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

Consultation on the Issuance of Four ESA Section 10(a)(1)(A) Scientific Research Permits affecting Salmon and Steelhead in the West Coast Region

NMFS Consultation Number: WCR-2018-10494
ARN 151422WCR2018PR00158

Action Agencies: The National Marine Fisheries Service (NMFS)
U.S. Fish and Wildlife Service (FWS)

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 (*Oncorhynchus 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 Resident (SR) killer whale (*Orcinus orca*)	Endangered	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:

For Barry A. Thom
Regional Administrator

Date: August 15, 2018

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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 a review of four scientific research permits proposed for issuance by NMFS under section 10(a)(1)(A) of the ESA and is based on information provided in the associated applications for the proposed permits, published and unpublished scientific information on the biology and ecology of listed salmonids in the action areas, and other sources of information.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 West Coast Region's (WCR's) Protected Resources Division (PRD) received four applications for permits to conduct scientific research (see dates below). One application was to modify an existing permit and three applications were for new permits. Because the permit requests are similar in nature and duration and are expected to affect the same listed species, we decided to combine them into a single consultation pursuant to 50 CFR 402.14(c). The affected species are Puget Sound (PS) Chinook salmon, Hood Canal Summer-run (HCS) chum salmon, and PS steelhead. The proposed actions also have the potential to affect Southern Resident (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).

We received a permit modification request (21330-2M) from the U.S. Fish and Wildlife Service (FWS) on February 6, 2018. Requested edits were sent on April 4, 2018; and all requests were addressed and completed by April 17, 2018.

We received a permit request (21870) from the Oregon State University (OSU) on December 1, 2017. Requested edits were sent on May 1, 2018; and all requests were addressed and completed by May 2, 2018.

We received a permit request (22093) from the Snoqualmie Valley Watershed Improvement District (SVWID) on March 9, 2018. Requested edits were sent on April 11, 2018; and all requests were addressed and completed by April 19, 2018.

We received a permit request (22127) from the FWS on March 21, 2018. Requested edits were sent on April 25, 2018; and all requests were addressed and completed by May 31, 2018.

Most of the requests were deemed incomplete to varying extents when they arrived. After numerous phone call and e-mail exchanges, the applicants revised and finalized their applications. After the applications were determined to be complete, we published notice in the Federal Register on July 5, 2018 asking for public comment on them (83 FR 31371). The public was given 30 days to comment on the permit applications and, once that period closed on August 6, 2018, the consultation began. The full consultation histories for the actions are lengthy and not directly relevant to the analysis for the proposed actions and so are not detailed here. 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.

The proposed actions here are NMFS' issuance of four scientific research permits pursuant to section 10(a)(1)(A) of the ESA for the associated activities proposed by the FWS, OSU, and SVWID. The permits would variously authorize researchers to take PS Chinook salmon, HCS chum salmon, and PS steelhead. "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.

Permit 21330-2M

The FWS is seeking to modify a five-year research permit, issued in 2017, that allows them to annually take juvenile PS Chinook salmon and PS steelhead in Jim Creek (South Fork Stillaguamish River watershed—Snohomish County, Washington). The purpose of the FWS study is to document ESA-listed fish presence, distribution, and abundance in Jim Creek within the boundaries of the Naval Radio Station Jim Creek facility. The research would benefit the listed species by helping refine the facility's Integrated Natural Resources Management plan—the information would help guide decisions regarding habitat restoration and fill data gaps regarding the distribution and abundance of ESA-listed PS Chinook salmon, PS steelhead, and bull trout (*Salvelinus confluentus*). The FWS proposes to capture fish using backpack electrofishing equipment. The captured fish would be removed from the water using a dip net, placed in aerated buckets, anesthetized with MS-222, identified to species, weighed, measured, and returned to their capture locations when recovered. In 2017, the researchers exceeded their authorized PS steelhead take, so they are seeking to modify the permit by increasing the number of PS steelhead they are allowed to take. The researchers do not intend to kill any listed fish, but some may die as an inadvertent result of the research.

Permit 21870

The OSU is seeking a five-year research permit to annually take juvenile PS Chinook salmon, HCS chum salmon, and PS steelhead in the South Fork of the Skokomish River (Mason County, Washington state). The purpose of the OSU study is to research the trophic pathways that support salmonids in the Skokomish River and to determine how invasive plants mediate terrestrial subsidies to streams throughout the year. The researchers would target PS steelhead, PS/Strait of Georgia coho salmon (*O. kisutch*), and sculpin species. This research would benefit the affected species by filling the knowledge gaps that have limited effective restoration of local food webs. The OSU proposes to use seine nets and minnow traps to capture the fish. Captured fish would be identified to species and temporarily held in aerated buckets. Juvenile PS steelhead (and all other target species) would be anesthetized with MS–222, measured for length, tissue sampled (scales and caudal fin clip), gastric lavaged, and released. All other non-targeted fish (including PS Chinook and HCS chum salmon) would be released after species identification. The researchers do not intend to kill any listed fish, but some may die as an inadvertent result of the research.

Permit 22093

The SVWID is seeking a five-year research permit to annually take juvenile and adult PS Chinook salmon and PS steelhead throughout the Snoqualmie River watershed (Snohomish County, Washington state). The purpose of the SVWID study is to assess fish passage barriers, habitat conditions, water quality, and fish presence/absence. This research would benefit the affected species by better informing plans that can effectively address drainage and flooding issues across hydrological boundaries (as opposed to property boundaries) and help restore salmon habitat. Further, this research would benefit listed species by providing data about the status of these species in agricultural drainage ditches and small streams that may not otherwise be studied. The SVWID proposes to capture fish using seine nets, minnow traps, and backpack electrofishing equipment. Captured fish would be held in aerated buckets, identified to species, measured to length, and released. The researchers do not intend to kill any listed fish, but some may die as an inadvertent result of the research.

Permit 22127

The FWS is seeking a five-year research permit to annually take juvenile and adult PS Chinook salmon and PS steelhead throughout the Puyallup River watershed (Pierce and King Counties, Washington state). The purpose of the FWS study is to research ESA-listed bull trout life history diversity and gather information about their temporal and spatial use of the watershed at multiple life stages. Other target species include brook trout (*Salvelinus fontinalis*), cutthroat trout (*O. clarkii*), and non-migratory sculpin species (Shorthead, Torrent, and Riffle). PS Chinook salmon and PS steelhead would be inadvertently taken during this study because their ranges overlap the target species. This research would benefit the listed species by providing fine scale information about their movement timing and upstream residency. Those data, in turn, would be used to inform management and recovery actions. The FWS proposes to capture fish using electro-fykes, backpack electrofishing equipment, gill nets, hook-and-line, and minnow traps. Bull trout would be anesthetized, PIT tagged, weighed, measured for length, tissue sampled (fin rays), and released. Other target species would be euthanized for otolith and fin ray analysis. All PS steelhead and PS Chinook salmon would be captured, handled, and immediately released. The researchers do not propose to kill any of the listed fish, but some may die as an unintended result of the activities.

Common Elements among the Proposed Permit Actions

Research permits lay out the conditions to be followed before, during, and after the research activities are conducted. These conditions are intended to (a) manage the interaction between scientists and listed salmonids by requiring that research activities be coordinated among permit holders and between permit holders and NMFS, (b) minimize impacts on listed species, and (c) ensure that NMFS receives information about the effects the permitted activities have on the species concerned. All research permits the NMFS' WCR issues have the following conditions:

1. The permit holder must ensure that listed species are taken only at the levels, by the means, in the areas and for the purposes stated in the permit application, and according to the terms and conditions in the permit.

2. The permit holder must not intentionally kill or cause to be killed any listed species unless the permit specifically allows intentional lethal take.

3. The permit holder must handle listed fish with extreme care and keep them in cold water to the maximum extent possible during sampling and processing procedures. When fish are transferred or held, a healthy environment must be provided; e.g., the holding units must contain adequate amounts of well-circulated water. When using gear that captures a mix of species, the permit holder must process listed fish first to minimize handling stress.

4. The permit holder must stop handling listed juvenile fish if the water temperature exceeds 70 degrees Fahrenheit (°F) at the capture site. Under these conditions, listed fish may only be visually identified and counted. In addition, electrofishing is not permitted if water temperature exceeds 64°F.

5. If the permit holder anesthetizes listed fish to avoid injuring or killing them during handling, the fish must be allowed to recover before being released. Fish that are only counted must remain in water and not be anesthetized.

6. The permit holder must use a sterilized needle for each individual injection when passive integrated transponder tags (PIT-tags) are inserted into listed fish.

7. If the permit holder unintentionally captures any listed adult fish while sampling for juveniles, the adult fish must be released without further handling and such take must be reported.

8. The permit holder must exercise care during spawning ground surveys to avoid disturbing listed adult salmonids when they are spawning. Researchers must avoid walking in salmon streams

whenever possible, especially where listed salmonids are likely to spawn. Visual observation must be used instead of intrusive sampling methods, especially when the only activity is determining fish presence.

9. The permit holder using backpack electrofishing equipment must comply with NMFS' Backpack Electrofishing Guidelines (June 2000) available at: http://www.westcoast.fisheries.noaa.gov/publications/reference_documents/esa_refs/section4d/electro2000.pdf.

10. The permit holder must obtain approval from NMFS before changing sampling locations or research protocols.

11. The permit holder must notify NMFS as soon as possible but no later than two days after any authorized level of take is exceeded or if such an event is likely. The permit holder must submit a written report detailing why the authorized take level was exceeded or is likely to be exceeded.

12. The permit holder is responsible for any biological samples collected from listed species as long as they are used for research purposes. The permit holder may not transfer biological samples to anyone not listed in the application without prior written approval from NMFS.

13. The person(s) actually doing the research must carry a copy of this permit while conducting the authorized activities.

14. The permit holder must allow any NMFS employee or representative to accompany field personnel while they conduct the research activities.

15. The permit holder must allow any NMFS employee or representative to inspect any records or facilities related to the permit activities.

16. The permit holder may not transfer or assign this permit to any other person as defined in section 3(12) of the ESA. This permit ceases to be in effect if transferred or assigned to any other person without NMFS' authorization.

17. NMFS may amend the provisions of this permit after giving the permit holder reasonable notice of the amendment.

18. The permit holder must obtain all other Federal, state, and local permits/authorizations needed for the research activities.

19. On or before January 31st of every year, the permit holder must submit to NMFS a post-season report in the prescribed form describing the research activities, the number of listed fish taken and the location, the type of take, the number of fish intentionally killed and unintentionally killed, the take dates, and a brief summary of the research results. The report must be submitted electronically on our permit website, and the forms can be found at https://apps.nmfs.noaa.gov/. Falsifying annual reports or permit records is a violation of this permit.

20. If the permit holder violates any permit condition they will be subject to any and all penalties provided by the ESA. NMFS may revoke this permit if the authorized activities are not

conducted in compliance with the permit and the requirements of the ESA or if NMFS determines that its ESA section 10(d) findings are no longer valid.

"Permit holder" means the permit holder or any employee, contractor, or agent of the permit holder. Also, NMFS may include conditions specific to the proposed research in the individual permits.

Finally, NMFS will use the annual reports to monitor the actual number of listed fish taken annually in the scientific research activities and will adjust permitted take levels if they are deemed to be excessive or if cumulative take levels rise to the point where they are detrimental to the listed species.

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.

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] Herein, the NMFS determined that the proposed action of issuing four scientific research permits, individually or in aggregate:

- May adversely affect PS Chinook salmon, HCS chum salmon, and PS steelhead, but would not jeopardize their continued existence.
- Is not likely to adversely affect SR killer whales or critical habitat designated for any of the subject species.

The reason for our determinations is presented below.

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).

[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."

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.

Climate change is likely to play an increasingly important role in determining the abundance and distribution of ESA-listed species, and the conservation value of designated critical habitats, in the Pacific Northwest. These changes will not be spatially homogeneous across the Pacific Northwest. The largest hydrologic responses are expected to occur in basins with significant snow accumulation, where warming decreases snow pack, increases winter flows, and advances the timing of spring melt (Mote et al. 2014, Mote 2016). Rain-dominated watersheds and those with significant contributions from groundwater may be less sensitive to predicted changes in climate (Tague et al. 2013, Mote et al. 2014).

During the last century, average regional air temperatures in the Pacific Northwest increased by 1-1.4°F as an annual average, and up to 2°F in some seasons (based on average linear increase per decade; Abatzoglou et al. 2014, Kunkel et al. 2013). Warming is likely to continue during the next century as average temperatures are projected to increase another 3 to 10°F, with the largest increases predicted to occur in the summer (Mote et al. 2014). Decreases in summer precipitation of as much as 30% by the end of the century are consistently predicted across climate models (Mote et al. 2014). Precipitation is more likely to occur during October through March, less during summer months, and more winter precipitation will be rain than snow (ISAB 2007, Mote et al. 2013, Mote et al. 2014). Earlier snowmelt will cause lower stream flows in late spring, summer, and fall, and water temperatures will be warmer (ISAB 2007, Mote et al. 2014). Models consistently predict increases in the frequency of severe winter precipitation events (i.e., 20-year and 50-year events), in the western

United States (Dominguez et al. 2012). The largest increases in winter flood frequency and magnitude are predicted in mixed rain-snow watersheds (Mote et al. 2014).

Overall, about one-third of the current cold-water salmonid habitat in the Pacific Northwest is likely to exceed key water temperature thresholds by the end of this century (Mantua et al. 2009). Higher temperatures will reduce the quality of available salmonid habitat for most freshwater life stages (ISAB 2007). Reduced flows will make it more difficult for migrating fish to pass physical and thermal obstructions, limiting their access to available habitat (Mantua et al. 2010; Isaak et al. 2012). Temperature increases shift timing of key life cycle events for salmonids and species forming the base of their aquatic foodwebs (Crozier et al. 2011, Tillmann and Siemann 2011, Winder and Schindler 2004). Higher stream temperatures will also cause decreases in dissolved oxygen and may also cause earlier onset of stratification and reduced mixing between layers in lakes and reservoirs, which can also result in reduced oxygen (Meyer et al. 1999, Winder and Schindler 2004, Raymondi et al. 2013). Higher temperatures are likely to cause several species to become more susceptible to parasites, disease, and higher predation rates (Crozier et al. 2008; Wainwright and Weitkamp 2013; Raymondi et al. 2013).

As more basins become rain-dominated and prone to more severe winter storms, higher winter stream flows may increase the risk that winter or spring floods in sensitive watersheds will damage spawning redds and wash away incubating eggs (Goode et al. 2013). Earlier peak stream flows will also alter migration timing for salmon smolts, and may flush some young salmon and steelhead from rivers to estuaries before they are physically mature, increasing stress and reducing smolt survival (McMahon and Hartman 1989; Lawson et al. 2004).

In addition to changes in freshwater conditions, predicted changes for coastal waters in the Pacific Northwest as a result of climate change include increasing surface water temperature, increasing but highly variable acidity, and increasing storm frequency and magnitude (Mote et al. 2014). Elevated ocean temperatures already documented for the Pacific Northwest are highly likely to continue during the next century, with sea surface temperature projected to increase by 1.0-3.7°C (1.8-6.7°F) by the end of the century (IPCC 2014). Habitat loss, shifts in species' ranges and abundances, and altered marine food webs could have substantial consequences to anadromous, coastal, and marine species in the Pacific Northwest (Tillmann and Siemann 2011, Reeder et al. 2013).

Moreover, as atmospheric carbon emissions increase, increasing levels of carbon are absorbed by the oceans, changing the pH of the water. Acidification also impacts sensitive estuary habitats, where organic matter and nutrient inputs further reduce pH and produce conditions more corrosive than those in offshore waters (Feely et al. 2012, Sunda and Cai 2012).

Global sea levels are expected to continue rising throughout this century, reaching likely predicted increases of 10-32 inches by 2081-2100 (IPCC 2014). These changes will likely result in increased erosion and more frequent and severe coastal flooding, and shifts in the composition of nearshore habitats (Tillmann and Siemann 2011, Reeder et al. 2013). Estuarine-dependent salmonids such as chum and Chinook salmon are predicted to be impacted by significant reductions in rearing habitat in some Pacific Northwest coastal areas (Glick et al. 2007). Historically, warm periods in the coastal Pacific Ocean have coincided with relatively low abundances of salmon and steelhead, while cooler ocean periods have coincided with relatively high abundances, and therefore these species are predicted to fare poorly in warming ocean conditions (Scheuerell and Williams 2005; Zabel et al.

2006). This is supported by the recent observation that anomalously warm sea surface temperatures off the coast of Washington from 2013 to 2016 resulted in poor coho and Chinook salmon body condition for juveniles caught in those waters (NWFSC 2015). Changes to estuarine and coastal conditions, as well as the timing of seasonal shifts in these habitats, have the potential to impact a wide range of listed aquatic species (Tillmann and Siemann 2011, Reeder et al. 2013).

The adaptive ability of these threatened and endangered species is depressed due to reductions in population size, habitat quantity and diversity, and loss of behavioral and genetic variation. Without these natural sources of resilience, systematic changes in local and regional climatic conditions will likely reduce long-term viability and sustainability of populations in many of these ESUs (NWFSC 2015). New stressors generated by climate change, or existing stressors with effects that have been amplified by climate change, may also have synergistic impacts on species and ecosystems (Doney et al. 2012). These conditions will possibly intensify the climate change stressors inhibiting recovery of ESA-listed species in the future.

2.2.1 Status of the Species

For Pacific salmon and steelhead, 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. When a population or species has sufficient spatial structure, diversity, abundance, and productivity, it will generally be able to maintain its capacity to adapt to various environmental conditions and 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 thus is a function of how well its biological requirements are being met: the greater the degree to which the requirements are fulfilled, the better the species' status. Information on the status and distribution of all the species considered here can be found in a number of documents, but the most pertinent are the Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest and the various recovery plans cited in Table 1 and the specific species sections that follow. These documents and other relevant information may be found at http://www.westcoast.fisheries.noaa.gov; the discussions they contain are summarized in the tables below. For the purposes of our later analysis, all the species considered here require functioning habitat and adequate spatial structure, abundance, productivity, and diversity to ensure their survival and recovery in the wild.

Table 1. Listing classification and date, recovery plan reference, most recent status review, status summary, and limiting factors for each species considered in this opinion.

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
Puget Sound Chinook salmon	Threatened 6/28/2005 (70 FR 37160)	SSDC 2007 NMFS 2006	NWFSC 2015	This ESU comprises 22 populations distributed over five geographic areas. Most populations within the ESU have declined in abundance over the past 7 to 10 years, with widespread negative trends in natural-origin spawner abundance, and hatchery-origin spawners present in high fractions in most populations outside of the Skagit watershed. Escapement levels for all populations remain well below the TRT planning ranges for recovery, and most populations are consistently below the spawner-recruit levels identified by the TRT as consistent with recovery.	• Degraded floodplain and in-river channel structure • Degraded estuarine conditions and loss of estuarine habitat • Degraded riparian areas and loss of in-river large woody debris • Excessive fine-grained sediment in spawning gravel • Degraded water quality and temperature • Degraded nearshore conditions • Impaired passage for migrating fish • Severely altered flow regime
Hood Canal summer-run chum salmon	Threatened 6/28/2005 (70 FR 37160)	HCCC 2005 NMFS 2007	NWFSC 2015	This ESU is made up of two independent populations in one major population group. Natural-origin spawner abundance has increased since ESA-listing and spawning abundance targets in both populations have been met in some years. Productivity was quite low at the time of the last review, 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.	• Reduced floodplain connectivity and function • Poor riparian condition • Loss of channel complexity Sediment accumulation • Altered flows and water quality
Puget Sound steelhead	Threatened 5/11/2007 (72 FR 26722)	In development	NWFSC 2015	This DPS comprises 32 populations. The DPS is currently at very low viability, with most of the 32 populations and all three population groups at low viability. Information considered during	• Continued destruction and modification of habitat • Widespread declines in adult abundance despite significant reductions in harvest

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
				the most recent status review indicates that the biological risks faced by the Puget Sound Steelhead DPS have not substantively changed since the listing in 2007, or since the 2011 status review. Furthermore, 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 populations. In the near term, the outlook for environmental conditions affecting Puget Sound steelhead is not optimistic. While harvest and hatchery production of steelhead in Puget Sound are currently at low levels and are not likely to increase substantially in the foreseeable future, some recent environmental trends not favorable to Puget Sound steelhead survival and production are expected to continue.	• Threats to diversity posed by use of two hatchery steelhead stocks • Declining diversity in the DPS, including the uncertain but weak status of summer-run fish • A reduction in spatial structure • Reduced habitat quality • Urbanization • Dikes, hardening of banks with riprap, and channelization
Southern resident killer whale	Endangered 11/18/2005 (70 FR 69903)	NMFS 2008	Ford 2013	The Southern Resident killer whale DPS is composed of a single population that ranges as far south as central California and as far north as southeast Alaska. The estimated effective size of the population (based on the number of breeding individuals under ideal genetic conditions) is very small — <30 whales, or about 1/3 of the current population size. The small effective population size, the absence of gene flow from other populations, and documented breeding within pods may elevate the risk from inbreeding and other issues associated with genetic deterioration. As of July 1, 2013, there were 26 whales in J pod, 19 whales in K pod and 37 whales in L pod, for a total of 82 whales. Estimates for the historical abundance of Southern Resident killer whales range from 140 whales (based on public display removals to 400 whales, as used in population viability analysis scenarios.	• Quantity and quality of prey • Exposure to toxic chemicals • Disturbance from sound and vessels • Risk from oil spills

2.2.1.1 Puget Sound Chinook Salmon

Listed Hatchery Juvenile Releases – Twenty-six artificial propagation programs are part of the species and are also listed (79 FR 20802; Table 2). 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 2 is 43,269,740 adipose-fin-clipped and non-clipped juvenile Chinook salmon.

Table 2. Expected 2018 Puget Sound Chinook salmon hatchery releases (WDFW 2017).

Subbasin	Artificial propagation program	Brood year	Run Timing	Clipped Adipose Fin	Intact Adipose Fin
Deschutes	Tumwater Falls	2017	Fall	3,800,000	-
Dungeness-Elwha	Dungeness	2017	Spring	-	50,000
	Elwha	2016	Fall	-	200,000
		2017	Fall	250,000	2,250,000
	Gray Wolf River	2017	Spring	-	50,000
	Hurd Creek	2016	Spring	-	50,000
	Upper Dungeness Pond	2017	Spring	-	50,000
Duwamish	Icy Creek	2016	Fall	300,000	-
	Palmer	2017	Fall	-	1,000,000
	Soos Creek	2017	Fall	3,000,000	200,000
Hood Canal	Hood Canal Schools	2017	Fall	-	500
	Hoodsport	2016	Fall	120,000	-
		2017	Fall	2,300,000	-
Kitsap	Bernie Gobin	2016	Spring	40,000	-
		2017	Fall	-	200,000
			Summer	2,300,000	100,000
	Chambers Creek	2017	Fall	400,000	-
	Garrison	2017	Fall	450,000	-
	George Adams	2017	Fall	3,575,000	225,000
	Gorst Creek	2017	Fall	1,530,000	-
	Grovers Creek	2017	Fall	450,000	-
	Hupp Springs	2017	Spring	-	400,000
	Lummi Sea Ponds	2017	Fall	500,000	-
	Minter Creek	2017	Fall	1,250,000	-
Lake Washington	Friends of ISH	2017	Fall	-	1,425
	Issaquah	2017	Fall	2,000,000	-
Nisqually	Clear Creek	2017	Fall	3,300,000	200,000
	Kalama Creek	2017	Fall	600,000	-
	Nisqually MS	2017	Fall	-	90
Nooksack	Kendall Creek	2017	Spring	800,000	-
	Skookum Creek	2017	Spring	-	1,000,000
Puyallup	Clarks Creek	2017	Fall	400,000	-
	Voights Creek	2017	Fall	1,600,000	-

Subbasin	Artificial propagation program	Brood year	Run Timing	Clipped Adipose Fin	Intact Adipose Fin
	White River	2016	Spring	-	55,000
		2017	Spring	-	340,000
San Juan Islands	Glenwood Springs	2017	Fall	725,000	-
	Orcas Island SD	2017	Fall	-	225
Skykomish	Wallace River	2016	Summer	500,000	-
		2017	Summer	800,000	200,000
Stillaguamish	Brenner	2017	Fall	-	200,000
	Whitehorse Pond	2017	Summer	220,000	-
Strait of Georgia	Samish	2017	Fall	3,800,000	200,000
Upper Skagit	Marblemount	2017	Spring	387,500	200,000
			Summer	200,000	-
Total Annual Release Number				**36,097,500**	**7,172,240**

Adult spawners and expected outmigration – The average[2] abundance (2012-2016) for PS Chinook salmon populations is 36,295 adult spawners (22,194 natural-origin and 14,101 hatchery-origin spawners; Table 3). Natural-origin spawners range from 15 (in the South Fork Nooksack River population) to 9,847 fish (in the Upper Skagit population). No populations are meeting minimum viability abundance targets, and only three 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).

Table 3. Average abundance estimates for PS Chinook salmon natural- and hatchery-origin spawners 2012-2016 (unpublished data, Mindy Rowse, NWFSC, July 3, 2018).

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[d]	159	953	85.70%	16,000	89,003
SF Nooksack River[d]	15	10	38.94%	9,100	1,983
Strait of Juan de Fuca MPG					
Elwha River	183	2,542	93.30%	15,100	217,967
Dungeness River	115	251	68.64%	4,700	29,310
Hood Canal MPG					
Skokomish River	267	641	70.63%	12,800	72,631
Mid-Hood Canal	125	165	56.92%	11,000	23,236
Whidbey Basin MPG					
Skykomish River	1,952	1,130	36.66%	17,000	246,604
Snoqualmie River	804	208	20.55%	17,000	80,990
NF Stillaguamish River	340	286	45.71%	17,000	50,133

[2] 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.

Population Name	Natural-origin Spawners[a]	Hatchery-origin Spawners[a]	% Hatchery Origin	Minimum Viability Abundance[b]	Expected Number of Outmigrants[c]
SF Stillaguamish River	58	15	20.11%	15,000	5,795
Upper Skagit River	9,847	470	4.56%	17,000	825,402
Lower Skagit River	2,146	44	2.02%	16,000	175,184
Upper Sauk River	1,124	24	2.09%	3,000	91,874
Lower Sauk River	507	14	2.62%	5,600	41,615
Suiattle River	516	3	0.65%	600	41,574
Cascade River	234	20	7.73%	1,200	20,250
Central / South Sound MPG					
Sammamish River	118	1,141	90.64%	10,500	100,693
Cedar River	805	308	27.67%	11,500	89,020
Duwamish/Green River	1,075	2,537	70.23%	17,000	288,981
Puyallup River	461	878	65.56%	17,000	107,106
White River	604	1,493	71.21%	14,200	167,792
Nisqually River	739	966	56.66%	13,000	136,431
ESU Average	**22,194**	**14,101**	**38.85%**		**2,903,573**

[a] Five-year geometric mean of post-fishery spawners (2012-2016).
[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
[d] 2011-2015 five year geometric mean (2016 data not available).

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 – 14,518 females), the ESU is estimated to produce approximately 29.0 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 2.90 million natural-origin outmigrants annually.

2.2.1.2 Hood Canal Summer-run Chum Salmon

Listed Hatchery Juvenile Releases – Four artificial propagation programs were listed as part of the ESU (79 FR 20802; Table 4); however, only one program is currently active. The combined hatchery production goal for listed HCS chum salmon from Table 4 is 150,000 unmarked juvenile chum salmon.

Table 4. Expected 2018 Hood Canal summer-run juvenile chum salmon hatchery releases (WDFW 2017).

Subbasin	Artificial propagation program	Brood year	Run Timing	Clipped Adipose Fin	Intact Adipose Fin
Hood Canal	LLTK - Lilliwaup	2017	Summer	-	150,000
Total Annual Release Number				-	**150,000**

Adult spawners and expected outmigration – The current average run size of 27,949 adult spawners (25,883 natural-origin and 2,066 hatchery-origin spawners; Table 5) 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, Mindy Rowse, NWFSC, Feb 2, 2017). From 2011 to 2015, Jimmycomelately Creek averaged 2,299 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 2,990 and 539, respectively, for the 2011-2015 period.

Table 5. Abundance of natural-origin and hatchery-origin HCS chum salmon spawners in escapements 2011-2015 (unpublished data, Mindy Rowse, NWFSC, Nov 1, 2017).

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	2,299	964	29.55%	477,215
Salmon Creek	2,990	2	0.05%	437,468
Snow Creek	539	2	0.36%	79,071
Chimacum Creek	1,273	0	0.00%	186,186
Population Average[d]	7,100	968	12.00%	1,179,941
Hood Canal Population				
Big Quilcene River	7,509	0	0.00%	1,098,212
Little Quilcene River	726	0	0.00%	106,243
Big Beef Creek	68	0	0.00%	9,891
Dosewallips River	2,387	4	0.17%	349,672
Duckabush River	4,136	11	0.25%	606,502
Hamma Hamma River	1,810	7	0.37%	265,673
Anderson Creek	1,810	0	0.00%	264,700
Dewatto River	100	0	0.00%	14,560
Lilliwaup Creek	544	488	47.32%	150,934
Skokomish River	345	130	27.41%	69,589
Tahuya River	176	419	70.42%	87,029
Union River	980	39	3.79%	148,984
Population Average[d]	18,783	1,098	5.52%	2,907,577
ESU Average	25,883	2,066	7.39%	4,087,518

[a] Five-year geometric mean of post fishery natural-origin spawners (2011-2015).
[b] Five-year geometric mean of post fishery hatchery-origin spawners (2011-2015).
[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 (2011-2015).

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 – 12,577 females), the ESU is estimated to produce approximately 31.4 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 4.09 million natural-origin outmigrants annually.

2.2.1.3 Puget Sound Steelhead

Listed Hatchery Juvenile Releases – Six artificial propagation programs, spread amongst seven locations, were listed as part of the DPS (79 FR 20802; Table 6). For 2018, 223,730 hatchery steelhead are expected to be released throughout the range of the PS steelhead DPS (WDFW 2017).

Table 6. Expected 2017 Puget Sound steelhead listed hatchery releases (WDFW 2017).

Subbasin	Artificial propagation program	Brood year	Run Timing	Clipped Adipose Fin	Intact Adipose Fin
Dungeness/Elwha	Dungeness	2017	Winter	10,000	-
	Hurd Creek	2018	Winter	-	34,500
Duwamish/Green	Flaming Geyser	2017	Winter	-	15,000
	Icy Creek	2017	Summer	50,000	-
			Winter	-	23,000
	Soos Creek	2017	Summer	50,000	-
Hood Canal	LLTK – Lilliwaup	2014	Winter	230	-
		2016	Winter	-	6,000
Puyallup	White River	2016	Winter	-	35,000
Total Annual Release Number				**110,230**	**113,500**

Adult spawners and expected outmigration – The average abundance (2012-2016) for the PS steelhead DPS is 19,313 adult spawners (natural-origin and hatchery-production combined). Juvenile PS steelhead abundance estimates is calculated from the escapement data (Table 7). 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 (9,657 females), 33.80 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 2.20 million natural-origin outmigrants annually.

Table 7. Abundance of PS steelhead spawner escapements (natural-origin and hatchery-production combined) from 2012-2016 (pers. comm., A. Marshall, WDFW, July 13, 2017; https://fortress.wa.gov/dfw/score/score/species/steelhead.jsp?species=Steelhead).

Demographically Independent Populations	Spawners	Expected Number of Outmigrants[b]
Central and South Puget Sound MPG		
Cedar River	3	391
Green River	977	111,179
Nisqually River	759	86,323
N. Lake WA/Lake Sammamish	-	-
Puyallup/Carbon River	603	68,646
White River	629	71,638
Hood Canal and Strait of Juan de Fuca MPG		
Dungeness River[c]	26	2,984
East Hood Canal Tribs.	89	10,120
Elwha River	878	99,954
Sequim/Discovery Bay Tribs.	19	2,186
Skokomish River	862	98,066
South Hood Canal Tribs.	73	8,304
Strait of Juan de Fuca Tribs.	173	19,697
West Hood Canal Tribs.	122	13,858
North Cascades MPG		
Nooksack River	1,790	203,631
Pilchuck River	868	98,709
Samish River/ Bellingham Bay Tribs.	977	111,167
Skagit River	8,038	914,353
Snohomish/Skykomish Rivers	1,053	119,762
Snoqualmie River	824	93,772
Stillaguamish River	476	54,170
Tolt River	70	7,988
TOTAL	**19,313**	**2,196,901**

[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.
[c] Spawner estimates for 2009-2013

2.2.2 Status of the Species' Critical Habitat

This section describes the status of designated critical habitat affected by the proposed action by examining the condition and trends of the essential physical and biological features of that habitat throughout the designated areas. These features are essential to the conservation of the ESA-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 most salmon and steelhead, NMFS's critical habitat analytical review teams (CHARTs) 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 ESA-listed species that they support (NMFS 2005). The conservation rankings were high, medium, or low. To determine the conservation value of each watershed to species viability, the CHARTs evaluated the quantity and quality of habitat features, 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. Even if a location had poor habitat quality, it could be ranked with a high conservation value if it were essential due to factors such as limited availability, a unique contribution of the population it served, or is serving another important role.

A summary of the status of critical habitats, considered in this opinion, is provided in Table 8, below.

Table 8. Critical habitat, designation date, federal register citation, and status summary for critical habitat considered in this opinion.

Species	Designation Date and Federal Register Citation	Critical Habitat Status Summary
Puget Sound Chinook salmon	9/02/05 70 FR 52630	Critical habitat for Puget Sound Chinook salmon includes 1,683 miles of streams, 41 square mile of lakes, and 2,182 miles of nearshore marine habitat in Puget Sounds. The Puget Sound Chinook salmon ESU has 61 freshwater and 19 marine areas within its range. Of the freshwater watersheds, 41 are rated high conservation value, 12 low conservation value, and eight received a medium rating. Of the marine areas, all 19 are ranked with high conservation value. Primary constitute elements relevant for this consultation include: 1) Estuarine areas free of obstruction with water quality and aquatic vegetation to support juvenile transition and rearing; 2) Nearshore marine areas free of obstruction with water quality conditions, forage, submerged and overhanging large wood, and aquatic vegetation to support growth and maturation; 3) Offshore marine areas with water quality conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation..
Hood Canal summer-run chum salmon	9/02/05 70 FR 52630	Critical habitat for Hood Canal summer-run chum salmon includes 79 miles and 377 miles of nearshore marine habitat in HC. Primary constituent elements relevant for this consultation include: 1) Estuarine areas free of obstruction with water quality and aquatic vegetation to support juvenile transition and rearing; 2) Nearshore marine areas free of obstruction with water quality conditions, forage, submerged and overhanging large wood, and aquatic vegetation to support growth and maturation; 3) Offshore marine areas with water quality conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation.
Puget Sound steelhead	2/24/16 81 FR 9252	Critical habitat for Puget Sound steelhead includes 2,031 stream miles. Nearshore and offshore marine waters were not designated for this species. There are 66 watersheds within the range of this DPS. Nine watersheds received a low conservation value rating, 16 received a medium rating, and 41 received a high rating to the DPS.
Southern resident killer whale	11/29/06 71 FR 69054	Critical habitat consists of three specific marine areas of inland waters of Washington: 1) the Summer Core Area in Haro Strait and waters around the San Juan Islands; 2) Puget Sound; and 3) the Strait of Juan de Fuca. These areas comprise approximately 2,560 square miles of marine habitat. Based on the natural history of the Southern Residents and their habitat needs, NMFS identified three PBFs, or physical or biological features, essential for the conservation of Southern Residents: 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)

Species	Designation Date and Federal Register Citation	Critical Habitat Status Summary
		passage conditions to allow for migration, resting, and foraging Water quality in Puget Sound, in general, is degraded. Some pollutants in Puget Sound persist and build up in marine organisms including Southern Residents and their prey resources, despite bans in the 1970s of some harmful substances and cleanup efforts. The primary concern for direct effects on whales from water quality is oil spills, although oil spills can also have long-lasting impacts on other habitat features In regards to passage, human activities can interfere with movements of the whales and impact their passage. In particular, vessels may present obstacles to whales' passage, causing the whales to swim further and change direction more often, which can increase energy expenditure for whales and impacts foraging behavior. Reduced prey abundance, particularly Chinook salmon, is also a concern for critical habitat.

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, 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 the proposed research activities 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) 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). For some of the work being contemplated here, the impacts that previous Federal, state, and private activities in the action area have had on the species are indistinguishable from those effects summarized below and in the previous section on the species' rangewide status. The same is true with respect to the species' habitat: for some of the work contemplated, the environmental baseline is the result of these activities' rangewide effects on the PBFs that are essential to the conservation of the species. However, for some of the work (that with a more limited geographic scope), the action area can be narrowed for a more specific analysis—and in those instances, the relevant local status information will be taken into account for both species and critical habitat.

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 9 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 9. Major factors limiting recovery.

Major Factors	PS Chinook salmon	HCS chum salmon	PS steelhead
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		•	

Major Factors	PS Chinook salmon	HCS chum salmon	PS steelhead
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, Ford 2011, NMFS 2016, NWFSC 2016, and section 2.2.2.

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 2018, 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) and tribal 4(d) research. Table 10 displays the total take for the ongoing research authorized under ESA sections 4(d) and 10(a)(1)(A).

Table 10. Total expected take of the ESA listed species for scientific research and monitoring already approved for 2018.

Species	Life Stage	Origin[a]	Total Take	Percent of ESU/DPS taken	Lethal Take	Percent of ESU/DPS killed
PS Chinook salmon[b]	Adult	LHAC	1,603	17.72970%	124	0.96450%
		LHIA	897		12	
		Natural	933	4.20383%	38	0.17122%
	Juvenile	LHAC	139,244	0.38574%	11,486	0.03182%
		LHIA	40,538	0.56521%	2,787	0.03886%
		Natural	478,643	16.48462%	9,588	0.33021%
HCS chum salmon	Adult	LHIA	0	0.00000%	0	0.00000%
		Natural	2,017	7.79276%	32	0.12363%
	Juvenile	LHIA	135	0.09000%	3	0.00200%
		Natural	756,277	18.50211%	2,845	0.06960%
PS steelhead[c]	Adult	LHAC	31	7.82892%	6	0.16569%
		LHIA	11		0	
		Natural	1,470		26	
	Juvenile	LHAC	4,511	4.09235%	106	0.09616%
		LHIA	766	0.67489%	27	0.02379%
		Natural	62,943	2.86508%	1,195	0.05439%

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

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 (20.45% of requested take and 14.74% of requested mortalities were used in ID, OR, and WA Section 10a1A permits from 2008 to 2017). 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. 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 all the permits. 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 a permit 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 every permit 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 18°C 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 permit 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), as described in section 1.3, 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

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 salmon 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.

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 or 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 Each Permit

In previous sections, we estimated the annual abundance of adult and juvenile listed salmonids. 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. Examining the magnitude of these effects at the individual and, where possible, population levels is the best way to determine effects at the species level. Table 11 displays the estimated annual abundance of the listed species.

Table 11. Estimated annual abundance of ESA listed fish.

Species	Origin[a]	Abundance	
		Adult	Juvenile
PS Chinook salmon	LHAC	14,101[b]	36,097,500
	LHIA		7,172,240
	Natural	22,194	2,903,573
HCS chum salmon	LHIA	2,066	150,000
	Natural	25,883	4,087,518
PS steelhead	LHAC	19,313[c]	110,230
	LHIA		113,500
	Natural		2,196,901

[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

In conducting the following analyses, we have tied the effects of each proposed action to its impacts on individual populations (or population groups) wherever it was possible to do so. In some instances, the nature of the project (i.e., it is broadly distributed or situated in marine habitat) was such that the take could not reliably be assigned to any population or group of populations. In those cases, 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)].

Permit 21330-2M

As noted previously, issuing permit 21330-2M would authorize the FWS to modify an existing permit that currently authorizes them to take juvenile PS Chinook salmon and PS steelhead in Jim Creek (South Fork Stillaguamish River watershed; Snohomish County, Washington). The modification is necessary due to higher than expected juvenile PS steelhead take at the study location in 2017. Using backpack electrofishing, the researchers would remove the fish from the water via dip net, place them in aerated buckets, anesthetize with MS-222, identify to species, weigh, measure, and return the fish to their capture locations once recovered. Up to 25 additional listed, natural-origin, juvenile PS steelhead may die as a result of the research. The requested take is laid out in Table 12.

Table 12. Proposed take under permit 21330-2M.

ESU/DPS	Life Stage	Origin	Take Action[b]	Original Permit[a] Issued		Modified Permit Requested		Analyzed for this opinion	
				Take	Mortality	Take	Mortality	Take	Mortality
PS Chinook salmon	Juvenile	Natural	C/H/R	5	1/5	5	1/5	-	-
PS steelhead	Juvenile	Natural	C/H/R	250	5/250	1500	30/1,500	1,250	25/1,250

C/H/R – Capture/Handle/Release

Because the majority of the fish that would be captured are expected to recover with no adverse physiological, behavioral, nor reproductive effects, the true effects of the proposed action considered herein are best seen in the context of the fish that are likely to be killed. To determine the effects of these losses, it is necessary to compare the numbers of fish that may be killed to the total abundance numbers expected for the population and species. This research may kill the following percentages of listed fish abundances (Table 13).

Table 13. Comparison of possible lethal take to annual abundance at the population (Stillaguamish sub-basin) and DPS scale for Permit 21330-2M.

DPS	Life Stage	Origin	Percent of Population	Percent of DPS
PS steelhead	Juvenile	Natural	0.046151%	0.000861%

At the population level, the permitted activities may kill at most 0.0462% of natural-origin juvenile PS steelhead. At the DPS level, the permitted activities may kill at most 0.0009% of natural-origin juvenile 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. In 2017, this project used only four of their five requested PS steelhead mortalities for an overall mortality rate of 0.57% (4 of 697).

An effect of the research that cannot be quantified is the conservation benefit to the species resulting from the research. The purpose of the research is to document ESA-listed fish presence, distribution, and abundance in Jim Creek within the boundaries of the Naval Radio Station Jim Creek facility. The research would benefit the listed species by refining the facility's Integrated Natural Resources Management plan, guiding decisions regarding habitat restoration, and helping fill data gaps in the distribution and abundance of ESA-listed PS Chinook salmon, PS steelhead, and bull trout.

Permit 21870

As noted previously, issuing permit 21870 would authorize the OSU to take juvenile PS Chinook salmon, HCS chum salmon, and PS steelhead in the South Fork of the Skokomish River (Mason County, Washington state). Using seine nets and minnow traps, fish would be captured, identified to species, and temporarily held in aerated buckets. Juvenile PS steelhead (and all other target species) would be anesthetized with MS–222, measured for length, tissue sampled (scales and caudal fin clip), gastric lavaged, and released. All other fish (including PS Chinook and HCS chum salmon) would be released after all the fish have been identified. Up to 32 listed, natural-origin salmonids (eight PS Chinook salmon, eight HCS chum salmon, and 16 PS steelhead) may die as a result of the research (Table 14).

Table 14. Proposed take under permit 21870.

ESU/DPS	Life Stage	Origin	Take Action	Requested Take	Requested Mortality
PS Chinook salmon	Juvenile	LHAC	C/H/R	800	8/800
PS Chinook salmon	Juvenile	Natural	C/H/R	800	8/800

ESU/DPS	Life Stage	Origin	Take Action	Requested Take	Requested Mortality
HCS chum salmon	Juvenile	Natural	C/H/R	800	8/800
PS steelhead	Juvenile	Natural	C/M,T,S/R	800	16/800

C/H/R – Capture/Handle/Release; C/M,T,S/R – Capture/Mark, Tag, Sample Tissue/Release Live Animal

Because the majority of the fish that would be captured are expected to recover with no adverse physiological, behavioral, nor reproductive effects, the true effects of the proposed action considered herein are best seen in the context of the fish that are likely to be killed. To determine the effects of these losses, it is necessary to compare the numbers of fish that may be killed to the total abundance numbers expected for the population and species. This research may kill the following percentages of listed fish abundances (Table 15).

Table 15. Comparison of possible lethal take to annual abundance at the population (Skokomish sub-basin) and ESU/DPS scale for Permit 21870.

ESU/DPS	Life Stage	Origin	Percent of Population	Percent of ESU/DPS
PS Chinook salmon	Juvenile	LHAC	0.000331%	0.000022%
PS Chinook salmon	Juvenile	Natural	0.011015%	0.000276%
HCS chum salmon	Juvenile	Natural	0.011496%	0.000196%
PS steelhead	Juvenile	Natural	0.016316%	0.000728%

At the population level, the permitted activities may kill at most 0.0163% of natural-origin PS steelhead. Other listed salmonid components impacted to lesser degrees include natural-origin HCS chum salmon (0.0115%), natural-origin PS Chinook salmon (0.0110%), and listed hatchery adipose-clipped PS Chinook salmon (0.0003%). At the ESU/DPS levels, the permitted activities may kill at most 0.0007% of natural-origin PS steelhead. Other listed salmonid components impacted to lesser degrees include natural-origin PS Chinook salmon (0.0003%), natural-origin HCS chum salmon (0.0002%), and listed hatchery adipose-clipped PS Chinook salmon (<0.0001%). 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 the conservation benefit to the species resulting from the research. The purpose of the OSU study is to research the trophic pathways that support salmonids in the Skokomish River and to determine how invasive plants mediate terrestrial subsidies to streams throughout the year. This will be completed by: (1) assessing what effects the widespread invasive terrestrial plants *Rubus armeniacus* and *Polygonum bohemicum* have on aquatic food webs vital to juvenile salmonids, (2) determining the importance and temporal variation of terrestrial and aquatic invertebrates as prey for juvenile salmonids and other stream fishes, and (3) exploring how aquatic-terrestrial linkages can inform salmon recovery and habitat restoration efforts. The researchers would target PS steelhead, PS/Strait of Georgia coho salmon, and sculpin species for this study. This research would benefit the affected species by filling the knowledge gaps that have limited effective restoration of local food webs.

Permit 22093

As noted previously, issuing permit 22093 would authorize the SVWID to take adult and juvenile PS Chinook salmon and PS steelhead throughout the Snoqualmie River watershed (Snohomish County, Washington state). Using seine nets, minnow traps, and backpack electrofishing equipment, fish would be captured, held in aerated buckets, identified to species, measured to length, and released. Up to 10 listed, natural-origin juvenile salmonids (five PS Chinook salmon and five PS steelhead) may die as a result of the research. No lethal take for adult salmonids was requested nor considered necessary due to the required measures described in section 2.5.1. The requested take is laid out in Table 16.

Table 16. Proposed take under permit 22093.

ESU/DPS	Life Stage	Origin	Take Action	Requested Take	Requested Mortality
PS Chinook salmon	Adult	LHAC	C/H/R	2	0/2
PS Chinook salmon	Adult	Natural	C/H/R	2	0/2
PS Chinook salmon	Juvenile	LHAC	C/H/R	300	5/300
PS Chinook salmon	Juvenile	Natural	C/H/R	300	5/300
PS steelhead	Adult	Natural	C/H/R	2	0/2
PS steelhead	Juvenile	Natural	C/H/R	300	5/300

C/H/R – Capture/Handle/Release

Because the majority of the fish that would be captured are expected to recover with no adverse physiological, behavioral, nor reproductive effects, the true effects of the proposed action considered herein are best seen in the context of the fish that are likely to be killed. To determine the effects of these losses, it is necessary to compare the numbers of fish that may be killed to the total abundance numbers expected for the population and species. This research may kill the following percentages of listed fish abundances (Table 17).

Table 17. Comparison of possible lethal take to annual abundance at the population (Snoqualmie sub-basin) and ESU/DPS scale for Permit 22093.

ESU/DPS	Life Stage	Origin	Percent of Population	Percent of ESU/DPS
PS Chinook salmon	Juvenile	LHAC	0.000385%	0.000014%
PS Chinook salmon	Juvenile	Natural	0.006174%	0.000172%
PS steelhead	Juvenile	Natural	0.005332%	0.000228%

At the population level, the permitted activities may kill at most 0.0062% of natural-origin PS Chinook salmon. Other listed salmonid components impacted to lesser degrees include natural-origin PS steelhead (0.0053%) and listed hatchery adipose-clipped PS Chinook salmon (0.0004%). At the ESU/DPS level, the permitted activities may kill at most 0.0002% of natural-origin PS steelhead. Other listed salmonid components impacted to lesser degrees include natural-origin PS Chinook salmon (0.0002%) and listed hatchery adipose-clipped PS Chinook salmon (<0.0001%). 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 the conservation benefit to the species resulting from the research. The purpose of the research is to assess the streams and agricultural drainage ditches in the Snoqualmie River Valley to the drainage basin level for fish presence/absence. Other study components include documenting barriers to fish passage, existing habitat conditions, characterize and delineate wetlands, and measure the water quality in each basin. This research would benefit the affected species by better informing plans that can effectively address drainage and flooding issues across hydrological boundaries (as opposed to property boundaries) and help restore salmon habitat. Further, this research would benefit listed species by providing data about the status of these species in agricultural drainage ditches and small streams that may not otherwise be studied.

Permit 22127

As noted previously, issuing permit 22127 would authorize the FWS to take adult and juvenile PS Chinook salmon and PS steelhead throughout the Puyallup River watershed (Pierce and King Counties, Washington state). Using electro-fykes, backpack electrofishing equipment, gill nets, hook-and-line, and minnow traps, fish would be captured and identified to species. Bull trout would be anesthetized, PIT tagged, weighed, measured for length, tissue sampled (fin rays), and released. Other target species [(brook trout, cutthroat trout, and non-migratory sculpin species (Shorthead, Torrent, and Riffle)] would be euthanized for otolith and fin ray analysis. All PS steelhead and PS Chinook salmon would be captured, handled, and immediately released. Up to two listed, natural-origin adult salmonids (one PS Chinook salmon and one PS steelhead) and 20 listed, natural-origin juvenile salmonids (four PS Chinook salmon and 16 PS steelhead) may die as a result of the research. The requested take is laid out in Table 18.

Table 18. Proposed take under permit 22127.

ESU/DPS	Life Stage	Origin	Take Action	Requested Take	Requested Mortality
PS Chinook salmon	Adult	LHAC	C/H/R	10	1/10
PS Chinook salmon	Adult	Natural	C/H/R	10	1/10
PS Chinook salmon	Juvenile	LHAC	C/H/R	200	4/200
PS Chinook salmon	Juvenile	Natural	C/H/R	200	4/200
PS steelhead	Adult	Natural	C/H/R	10	1/10
PS steelhead	Juvenile	Natural	C/H/R	600	16/600

C/H/R – Capture/Handle/Release

Because the majority of the fish that would be captured are expected to recover with no adverse physiological, behavioral, nor reproductive effects, the true effects of the proposed action considered herein are best seen in the context of the fish that are likely to be killed. To determine the effects of these losses, it is necessary to compare the numbers of fish that may be killed to the total abundance numbers expected for the population and species. This research may kill the following percentages of listed fish abundances (Table 19).

Table 19. Comparison of possible lethal take to annual abundance at the population (Puyallup sub-basin) and ESU/DPS scale for Permit 22127.

ESU/DPS	Life Stage	Origin	Percent of Population	Percent of ESU/DPS
PS Chinook salmon	Adult	LHAC/LHIA	0.042176%	0.007092%
PS Chinook salmon	Adult	Natural	0.093897%	0.004506%
PS Chinook salmon	Juvenile	LHAC	0.000200%	0.000011%
PS Chinook salmon	Juvenile	Natural	0.001455%	0.000138%
PS steelhead	Adult	Natural	0.081169%	0.005178%
PS steelhead	Juvenile	Natural	0.011405%	0.000728%

At the population level, the permitted activities may kill at most 0.0939% of natural-origin adult PS Chinook salmon. Other listed salmonid components impacted to lesser degrees include natural-origin adult PS steelhead (0.0812%), listed hatchery (LHAC/LHIA) adult PS Chinook salmon (0.00422%), natural-origin juvenile PS steelhead (0.0114%), natural-origin juvenile PS Chinook salmon (0.0015%), and listed hatchery adipose-clipped PS Chinook salmon (0.0002%). At the ESU/DPS levels, the permitted activities may kill at most 0.0071% of listed hatchery (LHAC/LHIA) adult PS Chinook salmon. Other listed salmonid components impacted to lesser degrees include natural-origin adult PS steelhead (0.0052%), natural-origin adult PS Chinook salmon (0.0045%), natural-origin juvenile PS steelhead (0.0007%), natural-origin juvenile PS Chinook salmon (0.0001%), and listed hatchery adipose-clipped PS Chinook salmon (<0.0001%). 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 the conservation benefit to the species resulting from the research. The purpose of the research is to study ESA-listed bull trout life history diversity and gather information about their temporal and spatial use of the watershed at multiple life stages. The Puyallup River watershed contains an anadromous life history pattern that is unique to bull trout from the Coastal-Puget Sound DPS, but information regarding these life history patterns from this distinct population segment is limited. Additionally, otolith and fin ray analysis of collected non-migratory species will provide validation of distribution patterns and life history strategies garnered from previously analyzed bull trout fin rays. This research would benefit the listed species by providing fine scale information about their movement timing and upstream residency. Those data, in turn, would be used to inform management and recovery actions.

2.5.3 Effects on Critical Habitat

Full descriptions of effects of the proposed research activities are found in the previous section. In general, the permitted 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 versus 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 navigable waters are present within the action area, 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. 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 plans 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 2016, the population in Puget Sound has increased from 1.77 to 4.86 million people (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 in the four permits 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 all the permits considered in this opinion for all components of each species (Table 20), (b) add the take proposed by the researchers in this opinion to the take that has already been authorized in the region (Table 10), and then (c) compare those totals to the estimated annual abundance of each species under consideration (Table 21).

Table 20. Total requested take for the permits and percentages of the ESA listed species for permits covered in this Biological Opinion.

Species	Life Stage	Origin[a]	Total Take	Percent of ESU/DPS taken	Lethal Take	Percent of ESU/DPS killed
PS Chinook salmon[b]	Adult	LHAC	12	0.08510%	1	0.00709%
		LHIA	0		0	
		Natural	12	0.05407%	1	0.00451%
	Juvenile	LHAC	1,300	0.00360%	17	0.00005%
		LHIA	0	0.00000%	0	0.00000%
		Natural	1,300	0.04477%	17	0.00059%
HCS chum salmon	Adult	LHIA	0	0.00000%	0	0.00000%
		Natural	0	0.00000%	0	0.00000%
	Juvenile	LHIA	0	0.00000%	0	0.00000%
		Natural	800	0.01957%	8	0.00020%
PS steelhead[c]	Adult	LHAC	0	0.06213%	0	0.00518%
		LHIA	0		0	
		Natural	12		1	
	Juvenile	LHAC	0	0.00000%	0	0.00000%
		LHIA	0	0.00000%	0	0.00000%
		Natural	2,950	0.13428%	62	0.00282%

[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 21. Total expected take of the ESA listed species for scientific research and monitoring already approved for 2018 plus the permits covered in this Biological Opinion.

Species	Life Stage	Origin[a]	Total Take	Percent of ESU/DPS taken	Lethal Take	Percent of ESU/DPS killed
PS Chinook salmon[b]	Adult	LHAC	1,615	17.81480%	125	0.97159%
		LHIA	897		12	
		Natural	945	4.25790%	39	0.17572%
	Juvenile	LHAC	140,544	0.38935%	11,503	0.03187%
		LHIA	40,538	0.56521%	2,787	0.03886%
		Natural	479,943	16.52939%	9,605	0.33080%
HCS chum salmon	Adult	LHIA	0	0.00000%	0	0.00000%
		Natural	2,017	7.79276%	32	0.12363%
	Juvenile	LHIA	135	0.09000%	3	0.00200%
		Natural	757,077	18.52168%	2,853	0.06980%
PS steelhead[c]	Adult	LHAC	31	7.89106%	6	0.17087%
		LHIA	11		0	
		Natural	1,482		27	
	Juvenile	LHAC	4,511	4.09235%	106	0.09616%
		LHIA	766	0.67489%	27	0.02379%
		Natural	65,893	2.99936%	1,257	0.05722%

[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

Juvenile life-stage

For juvenile salmonids, the total amount of estimated natural-origin, lethal take for the proposed research would be 17 PS Chinook salmon, 8 HCS chum salmon, and 62 PS steelhead. This is the maximum amount of natural-origin salmonid take contemplated in this biological opinion; if the various permits are granted and exercised, a lesser amount of take is expected to actually occur.

PS Chinook salmon – Overall, these numbers represent a very small fraction of the expected juvenile abundances and will kill at most 0.00059% of the natural-origin component and 0.00005% of the listed hatchery adipose-clipped PS Chinook salmon component (Table 20). The applicants requested no take of listed hatchery intact adipose PS Chinook salmon. All of the requested take for PS Chinook salmon was either unintentional take due to capture methods (two permits) or for presence/absence surveys (one permit) with minimal handling (i.e. identify to species, measure, weigh) for an overall mortality rate of 1.3% (34 of the requested 2,600 take being lethal). Overall, the amount of lethal take (baseline plus research from this biological opinion) represents very small fractions of the expected juvenile abundances and will be, at most, 0.33080% natural-origin and 0.03187% listed hatchery adipose-clipped PS Chinook salmon (Table 21).

HCS chum salmon – Overall, these numbers represent a very small fraction of the expected juvenile abundance and will kill at most 0.00020% of the natural-origin HCS chum salmon component (Table 20). Only one permit requested take of HCS chum salmon and only for the natural-origin component. All HCS chum salmon take was unintentional direct take, and the overall mortality rate is 1.0% (eight of the requested 800 take being lethal). Overall, the amount of lethal take (baseline plus research from this biological opinion) represents a very small fraction of the expected juvenile abundances and will be, at most, 0.06980% natural-origin component of HCS chum salmon (Table 21).

PS steelhead – Overall, these numbers represent a very small fraction of the expected juvenile abundances and will kill at most 0.00282% of the natural-origin PS steelhead component (Table 20). There was no request for any ESA-listed hatchery PS steelhead. All four permits requested natural-origin PS steelhead take with three of the permits requesting unintentional take due to capture methods. The fourth permit (permit #21870) would target and non-lethally sample PS steelhead (stomach samples, scale samples, fin clips). For all four permits combined, the mortality rate would be 2.1% (62 of the requested 2,950 take being lethal). Overall, the amount of lethal take (baseline plus research from this biological opinion) represents a very small fraction of the expected juvenile abundances and will be, at most, 0.05722% natural-origin PS steelhead (Table 21).

Adult life-stage

For adult salmonids, the total amount of estimated take for the proposed research would be two PS Chinook salmon (one natural-origin and one listed hatchery adipose-clipped) and one PS steelhead (natural-origin); the applicants requested no take of HCS chum salmon adults. This is the maximum amount of take contemplated in this biological opinion; if the various permits are granted and exercised, a lesser amount of take is expected to actually occur.

PS Chinook salmon – Overall, these numbers represent a very small fraction of the expected adult abundances and will kill at most 0.00709% of the listed hatchery component (intact and adipose fin clipped combined) and 0.00451% of the natural-origin PS Chinook salmon component (Table 20).

Of the two permits that requested adult PS Chinook salmon take, only one permit requested lethal take (permit #22127), unintentional mortalities due to capture methods, with the mortality rate being 8.3% (two of the requested 24 take being lethal). Overall, the amount of lethal take (baseline plus research from this biological opinion) represents a very small fraction of the estimated adult abundances and will be, at most, 0.97159% of the listed hatchery component and 0.17572% of the natural-origin PS Chinook salmon component (Table 21).

PS steelhead – Overall, the amount of take represents a very small fraction of the expected adult abundance and will kill at most 0.00518% of all adult PS steelhead (listed hatchery and natural-origin components combined) (Table 20). Of the two permits that requested adult PS steelhead, only one permit requested lethal take (permit #22127), one unintentional mortality due to capture methods, with the mortality rate being 8.3% (one of the requested 12 take being lethal). Overall, the amount of lethal take (baseline plus research from this biological opinion) represents a very small fraction of the estimated adult abundances and will be, at most, 0.17087% of all PS steelhead adults (Table 21).

Salmonid take and mortality review

When combined with scientific research and monitoring permits already approved (Section 10 (a)(1)(A) and state/tribal 4(d) permits) (Table 10), the total amounts of take and mortalities are extremely low (Table 21). Moreover, it is likely that the impacts on abundance and productivity of the listed species considered in this opinion are smaller than those laid out above. For the vast majority of scientific research permits, history has shown that researchers generally take far fewer salmonids than the allotted number every year. Thus, the activities contemplated in this opinion would add only very small fractions to those already low numbers. Thus, as Tables 10, 20, and 21 demonstrate, all the mortalities, even taken together, represent a very small fraction of the various species' abundances. Nonetheless, and for a number of reasons, the displayed percentages are in reality almost certainly much smaller than even the small figures stated.

For juvenile salmonids, the abundance estimates are conservative estimates of the total number of juvenile salmonids. Second, it is important to remember that estimates of take that kill fish are purposefully inflated to account for potential accidental deaths; and it is, therefore, very likely that fewer juveniles will be killed by the research than stated. For ID, OR, and WA Section 10a1A permits from 2008 to 2017, only 20.49% of the requested take (e.g., capture, collect, etc.) and 14.85% of requested mortalities were used for these research programs. Third, many of the fish that may be killed would be smolts but not all fish. 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 of take considered in this opinion are based on (a) a conservative estimate of the actual number of juveniles, (b) overestimating the number of fish likely to be killed, (c) treating each dead juvenile fish as part of the same year class, and (d) the number of juvenile salmonid fishes killed only represent a very small fraction of each species' abundance. 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.

For adults salmonids, it is important to remember that estimates of take that kill fish are purposefully inflated to account for potential accidental deaths; and it is, therefore, very likely that fewer adults will be killed by the research than stated. For ID, OR, and WA Section 10a1A permits from 2008 to 2017, only 18.19% of the requested take (e.g., capture, collect, etc.) and 6.70% of requested mortalities were used for these research programs. Second, some of the fish that may be killed would be sub-adults, which represent multiple spawning years and more individuals than reach the adult stage. Third, we do not allow for directed mortality of natural-origin, ESA-listed adult salmonids in Section 10a1A permits. Any research that requests directed mortality of adult salmonids must use hatchery-produced fish. Therefore, the already small percentages of take considered in this opinion are based on (a) overestimating the number of fish likely to be killed, (b) treating each dead adult fish as part of the same year class (some are sub-adults), (c) only allowing for directed mortality of hatchery-produced adults, and (d) the number of adult salmonid fishes killed only represent a very small fraction of each species' abundance. Thus, the actual numbers of adult salmonids the research is likely to kill are undoubtedly smaller than the stated figures—probably something on the order of one-fifteenth of the values given in the tables.

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 proposed permit 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 spread across multiple spawning years, 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 of any life-stage and/or origin for any of the listed species considered herein this Opinion. Further, 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, 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 existences of PS Chinook salmon, HCS chum salmon, and PS steelhead or destroy or adversely modify their designated critical habitats.

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 permits that allow the permit holders 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). Those amounts—displayed in the various permits' effects analyses—constitute hard limits on both the amount and extent of take the permit holders 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 "Consultation on the Issuance of Four ESA Section 10(a)(1)(A) Scientific Research Permits affecting Salmon and Steelhead in the West Coast Region."

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 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 2008).

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 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 the Queen Charlotte Islands south to central California.

SR killer whales consume a variety of fish and one species of squid, but salmon, and Chinook salmon in particular, are their preferred prey (review in NMFS 2008). Ongoing and past diet studies of SR killer whales conduct sampling primarily during the spring, summer and fall months in inland waters of Washington State and British Columbia (i.e., Hanson and Emmons 2010, Hanson et al 2010; ongoing research by NWFSC). Therefore, our knowledge of diet preferences is specific to inland waters. Chemical analyses also support the importance of salmon in the year-round diet of SR killer whales (Krahn et al. 2002; Krahn et al. 2007). SR killer whales' preference for Chinook salmon in inland waters, even when other species are more abundant, combined with information indicating that the killer whales consume salmon year round, makes it reasonable to expect that SR killer whales likely prefer Chinook salmon when available in coastal waters.

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 17 juvenile and one adult natural-origin PS Chinook salmon may be killed during proposed research activities. As the previous effects analysis illustrated, these losses—even in total—are expected to have only very small effects on salmonid abundance and productivity and no appreciable effect on diversity or distribution.

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 salmon is 1%. If one percent of the 17 juvenile Chinook salmon taken by research activities were to survive to adulthood, this would translate to the effective loss of zero 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). Given that the SR killer whale population must catch a minimum of 1,400 salmon daily to sustain their needs (Center for Whale Research 2018), this means that the research contemplated in this opinion could kill, in its entirety, 0.07% of *one day's* worth of the fish that the SRKW's need to survive. Moreover, that figure would only hold if the SR killer whales could somehow intercept *all* the fish that might otherwise have grown to maturity. So even the maximum effect of a loss of 0.07% of one day's worth of SR killer whale food could only occur under the most extremely unlikely circumstances.

In addition, the estimated Chinook salmon mortality is likely to be much smaller than stated. First, the mortality rate estimates for most of the proposed studies are purposefully inflated to account for potential accidental deaths and it is therefore very likely that fewer salmonids will be killed by the research than stated. In fact, over the last nine years, researchers have only killed about 15% of the juvenile Chinook salmon they were permitted to kill. Thus, the actual reduction in prey available to the SR killer whales is probably closer to zero than to one.

But even if the equivalent of one adult was killed, given the total quantity of prey available to SR killer whales throughout their range, this small reduction in prey (and the very low probability that any potential adult Chinook salmon could even be intercepted by the whales in the first place), means the research would have at most an insignificant effect on the whales' survival and recovery.

Similarly, the future loss of Chinook salmon from Puget Sound Chinook salmon populations could affect the prey PBF of designated critical habitat for killer whales. As described above, however, and considering the conservative estimate of one Chinook salmon adult equivalents that could be taken by the proposed actions (fish that are unlikely ever to be found in the Puget Sound in any case), and the total amount of prey available in critical habitat, the reduction would be so small that it would not affect the conservation value of the critical habitat in any meaningful or measurable way.

Given these circumstances, and the fact that we anticipate no direct interaction between any of the researchers and the SR killer whales, NMFS finds that potential adverse effects of the proposed research on SR killer whales are 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 ESA section 10(a)(1)(A) research permit 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

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.

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.

July 5, 2018 (88 FR 31371). Notice: Endangered and Threatened Species; Take of Anadromous Fish.

5.2 Literature Cited

Abatzoglou, J. T., D. E. Rupp, and P. W. Mote. 2014. Seasonal climate variability and change in the Pacific Northwest of the United States. Journal of Climate. 27(5):2125-2142.

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: 18(4):905-918.

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

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.

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.

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.

Center for Whale Research. 2018. Chinook Orca Survival – FACTS about Chinook Salmon. https://www.whaleresearch.com/about-salmon

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.

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., A. P. Hendry, P. W. Lawson, T. P. Quinn, N. J. Mantua, J. Battin, R. G. Shaw, and R. B. Huey. 2008. Potential responses to climate change in organisms with complex life histories: evolution and plasticity in Pacific salmon. Evolutionary Applications. 1(2):252-270.

Crozier, L. G., M. D. Scheuerell, and E. W. Zabel. 2011. Using Time Series Analysis to Characterize Evolutionary and Plastic Responses to Environmental Change: A Case Study of a Shift Toward Earlier Migration Date in Sockeye Salmon. *The American Naturalist* 178 (6): 755-

773.

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.

Dominguez, F., E. Rivera, D. P. Lettenmaier, and C. L. Castro. 2012. Changes in Winter Precipitation Extremes for the Western United States under a Warmer Climate as Simulated by Regional Climate Models. Geophysical Research Letters. 39(5). DOI:10.1029/2011GL050762.

Doney, S. C., M. Ruckelshaus, J. E. Duffy, J. P. Barry, F. Chan, C. A. English, H. M. Galindo, J. M. Grebmeier, A. B. Hollowed, N. Knowlton, J. Polovina, N. N. Rabalais, W. J. Sydeman, and L. D. Talley. 2012. Climate Change Impacts on Marine Ecosystems. Annual Review of Marine Science. 4:11-37.

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.

Feely, R. A., T. Klinger, J. A. Newton, and M. Chadsey (editors). 2012. Scientific summary of ocean acidification in Washington state marine waters. NOAA Office of Oceanic and Atmospheric Research Special Report.

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.

Ford, M. J. 2013. Status review update of Southern Resident killer whales. U.S. Dept. of Commerce, Northwest Fisheries Science Center.41p. Available at (Accessed July 2015): http://www.westcoast.fisheries.noaa.gov/publications/protected_species/marine_mammals/killer_whales/srkw_status_revew_update_final_july_31_2013.pdf

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.

Glick, P., J. Clough, and B. Nunley. 2007. Sea-Level Rise and Coastal Habitats in the Pacific Northwest: An analysis for Puget Sound, southwestern Washington, and northwestern Oregon. National Wildlife Federation, Seattle, WA.

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.

Goode, J. R., J. M. Buffington, D. Tonina D. J. Isaak, R. F. Thurow, S. Wenger, D. Nagel, C. Luce, D. Tetzlaff, and C. Soulsby. 2013. Potential effects of climate change on streambed scour and risks to salmonid survival in snow-dominated mountain basins. Hydrological Processes 27(5):750-765.

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

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.

Hanson, M. B., and C. K. Emmons. 2010. Annual Residency Patterns of Southern Resident Killer Whales in the Inland Waters of Washington and British Columbia. Revised Draft - 30 October 10. 11p.

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,

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.

HCCC (Hood Canal Coordinating Council). 2005. Hood Canal & Eastern Strait of Juan de Fuca summer chum salmon recovery plan. Hood Canal Coordinating Council. Poulsbo, Washington.

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.

IPCC (Intergovernmental Panel on Climate Change). 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

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.

Isaak, D. J., S. Wollrab, D. Horan, and G. Chandler. 2012. Climate change effects on stream and river temperatures across the northwest US from 1980–2009 and implications for salmonid fishes. Climatic Change. 113(2):499-524.

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

Krahn, M. M., P. R. Wade, S. T. Kalinowski, M. E. Dahlheim, B. L. Taylor, M. B. Hanson, G. M. Ylitalo, R. P. Angliss, J. E. Stein, and R. S. Waples. 2002. Status review of southern resident killer whales (*Orcinus orca*) under the Endangered Species Act. NOAA Technical Memorandum NMFS-NWFSC54, U.S. Department of Commerce, Seattle, Washington.

Krahn, M. M., M. B. Hanson, R. W. Baird, R. H. Boyer, D. G. Burrows, C. E. Emmons, J. K. B. Ford, L. L. Jones, D. P. Noren, P. S. Ross, G. S. Schorr, and T.K. Collier. 2007. Persistent organic pollutants and stable isotopes in biopsy samples (2004/2006) from Southern Resident killer whales. Marine Pollution Bulletin. 54:1903-1911.

Kunkel, K. E., L. E. Stevens, S. E. Stevens, L. Sun, E. Janssen, D. Wuebbles, K. T. Redmond, and J. G. Dobson. 2013. Regional Climate Trends and Scenarios for the U.S. National Climate Assessment: Part 6. *Climate of the Northwest U.S. NOAA Technical Report NESDIS 142-6.* 83 pp. National Oceanic and Atmospheric Administration, National Environmental Satellite, Data, and Information Service, Washington, D.C.

Lawson, P. W., E. A. Logerwell, N. J. Mantua, R. C. Francis, and V. N. Agostini. 2004. Environmental factors influencing freshwater survival and smolt production in Pacific Northwest coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences. 61(3):360-373

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.

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.

Mantua, N., I. Tohver, and A. Hamlet. 2009. Impacts of Climate Change on Key Aspects of Freshwater Salmon Habitat in Washington State. *in* The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate, M. M. Elsner, J. Littell, and L. Whitely Binder, Eds. The Climate Impacts Group, University of Washington, Seattle, Washington, pp. 217-253.

Mantua, N., I. Tohver, and A. Hamlet. 2010. Climate change impacts on streamflow extremes and summertime stream temperature and their possible consequences for freshwater salmon habitat in Washington State. Climatic Change. 102(1):187-223.

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.

McMahon, T. E. and G. F. Hartman. 1989. Influence of cover complexity and current velocity on winter habitat use by juvenile coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences. 46:1551-1557.

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.

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.

Meyer, J. L., M. J. Sale, P. J. Mulholland, and N. L. Poff. 1999. Impacts of climate change on aquatic ecosystem functioning and health. JAWRA Journal of the American Water Resources Association. 35(6):1373-1386.

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

Mote, P. W., J. Abatzoglou, and K. Kunkel. 2013. Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities. Island Press, 224 pp.

Mote, P. W, A. K. Snover, S. Capalbo, S. D. Eigenbrode, P. Glick, J. Littell, R. R. Raymondi, and W. S. Reeder. 2014. Ch. 21: Northwest. *in* Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, T.C. Richmond, and G.W. Yohe, Eds., U.S. Global Change Research Program, pp. 487-513.

Mote, P. W., D. E. Rupp, S. Li, D. J. Sharp, F. Otto, P. F. Uhe, M. Xiao, D. P. Lettenmaier, H. Cullen, and M. R. Allen. 2016. Perspectives on the cause of exceptionally low 2015 snowpack in the western United States. Geophysical Research Letters. 43:10980-10988. doi:10.1002/2016GLO69665

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.

NMFS (National Marine Fisheries Service). 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). 2005. Assessment of NOAA Fisheries' critical habitat analytical review teams for 12 evolutionarily significant units of West Coast salmon and steelhead. NMFS, Protected Resources Division, Portland, Oregon.

NMFS (National Marine Fisheries Service). 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 (National Marine Fisheries Service). 2007. Final Supplement to the recovery plan for the Hood Canal and eastern Strait of Juan de Fuca summer chum salmon (*Oncorhynchus keta*). National Marine Fisheries Service, Northwest Region. Portland, Oregon

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

NMFS (National Marine Fisheries Service). 2016. 2016 5-Year Review: Summary & Evaluation of Puget Sound Chinook, Hood Canal Summer-run Chum, and Puget Sound Steelhead. NMFS, West Coast Region. 98 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.

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.

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.

PFMC (Pacific Fishery Management Council). 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.

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

Raymondi, R. R., J. E. Cuhaciyan, P. Glick, S. M. Capalbo, L. L. Houston, S .L. Shafer, and O. Grah. 2013. Water Resources: Implications of Changes in Temperature and Precipitation *in* Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities, M. M. Dalton, P. W. Mote, and A. K. Snover, Eds., Island Press, Washington, DC, pp. 41-58.

Reeder, W. S., P. R. Ruggiero, S. L. Shafer, A. K. Snover, L. L Houston, P. Glick, J. A. Newton, and S. M. Capalbo. 2013. Coasts: Complex Changes Affecting the Northwest's Diverse Shorelines. *in* Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities, M. M. Dalton, P. W. Mote, and A. K. Snover, Eds. Island Press, Washington, DC, pp 41-58.

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

Scheuerell, M. D. and J. G. Williams. 2005. Forecasting climate-induced changes in the survival of Snake River spring/summer Chinook salmon (*Oncorhynchus tshawytscha*). Fisheries Oceanography. 14:448-457.

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.

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.

Sunda, W. G., and W. J. Cai. 2012. Eutrophication induced CO2-acidification of subsurface coastal waters: interactive effects of temperature, salinity, and atmospheric p CO2. Environmental Science & Technology. 46(19):10651-10659.

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.

Tague, C. L., J. S. Choate, and G. Grant. 2013. Parameterizing sub-surface drainage with geology to improve modeling streamflow responses to climate in data limited environments. Hydrology and Earth System Sciences. 17(1): 341-354.

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.

Tillmann, P., and D. Siemann. 2011. Climate Change Effects and Adaptation Approaches in Marine and Coastal Ecosystems of the North Pacific Landscape Conservation Cooperative Region. National Wildlife Federation.

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.

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.

WDFW (Washington Department of Fish and Wildlife). 2017. 2017 Future Brood Document Final (Tuesday, August 1, 2017). Online at https://wdfw.wa.gov/publications/01878/wdfw_region_3_2017_final.pdf

WDFW/PNPTT (Washington Department of Fish and Wildlife and Point No Point Treaty Tribes). 2000. Summer chum salmon conservation initiative. Washington Department of Fish and Wildlife, Olympia.

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.

Winder, M. and D. E. Schindler. 2004. Climate change uncouples trophic interactions in an aquatic ecosystem. Ecology. 85:2100–2106.

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.

Zabel, R. W., M. D. Scheuerell, M. M. McClure, and J. G. Williams. 2006. The interplay between climate variability and density dependence in the population viability of Chinook salmon. Conservation Biology. 20(1):190-200.