performance report. Idaho Department of Fish and Game, Boise.

Schisler, G. J. and E. P. Bergersen. 1996. Post release hooking mortality of rainbow trout caught on scented artificial baits. North American Journal of Fisheries Management. 16(3):570-578.

Scholz, N. L., M. S. Myers, S. G. McCarthy, J. S. Labenia, J. K. McIntyre, G. M. Ylitalo, L. D. Rhodes, C. A. Laetz, C. M. Stehr, B. L. French, B. McMillan, D. Wilson, L. Reed, K. D. Lynch, S. Damm, J. W. Davis, and T. K. Collier. 2011. Recurrent die-offs of adult coho salmon returning to spawn in Puget Sound lowland urban streams. PLos One. 6(12):1-12

Schroeder, R. K., K. R. Kenaston, and R. B. Lindsay. 2000. Spring Chinook salmon in the Willamette and Sandy Rivers. October 1998 through September 1999. Annual progress report, Fish Research Project Oregon. Oregon Department of Fish and Wildlife, Portland.

Seiler, D., G. Volkhardt, P. Topping, and L. Kishimoto. 2002. 2000 Green River juvenile salmonid production evaluation. Washington Department of Fish and Wildlife.

Seiler, D., G. Volkhardt, P. Topping, L. Fleischer, T. Miller, S. Schonning, D. Rawding, M. Groesbeck, R. Woodard, and S. Hawkins. 2004. 2003 juvenile salmonid production evaluation report. Green River, Wenatchee River, and Cedar Creek. Washington Department of Fish and Wildlife.

Seiler, D., G. Volkhardt, and L. Fleischer. 2005. Evaluation of downstream migrant salmon production in 2004 from the Cedar River and Bear Creek. Washington Department of Fish and Wildlife.

Sharber, N. G. and S. W. Carothers. 1988. Influence of electrofishing pulse shape on spinal injuries in adult rainbow trout. North American Journal of Fisheries Management. 8:117-122.

Sharber, N. G., S. W. Carothers, J. P. Sharber, J. C. DeVos, Jr., and D. A. House. 1994. Reducing electrofishing-induced injury of rainbow trout. North American Journal of Fisheries Management. 14:340-346.

Sharpe, C. S., D. A. Thompson, H. L. Blankenship, and C. B. Schreck. 1998. Effects of routine handling and tagging procedures on physiological stress responses in juvenile Chinook salmon. Progressive Fish-Culturist. 60(2):81-87.

Smith, W. E. and R. W. Saalfeld. 1955. Studies on Columbia River smelt *Thaleichthys pacificus* (Richardson). Washington Department of Fisheries, Fisheries Research Paper 1(3):3–26.

Snyder, D. E. 1992. Impacts of electrofishing on fish. Contribution number 50 of the Larval Fish Laboratory, Colorado State University, Fort Collins.

Snyder, D. E. 1995. Impacts of electrofishing on fish. Fisheries. 20(1):26-27.

SSDC (Shared Strategy Development Committee). 2007. Puget Sound Salmon Recovery Plan. Adopted by the National Marine Fisheries Service January 19, 2007. Available on-line at http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/puget_sound/chinook/pugetsoundchinookrecoveryplan.pdf

Stolte, L. W. 1973. Differences in survival and growth of marked and unmarked coho salmon. Progressive Fish-Culturist 35: 229-230.

Strange, C.D. and G.J. Kennedy. 1981. Stomach flushing of salmonids: a simple and effective technique for the removal of the stomach contents. Fish. Manage. 12:9-15.

TAC [TAC (U.S. v. Oregon Technical Advisory Committee)]. 2008. Biological assessment of incidental impacts on salmon species listed under the Endangered Species Act in the 2008-2017 non-Indian and treaty Indian fisheries in the Columbia River Basin.

Taylor, G. and R. A. Barnhart. 1999. Mortality of angler caught and released steelhead. California Cooperative Fish and Wildlife Research Unit, Arcata.

Taylor, M. J. and K. R. White. 1992. A meta-analysis of hooking mortality of non-anadromous trout. North American Journal of Fisheries Management. 12:760-767.

Thompson, K. G., E. P. Bergersen, R. B. Nehring, and D. C. Bowden. 1997. Long-term effects of electrofishing on growth and body condition of brown and rainbow trout. North American Journal of Fisheries Management. 17:154-159.

Volkhardt, G., P. Topping, L. Fleischer, T. Miller, S. Schonning, D. Rawding, M. Groesbeck. 2005. 2004 Juvenile salmonid production evaluation report. Green River, Wenatchee River, and Cedar Creek. Washington Department of Fish and Wildlife.

Wade, A .A., T. J. Beechie, E. Fleishman, N. J. Mantua, H. Wu, J. S. Kimball, D. M. Stoms, and J. A. Stanford. 2013. Steelhead vulnerability to climate change in the Pacific Northwest. Journal of Applied Ecology. 50:1093-1104.

Wainwright, T.C. and L.A. Weitkamp. 2013. Effects of Climate Change on Oregon Coast Coho Salmon: Habitat and Life-Cycle Interactions. Northwest Science. 87:219-242.

Waples, R. S. 1991. Definition of “Species” under the Endangered Species Act: Application to Pacific Salmon. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS, F/NWC-194. 29 pp.

Ward, B. R. and P. A. Slaney. 1993. Egg-to-smolt survival and fry-to-smolt density dependence in Keogh River steelhead trout, p. 209-217. *In* R. J. Gibson and R. E. Cutting [ed.] Production of juvenile Atlantic salmon, *Salmon salar*, in natural waters. Can. Spec. Publ. Fish. Aquat. Sci. 118.

WDF (Washington Department of Fisheries). 1974. 1974 Fisheries Statistical Report. Department of Fisheries, State of Washington.

WDF. 1991. Revised stock transfer guidelines. Memo, 28 May 1991, Salmon Culture Division Olympia, WA, 10 pp.

WDF, WDW (Washington Department of Wildlife), and WWTIT (Western Washington Treaty Indian Tribes). 1993. 1992 Washington State salmon and steelhead stock inventory (SASSI). Wash. Dep. Fish Wildlife, Olympia, 212 pp. and 5 regional volumes. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N, Olympia, WA 98501-1091.)

WDFW and ODFW. 2001. Washington and Oregon eulachon management plan.

WDFW. 2016. 2016 Future Brood Document Final (July 28, 2016). Online at http://wdfw.wa.gov/publications/01776/wdfw01776.pdf

WDFW/PNPTT (Point No Point Treaty Tribes). 2000. Summer Chum Salmon Conservation Initiative: An implementation plan to recovery summer chum in the Hood Canal and Strait of Juan de Fuca Region. Wash. Dept. Fish and Wild., Olympia, WA. p.423 + appendix.

WDFW/PNPTT. 2001. Summer chum salmon conservation initiative: annual report for the 2000 summer chum salmon return to the Hood Canal and Strait of Juan de Fuca region. Wash. Dept. Fish and Wild., Olympia, WA. 138pp.

Welch, H. E. and K. H. Mills. 1981. Marking fish by scarring soft fin rays. Canadian Journal of Fisheries and Aquatic Sciences 38:1168-1170.

Willson, M. F., R. H. Armstrong, M. C. Hermans, and K Koski. 2006. Eulachon: a review of biology and an annotated bibliography. Alaska Fisheries Science Center Processed Report 2006-12. Auke Bay Laboratory, Alaska Fish. Sci. Cent., NOAA, Natl. Mar, Fish. Serv., Juneau, AK.

Wydoski, R. S. 1977. Relation of hooking mortality and sublethal hooking stress to quality fishery management. Pages 43-87 in R.A. Barnhart and T.D. Roelofs, editors. Proceedings of a national symposium on catch-and-release fishing as a management tool. Humboldt State University, Arcata, California.

Wydoski, R. S. and R. R. Whitney. 2003. Inland fishes of Washington, second edition, revised and expanded. University of Washington Press, Seattle.

Zamon, J. E. and D. W. Welch. 2005. Rapid shift in zooplankton community composition on the northeast Pacific shelf during the 1998–1999 El Niño-La Niña event. Can. J. Fish. Aquat. Sci. 62:133–144.