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

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

NMFS Consultation Number: WCR-2017-7147
ARN 151422WCR2017PR00171

Action Agencies:
The National Marine Fisheries Service (NMFS)
Northwest Fisheries Science Center (NWFSC)
U.S. Army Corps of Engineers (USACE)
U.S. Department of Defense (USDOD)
U.S. Environmental Protection Agency (EPA)
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
Puget Sound/Georgia Basin (PS/GB) bocaccio (*Sebastes paucispinis*)	Endangered	Yes	No	No	No
PS/GB yelloweye rockfish (*S. ruberrimus*)	Threatened	Yes	No	No	No
Southern (S) eulachon (*Thaleichthys pacificus*)	Threatened	Yes	No	No	No
S green sturgeon (*Acipenser medirostris*)	Threatened	Yes	No	No	No
Southern Resident (SR) killer whale (*Orcinus orca*)	Threatened	No	No	No	No

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

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

Issued By: for Scott R
Barry A. Thom
Regional Administrator

Date: 7/26/2017

TABLE OF CONTENTS

1. INTRODUCTION

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

1.1 Background

The National Marine Fisheries Service (NMFS) prepared the biological opinion (opinion) and incidental take statement (ITS) portions of this document in accordance with section 7(b) of the Endangered Species Act (ESA) of 1973 (16 USC 1531 et seq.), and implementing regulations at 50 CFR 402. It constitutes NMFS' review of eight proposed scientific research permit applications and is based on information provided in the applications for the proposed permits, published and unpublished scientific information on the biology and ecology of listed salmonids, eulachon, green sturgeon, and rockfish 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 Protected Resources Division (PRD) received eight applications for original permits and permit modifications (see dates below). 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 PS Chinook salmon, HCS chum salmon, PS steelhead, S eulachon, S green sturgeon, PS/GB bocaccio, and PS/GB yelloweye rockfish. The proposed actions also have the potential to affect SR killer whales and their critical habitat by diminishing the whales' prey base. We concluded that the proposed activities are not likely to adversely affect SR killer whales or their critical habitat and the full analysis is found in the "Not Likely to Adversely Affect" Determination section (2.11).

We received a permit renewal request (15848-2R) from the Washington Department of Fish and Wildlife (WDFW) on May 9, 2017. Requested edits were sent on May 9, 2017; and all requests were addressed and completed by May 10, 2017.

We received a permit renewal request (15890-2R) from WDFW on December 16, 2016. Requested edits were sent on May 5, 2017; and all requests were addressed and completed by May 26, 2017.

We received a permit renewal request (16021-2R) from WDFW on May 8, 2017. Requested edits were sent on May 12, 2017; and all requests were addressed and completed by May 23, 2017.

We received a permit renewal request (16091-2R) from WDFW on February 1, 2017. Requested edits were sent on May 16, 2017; and all requests were addressed and completed by June 2, 2017.

We received a permit modification request (20535-2M) from the U.S. Army Corps of Engineers – Seattle District (USACE) on April 17, 2017. Requested edits were sent on May 17, 2017; and all requests were addressed and completed by June 2, 2017.

We received a permit request (21061) from the Windward Environmental (WE) on December 19, 2016. Requested edits were sent on May 3, 2017; and all requests were addressed and completed by May 18, 2017.

We received a permit request (21185) from the Wild Fish Conservancy (WFC) on January 31, 2017. Requested edits were sent on May 3, 2017; and all requests were addressed and completed by May 9, 2017.

We received a permit request (21330) from the U.S. Fish and Wildlife Service (FWS) on May 9, 2017. Requested edits were sent on May 10, 2017; and all requests were addressed and completed by May 12, 2017.

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 June 15, 2017 asking for public comment on them (82 FR 27468). The public was given 30 days to comment on the permit applications and, once that period closed on July 17, 2017, 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. Thus, the proposed actions here are the activities proposed by the NWFSC, USACE, USDOD, EPA, FWS, and NMFS’ issuance of permits to them and to WDFW, WE, and WFC.

We are thus proposing to issue eight separate research permits pursuant to section 10(a)(1)(A) of the ESA. The permits would variously authorize researchers to take PS Chinook salmon, HCS chum salmon, PS steelhead, S eulachon, S green sturgeon, PS/GB bocaccio, and PS/GB yelloweye rockfish. “Take” is defined in section 3 of the ESA; it means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect [a listed species] or to attempt to engage in any such conduct.

This opinion constitutes formal consultation and an analysis of effects solely for the evolutionarily significant units (ESUs) and distinct population segments (DPSs) that are the subject of this opinion.[1]

Permit 15848-2R

The Washington Department of Fish and Wildlife (WDFW) is seeking to renew, for five years, a research permit that currently allows them to take juvenile and adult PS Chinook salmon, HCS chum salmon, PS steelhead, and PS/GB bocaccio and adult S green sturgeon in the Puget Sound (Washington State). The WDFW research may also cause them to take juvenile and adult S eulachon and PS/GB yelloweye rockfish—species for which there are currently no ESA take prohibitions. The purpose of the WDFW study is to estimate the relative abundance of bottomfish in Puget Sound and collect information on the distribution and biology of key marine vertebrate and invertebrate resources. The research would benefit the affected species by providing the WDFW with information on encounter rates and species distributions—information that fisheries managers would use to promulgate regulations designed to protect and promote the recovery of listed species and to properly manage non-listed fishery resources. The WDFW proposes to capture fish using a bottom trawl. All captured eulachon, salmonids, and green sturgeon would either be released immediately at the surface or held temporarily in an aerated live well to help them recover before being released. Listed rockfish would be released via rapid submergence to their capture depth to reduce adverse effects from barotrauma. The researchers do not propose to kill any fish but a small number may die as an unintended result of research activities. Some unintentional mortalities may be retained for further analysis.

Permit 15890-2R

The WDFW is seeking to renew, for five years, a research permit that currently allows them to take juvenile and adult PS Chinook salmon, HCS chum salmon, PS steelhead, and PS/GB bocaccio in the Puget Sound (Washington State). The WDFW research may also cause them to take juvenile and adult S eulachon and PS/GB yelloweye rockfish—species for which there are currently no ESA take prohibitions. The purpose of the WDFW study is to estimate abundance and determine other important demographic information for pelagic forage fish in key areas of Puget Sound. The research would benefit both listed and non-listed species by monitoring their relative abundance in Puget Sound and obtaining information on the spatial and temporal locations of all pelagic species in the region. The WDFW proposes to capture fish with a mid-water trawl working in tandem with an acoustic survey boat. All captured salmonids would be sampled (fin clips, sample scale) and either released immediately at the surface or held temporarily in an aerated live well to help them recover before release. All viable eulachon would be released at the surface without sampling. Listed rockfish would have a fin clip collected for genetic analyses and then be released via rapid submergence to their capture depth to reduce adverse effects from barotrauma. The researchers do

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[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."

not propose to kill any fish, but a small number may die as an unintentional result of research activities. Some unintentional mortalities may be retained for further analysis.

Permit 16021-2R

The WDFW is seeking to renew, for five years, a research permit that currently allows them to take juvenile and adult PS Chinook salmon and PS/GB bocaccio and adult S green sturgeon in the Puget Sound (Washington State). The WDFW research may also cause them to take adult S eulachon and juvenile and adult PS/GB yelloweye rockfish—species for which there are currently no ESA take prohibitions. The purpose of the WDFW study is to improve the understanding of groundfish stock structure, life history, biology, geographic distribution, habitat use, and food web relationships. The research would benefit the affected species by providing data critical for population modeling—information that would be used to improve management of Puget Sound groundfish resources. The WDFW proposes to capture fish using hook and line and live-capture traps. All captured salmonids, eulachon, and green sturgeon would either be released immediately at the surface or held temporarily in an aerated live well to help them recover before being released. Listed rockfish would have a fin clip collected for genetic analysis and researchers would attach a floy tag to the fish before releasing them via rapid submergence to their capture depth. After being captured, the listed salmon and steelhead would be placed in aerated live wells, identified, and released. The researchers do not propose to kill any listed fish being captured, but a small number may die as an unintended result of the activities. Some unintentional mortalities may be retained for further analysis.

Permit 16091-2R

The WDFW is seeking to renew, for five years, a research permit that currently allows them to take juvenile and adult PS Chinook salmon, HCS chum salmon, PS steelhead, and PS/GB bocaccio and adult S green sturgeon in the Puget Sound (Washington State). The WDFW research may also cause them to take juvenile and adult S eulachon and PS/GB yelloweye rockfish—species for which there are currently no ESA take prohibitions. The purpose of the WDFW study is to capture English sole (*Parophrys vetulus*) throughout the Salish Sea to monitor tissue levels of toxic chemical contaminants, frequency of pathological disorders, and biomarkers signifying biological effects. The research would benefit the listed species as well as the target species by providing managers with a better understanding of toxic contaminant impacts on the benthic food web, measuring changes in toxic contaminant levels on a local level, and helping prioritize cleanup efforts. The WDFW proposes to capture fish using a bottom trawl. All captured eulachon, salmonids, and green sturgeon would either be released immediately at the surface or held temporarily in an aerated live well to help them recover before being released. Listed rockfish would be released via rapid submergence to their capture depth to reduce adverse effects from barotrauma. The researchers do not propose to kill any fish but a small number may die as an unintended result of research activities. Some unintentional mortalities may be retained for further analysis.

Permit 20535-2M

The U.S. Army Corps of Engineers (USACE) is seeking to modify a three-year research permit that allows them to annually take juvenile PS Chinook salmon and PS steelhead in the lower Duwamish

River (King County, Washington). The USACE research may also cause them to take adult S eulachon—species for which there are currently no ESA take prohibitions. The purpose of the USACE study is to collect starry flounder (*Platichthys stellatus*), shiner surfperch (*Cymatogaster aggregate*), English sole, and Pacific staghorn sculpin (*Leptocottus armatus*) for tissue sampling and PCB congener analysis. The research would benefit the listed species by enhancing managers' understanding of contaminant partitioning within the food web near the Lower Duwamish Waterway Superfund Site. The USACE proposes to capture fish using beach seines. All listed fish would be captured, handled, and released. The modification would result in a slight increase in PS Chinook take and mortality levels. The researchers do not propose to kill any listed fish being captured, but a small number may die as an unintended result of the activities.

Permit 21061

Windward Environmental (WE) is seeking a two-year research permit to annually take juvenile and adult PS Chinook salmon and PS steelhead and juvenile PS/GB bocaccio in the lower Duwamish River (King County, Washington). The WE research may also cause them to take juvenile PS/GB yelloweye rockfish—species for which there are currently no ESA take prohibitions. The purpose of the WE study is to establish baseline tissue chemical concentrations for English sole, starry flounder, shiner surfperch, Dungeness crab (*Metacarcinus magister*), and graceful crab (*M. gracilis*) in the lower Duwamish River to assess the progress toward meeting target tissue chemical concentrations identified in the Environmental Protection Agency's (EPA) Record of Decision (ROD). The research would benefit the affected species by helping delineate contaminated areas and using that information to minimize animals' exposure to contaminated sediments by performing sediment remediation designed to protect aquatic wildlife. The WE proposes to capture fish using an otter trawl and crab traps. All listed fish would be captured, handled, and released. The researchers do not propose to kill any listed fish being captured, but a small number may die as an unintended result of the activities.

Permit 21185

The Wild Fish Conservancy (WFC) is seeking a five-year research permit to annually take juvenile PS Chinook salmon and PS steelhead in the Deschutes River subbasin and Kitsap Peninsula (Washington State). The purpose of the WFC study is to watertype existing channel classifications in selected sub-basins and floodplain areas to validate and correct Washington Department of Natural Resources (WDNR) classifications. The research would benefit the listed species by filling data gaps regarding fish passage impediments (i.e., tidegates, culverts) and fish species composition and distribution—information needed to responsibly identify, prioritize, and implement restoration projects. The WFC proposes to capture fish using backpack electrofishing equipment. The captured fish would be identified to species, fin clipped (PS steelhead only), and returned to their capture locations. Once fish presence is established, either through visual observation or electrofishing, electrofishing would be discontinued. Surveyors would then proceed upstream until a change in habitat parameters is encountered, at which point the electrofishing would be continued. The researchers do not propose to kill any listed fish being captured, but a small number may die as an unintended result of the activities.

Permit 21330

The U.S. Fish and Wildlife Service (FWS) is seeking a five-year research permit to annual 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 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, 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, allowed to recover, and returned to their capture locations. The researchers do not propose to kill any listed fish being captured, but a small number may die as an unintended result of the activities.

The proposed Federal action regarding these permits is for NMFS to issue a permit authorizing the research activities. As the action agency, NMFS is responsible for complying with section 7 of the ESA, which requires Federal agencies to ensure any actions they fund, permit, or carry out are not likely to jeopardize listed species' continued existence nor destroy or adversely modify their critical habitat. This consultation examines the effects of the proposed research PS Chinook salmon, HCS chum salmon, PS steelhead, S eulachon, S green sturgeon, PS/GB bocaccio, and PS/GB yelloweye rockfish. Therefore, this consultation fulfills NMFS's section 7 consultation obligations for those species.

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 NMFS' WC 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 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 degrees Fahrenheit.

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.

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

2.1 Analytical Approach

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

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

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

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

- *Identify the rangewide status of the species and critical habitat likely to be adversely affected by the proposed action.* This section describes the current status of each listed species and its critical habitat relative to the conditions needed for recovery. For listed salmon and steelhead, NMFS has developed specific guidance for analyzing the status of the listed species' component populations in a "viable salmonid populations" paper (VSP; McElhany et al. 2000). The VSP approach considers the abundance, productivity, spatial structure, and diversity of each population as part of the overall review of a species' status. For listed salmon and steelhead, the VSP criteria therefore encompass the species' "reproduction, numbers, or distribution" (50 CFR 402.02). In describing the range-wide status of listed species, we rely on viability assessments and criteria in technical recovery team documents and recovery plans, where available, that describe how VSP criteria are applied to specific populations, major population groups, and species. We determine the rangewide status of critical habitat by examining the condition of its PBFs - which were identified when the critical habitat was designated. Species and critical habitat status are discussed in Section 2.2.
- *Describe the environmental baseline in the action area*. The environmental baseline includes the past and present impacts of Federal, state, or private actions and other human activities *in the action area*. It includes the anticipated impacts of proposed Federal projects that have already undergone formal or early section 7 consultation and the impacts of state or private actions that are contemporaneous with the consultation in process. The environmental baseline is discussed in Section 2.4 of this opinion.
- *Analyze the effects of the proposed action on both species and their habitat using an "exposure-response-risk" approach.* In this step, NMFS considers how the proposed action would affect the species' reproduction, numbers, and distribution or, in the case of salmon and steelhead, their VSP characteristics. NMFS also evaluates the proposed action's effects on critical habitat features. The effects of the action are described in Section 2.5 of this opinion.
- *Describe any cumulative effect in the action area*. Cumulative effects, as defined in NMFS' implementing regulations (50 CFR 402.02), are the effects of future state or private activities, not involving Federal activities, that are reasonably certain to occur within the action area. Future Federal actions that are unrelated to the proposed action are not considered because they require separate section 7 consultation. Cumulative effects are considered in Section 2.6 of this opinion.
- *Integrate and synthesize the above factors by: (1) Reviewing the status of the species and critical habitat; and (2) adding the effects of the action, the environmental baseline, and cumulative effects to assess the risk that the proposed action poses to species and critical habitat.* In this step, NMFS adds the effects of the action (Section 2.5) to the environmental baseline (Section 2.4) and the cumulative effects (Section 2.6) to assess whether the action could reasonably be expected to: (1) appreciably reduce the likelihood of both survival and recovery of the species in the wild by reducing its numbers, reproduction, or distribution; or (2) reduce the value of designated or proposed critical habitat for the conservation of the species. These assessments are made in full consideration of the status of the species and critical habitat (Section 2.2). Integration and synthesis occurs in Section 2.7 of this opinion.
- *Reach a conclusion about whether species are jeopardized or critical habitat is adversely modified*. Conclusions regarding jeopardy and the destruction or adverse modification of

critical habitat are presented in Section 2.8. These conclusions flow from the logic and rationale presented in the Integration and Synthesis section (2.7).

- *If necessary, suggest a reasonable and prudent alternative to the proposed action.*

2.2 Rangewide Status of the Species and Critical Habitat

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

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

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

2.2.1 Climate Change

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

Projected Climate Change

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

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

Freshwater environments

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

Impacts on Salmon

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

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

2.2.2 Status of the Species

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

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

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

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

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

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

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

- Status review of West Coast steelhead from Washington, Idaho, Oregon, and California (Busby et al. 1996)
- Status review of chum salmon from Washington, Idaho, Oregon, and California (Johnson et al. 1997)
- Status review of Chinook salmon from Washington, Idaho, Oregon, and California (Myers et al. 1998)
- Status review for North American Green Sturgeon, *Acipenser medirostris* (Adams et al. 2002)
- Updated status of Federally listed ESUs of West Coast salmon and steelhead (Good et al. 2005)
- Green sturgeon (*Acipenser medirostris*) status review update (NMFS 2005c)
- Status review of Puget Sound steelhead (*Oncorhynchus mykiss*) (Hard et al. 2007)
- Status review of eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California (Gustafson et al. 2010)
- Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest (Ford 2011)
- Southern Distinct Population Segment of the North American green sturgeon (*Acipenser medirostris*) – 5-year review: summary and evaluation (NMFS 2015)
- Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest (NWFSC 2015)

- Status review update of eulachon (*Thaleichthys pacificus*) listed under the Endangered Species Act: Southern Distinct Population Segment (Gustafson et al. 2016)
- Yelloweye rockfish (*Sebastes ruberrimus*), canary rockfish (*Sebastes pinniger*), and bocaccio (*Sebastes paucispinis*) of the Puget Sound/Georgia Basin – 5-year review: summary and evaluation (Tonnes et al. 2016)

2.2.2.1 Puget Sound Chinook Salmon

Description and Geographic Range

On June 28, 2005, NMFS listed PS Chinook salmon—both natural-origin and some artificially-propagated fish—as a threatened species (70 FR 37160). The species includes all naturally spawned Chinook salmon populations from rivers and streams flowing into Puget Sound including the Straits of Juan De Fuca from the Elwha River, eastward. This includes rivers and streams flowing into Hood Canal, South Sound, North Sound, and the Strait of Georgia in Washington. The following 26 artificial propagation programs are part of the species and are also listed (79 FR 20802; Table 1): Kendall Creek Hatchery Program; Marblemount Hatchery Program (spring subyearlings and summer-run), Harvey Creek Hatchery Program (summer-run and fall-run), Whitehorse Springs Pond Program, Wallace River Hatchery Program (yearlings and subyearlings), Tulalip Bay Program, Issaquah Hatchery Program, Soos Creek Hatchery Program, Icy Creek Hatchery Program, Keta Creek Hatchery Program, White River Hatchery Program, White Acclimation Pond Program, Hupp Springs Hatchery Program, Voights Creek Hatchery Program, Diru Creek Program, Clear Creek Program, Kalama Creek Program, George Adams Hatchery Program, Rick's Pond Hatchery Program, Hamma Hamma Hatchery Program, Dungeness/Hurd Creek Hatchery Program, Elwha Channel Hatchery Program, and the Skookum Creek Hatchery Spring-run Program. Under the final listing in 2005, the section 4(d) protections (and limits on them) apply to natural-origin and hatchery PS Chinook salmon with an intact adipose fin, but not to listed hatchery fish that have had their adipose fin removed.

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

Subbasin	Artificial propagation program	Brood year	Run Timing	Clipped Adipose Fin	Intact Adipose Fin
Deschutes	Tumwater Falls	2016	Fall	3,800,000	-
Dungeness-Elwha	Dungeness	2016	Spring	-	50,000
	Elwha	2015	Fall	-	200,000
		2016	Fall	250,000	2,250,000
	Gray Wolf River	2016	Spring	-	50,000
	Hurd Creek	2015	Spring	-	50,000
	Upper Dungeness Pond	2016	Spring	-	50,000
Duwamish	Icy Creek	2015	Fall	300,000	-
	Soos Creek	2016	Fall	3,000,000	200,000
Hood Canal	Hood Canal Schools	2016	Fall	-	500
	Hoodsport	2015	Fall	120,000	-
		2016	Fall	2,800,000	-
Kitsap	Bernie Gobin	2015	Spring	40,000	-
		2016	Fall	-	200,000
			Summer	2,300,000	100,000

Subbasin	Artificial propagation program	Brood year	Run Timing	Clipped Adipose Fin	Intact Adipose Fin
	Chambers Creek	2016	Fall	400,000	-
	Garrison	2016	Fall	450,000	-
	George Adams	2016	Fall	3,575,000	225,000
	Gorst Creek	2016	Fall	1,530,000	-
	Grovers Creek	2016	Fall	450,000	-
	Hupp Springs	2016	Spring	-	400,000
	Lummi Sea Ponds	2016	Fall	500,000	-
	Minter Creek	2016	Fall	1,250,000	-
Lake Washington	Friends of ISH	2016	Fall	-	1,425
	Issaquah	2016	Fall	2,000,000	-
Nisqually	Clear Creek	2016	Fall	3,300,000	200,000
	Kalama Creek	2016	Fall	600,000	-
Nooksack	Kendall Creek	2016	Spring	800,000	-
	Skookum Creek	2016	Spring	-	1,000,000
Puyallup	Clarks Creek	2016	Fall	400,000	-
	Voights Creek	2016	Fall	1,600,000	-
	White River	2015	Spring	-	55,000
		2016	Spring	-	340,000
San Juan Islands	Friday Harbor ES	2016	Fall	-	225
	Glenwood Springs	2016	Fall	725,000	-
Skykomish	Wallace River	2015	Summer	500,000	-
		2016	Summer	800,000	200,000
Stillaguamish	Brenner	2016	Fall	-	45,000
	Whitehorse Pond	2016	Summer	220,000	-
Strait of Georgia	Samish	2016	Fall	3,800,000	200,000
Upper Skagit	Marblemount	2016	Spring	387,500	200,000
			Summer	200,000	-
Total Annual Release Number				**36,097,500**	**6,017,150**

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

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

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

Spatial Structure and Diversity

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

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

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

Population	MPG	Status	Run Timing
Elwha River	Strait of Juan de Fuca	Extant	Late
Elwha River early	Strait of Juan de Fuca	*Extinct*	Early

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

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

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

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

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

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

Abundance and Productivity

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

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

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

ESU escapement (total spawners) increased to 47,686 (2000-2004), but has since declined to 40,411(2005-2009) and to 32,451 (2010-2014; Tables 4 and 5).

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

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

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

Table 5. Average abundance estimates for PS Chinook salmon natural- and hatchery-origin spawners 2011-2015 (unpublished data, Mindy Rowse, NWFSC, July 17, 2017).

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	160	957	85.68%	16,000	89,360
SF Nooksack River	15	10	40.00%	9,100	2,000
Strait of Juan de Fuca MPG					
Elwha River	202	1,985	90.76%	15,100	174,960
Dungeness River	96	290	75.13%	4,700	30,880
Hood Canal MPG					
Skokomish River	205	951	82.27%	12,800	92,480
Mid-Hood Canal	102	204	66.67%	11,000	24,480
Whidbey Basin MPG					
Skykomish River	1,617	839	34.16%	17,000	196,480
Snoqualmie River	710	195	21.55%	17,000	72,400
NF Stillaguamish River	331	374	53.05%	17,000	56,400
SF Stillaguamish River	63	14	18.18%	15,000	6,160
Upper Skagit River	7,755	381	4.68%	17,000	650,880
Lower Skagit River	1,673	90	5.10%	16,000	141,040
Upper Sauk River	849	24	2.75%	3,000	69,840
Lower Sauk River	383	6	1.54%	5,600	31,120
Suiattle River	417	3	0.71%	600	33,600
Cascade River	232	20	7.94%	1,200	20,160
Central / South Sound MPG					
Sammamish River	88	1,083	92.49%	10,500	93,680
Cedar River	825	260	23.96%	11,500	86,800
Duwamish/Green River	1,230	936	43.21%	17,000	173,280
Puyallup River	529	643	54.86%	17,000	93,760
White River	685	2,018	74.66%	14,200	216,240
Nisqually River	679	1,321	66.05%	13,000	160,000
ESU Average	**18,846**	**12,604**	**40.08%**		**2,516,000**

[a] Five-year geometric mean of post-fishery spawners.

[b] Ford 2011

[c] Expected number of outmigrants=Total spawners*40% proportion of females*2,000 eggs per female*10% survival rate from egg to outmigrant

The average[3] abundance (2011-2015) for PS Chinook salmon populations is 31,450 adult spawners (18,846 natural-origin and 12,604 hatchery-origin spawners). Natural-origin spawners range from

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

15 (in the South Fork Stillaguamish River population) to 7,755 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). The populations closest to planning targets (the Upper Skagit, Cascade, Upper Sauk, and Suiattle) need to increase substantially just to meet the minimum viability abundance target. The Lower Skagit population is the second most abundant population, but its natural-origin spawner abundance is only 10% of the minimum viability abundance target.

Juvenile PS Chinook salmon abundance estimates come from escapement data, the percentage of females in the population, and fecundity. Fecundity estimates for the ESU range from 2,000 to 5,500 eggs per female, and the proportion of female spawners in most populations is approximately 40% of escapement. By applying a conservative fecundity estimate (2,000 eggs/female) to the expected female escapement (both natural-origin and hatchery-origin spawners – 12,580 females), the ESU is estimated to produce approximately 25.2 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 2.52 million natural-origin outmigrants annually.

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

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

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

	1990-2005		1999-2014	
Population	**Trend**	**95% CI**	**Trend**	**95% CI**
Strait of Georgia MPG				
NF Nooksack River	0.07	(0.04, 0.09)	0.04	(0, 0.07)
SF Nooksack River	0.03	(0, 0.06)	-0.06	(-0.10, -0.02)
Strait of Juan de Fuca MPG				
Elwha River	-0.02	(-0.06, 0.02)	-0.06	(-0.10, -0.03)
Dungeness River	0.14	(0.08, 0.19)	0.09	(0.03, 0.14)
Hood Canal MPG				
Skokomish River	0.02	(-0.01, 0.05)	-0.07	(-0.11, -0.02)
Mid-Hood Canal	0.03	(0, 0.07)	-0.07	(-0.11, -0.02)
Whidbey Basin MPG				
Skykomish River	0.03	(0, 0.06)	-0.02	(-0.04, 0.01)
Snoqualmie River	0.09	(0.05, 0.12)	-0.05	(-0.08, -0.03)
NF Stillaguamish River	0.04	(0.02, 0.06)	-0.04	(-0.06, -0.01)
SF Stillaguamish River	0.01	(-0.01, 0.03)	-0.10	(-0.12, -0.08)
Upper Skagit River	0.07	(0.05, 0.09)	-0.03	(-0.06, 0)
Lower Skagit River	0.05	(0.02, 0.09)	-0.03	(-0.06, -0.01)
Upper Sauk River	0.01	(-0.02, 0.04)	0.06	(0.04, 0.08)
Lower Sauk River	0.05	(0.01, 0.08)	-0.04	(-0.07, -0.01)
Suiattle River	0.01	(-0.01, 0.03)	-0.01	(-0.04, 0.01)
Cascade River	0.06	(0.04, 0.08)	0.01	(-0.01, 0.03)
Central / South Sound MPG				
Sammamish River	0.17	(0.11, 0.23)	-0.02	(-0.06, 0.02)
Cedar River	0.03	(0, 0.06)	0.07	(0.05, 0.10)
Green River	0.02	(-0.02, 0.06)	-0.12	(-0.16, -0.09)
Puyallup River	-0.03	(-0.05, -0.02)	-0.06	(-0.08, -0.03)
White River	0.19	(0.17, 0.21)	-0.03	(-0.08, 0.01)
Nisqually River	0.05	(0.03, 0.06)	-0.01	(-0.05, 0.03)

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

Limiting Factors

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

Status Summary

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

2.2.2.2 Hood Canal Summer-run Chum Salmon

Description and Geographic Range

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

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

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

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

Spatial Structure and Diversity

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

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

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

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

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

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

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

Abundance and Productivity

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

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

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

The current average run size of 27,452 adult spawners (25,542 natural-origin and 1,910 hatchery-origin spawners; Table 10) is largely the result of aggressive reintroduction and supplementation programs throughout the ESU. In the Strait of Juan de Fuca population, the annual natural-origin spawners returns for Jimmycomelately Creek dipped to a single fish in 1999 and again in 2002 (unpublished data, 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 10. Abundance of natural-origin and hatchery-origin HCS chum salmon spawners in escapements 2011-2015 (unpublished data, Mindy Rowse, NWFSC, Feb 2, 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%	349,681
Duckabush River	4,137	11	0.25%	606,505
Hamma Hamma River	1,810	7	0.37%	265,681

Population Name	Natural-origin Spawners[a]	Hatchery-origin Spawners[a]	% Hatchery Origin	Expected Number of Outmigrants[c]
Anderson Creek	0	0	-	0
Dewatto River	100	0	0.00%	14,574
Lilliwaup Creek	521	510	49.51%	150,780
Tahuya River	207	369	64.10%	84,194
Union River	979	41	3.98%	149,115
Population Average[d]	18,442	942	4.86%	2,834,877
ESU Average	**25,542**	**1,910**	**6.96%**	**4,014,817**

[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).

The Hood Canal populations have a similar success story. In 1989, only two summer chum salmon were found in spawning surveys conducted on the Big and Little Quilcene Rivers. Now, they have a combined average of 8,235 natural-origin spawners annually from 2011-2015. Hamma Hamma River returns averaged in the thousands between 1968 and 1979. But by 1989, there were an estimated 16 natural-origin spawners in the Hamma Hamma River. Recent estimates show an average of 1,810 natural-origin HCS chum salmon returning to the Hamma Hamma River annually.

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

Escapement data, the percentage of females in the population, and fecundity can estimate juvenile HCS chum salmon abundance. ESU fecundity estimates average 2,500 eggs per female, and the proportion of female spawners is approximately 45% of escapement in most populations (WDFW/PNPTT 2000). By applying fecundity estimates to the expected escapement of females (both natural-origin and hatchery-origin spawners – 12,353 females), the ESU is estimated to produce approximately 30.9 million eggs annually. For HCS chum salmon, freshwater mortality rates are high with no more than 13% of the eggs expected to survive to the juvenile migrant stage (Quinn 2005). With an estimated survival rate of 13%, the ESU should produce roughly 4.01 million natural-origin outmigrants annually.

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

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

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

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

Limiting Factors

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

Status Summary

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

2.2.2.3 Puget Sound Steelhead

Description and Geographic Range

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

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

Subbasin	Artificial propagation program	Brood year	Run Timing	Clipped Adipose Fin	Intact Adipose Fin
Dungeness/Elwha	Dungeness	2016	Winter	10,000	-
	Hurd Creek	2017	Winter	-	34,500
Duwamish/Green	Flaming Geyser	2016	Winter	-	15,000
	Icy Creek	2016	Summer	20,000	-
			Winter	-	23,000
	Soos Creek	2016	Summer	30,000	-
Hood Canal	LLTK – Lilliwaup	2013	Winter	230	-
		2015	Winter	-	6,000
Puyallup	White River	2016	Winter	-	35,000
Total Annual Release Number				**60,230**	**113,500**

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

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

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

Spatial Structure and Diversity

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

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

Demographically Independent Populations	Run(s)	Population Capacity
Central and South Puget Sound MPG		
Cedar River	Winter	5,949 – 11,899
N Lake Washington/Lake Sammamish	Winter	5,268 – 10,536
Green River	Winter	19,768 – 39,537
Puyallup/Carbon River	Winter	14,716 – 29,432
White River	Winter	17,490 – 34,981
Nisqually River	Winter	15,330 – 30,660
South Puget Sound Tributaries	Winter	9,854 – 19,709
East Kitsap Peninsula Tributaries	Winter	1,557 – 3,115

Demographically Independent Populations	**Run(s)**	**Population Capacity**
	TOTAL	**89,932 – 179,869**
Hood Canal and Strait of Juan de Fuca MPG		
East Hood Canal Tributaries	Winter	1,270 – 2,540
South Hood Canal Tributaries	Winter	2,985 – 5,970
Skokomish River	Winter	10,030 – 20,060
West Hood Canal Tributaries	Winter	3,608 – 7,217
Sequim/Discovery Bays Independent Tributaries	Winter	512 – 1,024
Dungeness River	Summer; Winter	2,465 – 4,930
Strait of Juan de Fuca Independent Tributaries	Winter	728 – 1,456
Elwha River	Winter	7,116 – 14,231
	TOTAL	**28,714 – 57,428**
North Cascades MPG		
Drayton Harbor Tributaries	Winter	2,426 – 4,852
Nooksack River	Winter	22,045 – 44,091
SF Nooksack River	Summer	1,137 – 2,273
Samish River and Bellingham Bay Tributaries	Winter	3,193 – 6,386
Skagit River	Summer; Winter	64,775 – 129,551
Nookachamps Creek	Winter	1,231 – 2,462
Baker River	Summer; Winter	5,028 – 10,056
Sauk River	Summer; Winter	23,230 – 46,460
Stillaguamish River	Winter	19,118 – 38,236
Deer Creek	Summer	1,572 – 3,144
Canyon Creek	Summer	121 - 243
Snohomish/Skykomish River	Winter	21,389 – 42,779
Pilchuck River	Winter	5,193 – 10,386
NF Skykomish River	Summer	663 – 1,325
Snoqualmie River	Winter	16,740 – 33,479
Tolt River	Summer	321 - 641
	TOTAL	**188,182 – 376,364**
	GRAND TOTAL	**306,828 – 613,661**

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

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

Artificial propagation is a major factor affecting the genetic diversity of both summer- and winter-run steelhead in the Puget Sound DPS. Although offsite releases and releases of steelhead fry and parr have largely ceased in the DPS, annual hatchery steelhead smolt releases derived from non-local steelhead (Skamania summer-run steelhead) or domesticated steelhead originally found within the DPS (Chambers Creek winter-run steelhead) persist in most systems. And several of these releases are still composed of tens or hundreds of thousands of fish. This sustained hatchery management practice has increased the likelihood of interbreeding and ecological interaction between wild and hatchery fish—in spite of the apparent differences in average spawning time and its associated adverse fitness consequences for both summer- and winter-run steelhead. As NMFS (2005a) noted, even low levels (e.g., <5%) of gene flow per year from a non-DPS hatchery stock to a naturally spawning population can have a significant genetic impact after several generations. For 2017, 1.15 million hatchery steelhead are expected to be released throughout the range of the PS steelhead DPS (WDFW 2016).

Abundance and Productivity

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

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

Demographically Independent Populations	**Geometric means**					
	1990-1994	**1995-1999**	**2000-2004**	**2005-2009**	**2010-2014**	**% Change**
Central and South Puget Sound MPG						
Cedar River	(321)	(298)	(37)	(12)	(4)	(-67)
Green River	1,566 (1,730)	2,379 (2,505)	1,618 (1,693)	(716)	(552)	(-23)
Nisqually River	1,201 (1,208)	759 (759)	394 (413)	278 (375)	(442)	(18)
N. Lake WA/Lake Sammamish	321 (321)	298 (298)	37 (37)	12 (12)	-	-
Puyallup/Carbon River	1,156 (1,249)	1,003 (1,134)	428 (527)	315 (322)	(277)	(-14)
White River	696 (696)	519 (519)	466 (466)	225 (225)	531 (531)	136 (136)
Hood Canal and Strait of Juan de Fuca MPG						
Dungeness River	356 (356)	-	38 (38)	24 (25)	-	-
East Hood Canal Tribs.	110 (110)	176 (176)	202 (202)	62 (62)	60 (60)	-3 (-3)
Elwha River	206 (358)	127 (508)	(303)	-	(237)	-
Sequim/Discovery Bay Tribs	(30)	(69)	(63)	(17)	(19)	(12)
Skokomish River	385 (503)	359 (359)	205 (259)	351 (351)	(580)	(65)
South Hood Canl Tribs	89 (89)	111 (111)	103 (103)	113 (113)	64 (64)	-43 (-43)
Strait of Juan de Fuca Tribs	89 (89)	191 (191)	212 (212)	101 (101)	147 (147)	46 (46)
West Hood Canal Tribs	-	97 (97)	210 (210)	149 (174)	(74)	(-50)

Demographically Independent Populations	**Geometric means**					
	1990-1994	**1995-1999**	**2000-2004**	**2005-2009**	**2010-2014**	**% Change**
North Cascades MPG						
Nooksack River	-	-	-	-	1,693 (1,745)	-
Pilchuck River	1,225 (1,225)	1,465 (1,465)	604 (604)	597 (597)	614 (614)	3 (3)
Samish River/ Bellingham Bay Tribs	316 (316)	717 (717)	852 (852)	534 (534)	846 (846)	58 (58)
Skagit River	7,189 (7,650)	7,656 (8,059)	5,424 (5,675)	4,767 (5,547)	(5,123)	(7)
Snohomish/Skykomish Rivers	6,654 (7,394)	6,382 (7,200)	3,230 (3,980)	4,589 (5,399)	(930)	(-83)
Snoqualmie River	1,831 (1,831)	2,056 (2,056)	1,020 (1,020)	944 (944)	680 (680)	-28 (-28)
Stillaguamish River	1,078 (1,078)	1,024 (1,166)	401 (550)	259 (327)	(392)	(20)
Tolt River	112 (112)	212 (212)	119 (119)	73 (73)	105 (105)	44 (44)

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

Table 15. Abundance of PS steelhead spawner escapements (natural-origin and hatchery-production combined) from 2012-2016 (pers. comm., A. Marshall, WDFW, July 13, 2017).

Demographically Independent Populations	**Spawners**	**Expected Number of Outmigrants**[b]
Central and South Puget Sound MPG		
Cedar River	1	114
Green River	977	111,134
Nisqually River	759	86,336
N. Lake WA/Lake Sammamish	-	-
Puyallup/Carbon River	590	67,113
White River	124	14,105
Hood Canal and Strait of Juan de Fuca MPG		
Dungeness River	-	-
East Hood Canal Tribs.	87	9,896
Elwha River[c]	273	31,054
Sequim/Discovery Bay Tribs.	19	2,161
Skokomish River	862	98,053
South Hood Canal Tribs.	72	8,190
Strait of Juan de Fuca Tribs.	238	27,073
West Hood Canal Tribs.	159	18,086
North Cascades MPG		
Nooksack River	1,790	203,613
Pilchuck River	868	98,735
Samish River/ Bellingham Bay Tribs.	977	111,134
Skagit River	8,038	914,323

Demographically Independent Populations	Spawners	Expected Number of Outmigrants[b]
Snohomish/Skykomish Rivers	1,053	119,779
Snoqualmie River	824	93,730
Stillaguamish River	476	54,145
Tolt River	70	7,963
TOTAL	**18,257**	**2,076,734**

[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] Hatchery-origin steelhead not included in abundance estimate

The average abundance (2012-2016) for the PS steelhead DPS is 18,257 adult spawners (natural-origin and hatchery-production combined). Juvenile PS steelhead abundance estimates is calculated from the escapement data (Table 15). For the species, fecundity estimates range from 3,500 to 12,000; and the male to female ratio averages 1:1 (Pauley et al. 1986). By applying a conservative fecundity estimate of 3,500 eggs to the expected escapement of females (9,129 females), 31.95 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 2.08 million natural-origin outmigrants annually.

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

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

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

Demographically Independent Populations	1990-2005 Trend	1990-2005 95% CI	1999-2014 Trend	1999-2014 95% CI
North Cascades MPG				
Nooksack River	-	-	-	-
Pilchuck River	-0.04	(-0.06, -0.02)	-0.02	(-0.05, 0.01)
Samish River/Bellingham Bay Tribs	0.04	(0.02, 0.07)	0.02	(-0.01, 0.05)
Skagit River	-0.02	(-0.04, 0)	-	-
Snohomish/Skykomish Rivers	-0.05	(-0.08, -0.03)	-	-
Snoqualmie River	-0.03	(-0.06, -0.01)	-0.05	(-0.08, -0.02)
Stillaguamish River	-0.09	(-0.11, -0.06)	-	-
Tolt River	0.01	(-0.02, 0.04)	-0.02	(-0.06, 0.01)

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

Limiting Factors

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

Status Summary

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

2.2.2.4 Southern Eulachon

Description and Geographic Range

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

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

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

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

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

Adult eulachon weigh an average of 40 g each (approximately 11.2 eulachon per pound) and are 15 to 20 cm long with a maximum recorded length of 30 cm. They are an important link in the food chain between zooplankton and larger organisms. Small salmon, lingcod, white sturgeon, and other fish feed on small larvae near river mouths. As eulachon mature, a wide variety of predators consume them (Gustafson et al. 2010).

Spatial Structure and Diversity

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

Eulachon of the southern DPS are distinguished from eulachon occurring north of the DPS range by a number of factors including genetic characteristics. Significant microsatellite DNA variation in eulachon has been reported from the Columbia River to Cook Inlet, Alaska (Beacham et al. 2005). Within the range of the southern DPS, Beacham et al. (2005) found genetic affinities among the populations in the Fraser, Columbia, and Cowlitz rivers and also among the Kemano, Klinaklini, and Bella Coola rivers along the central British Columbia coast. In particular, there was evidence of a genetic discontinuity north of the Fraser River, with Fraser and Columbia/Cowlitz samples diverging three to six times more from samples further to the north than they did from each other. Similar to the study of McLean et al. (1999), Beacham et al. (2005) found that genetic differentiation among populations was correlated with geographic distances. The authors also suggested that the pattern of eulachon differentiation was similar to that typically found in studies of marine fish, but less than that observed in most salmon species.

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

Abundance and Productivity

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

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

Similar abundance declines have occurred in the Fraser and other coastal British Columbia rivers (Hay and McCarter 2000, Moody 2008). Over a three-generation time of 10 years (1999-2009), the overall Fraser River eulachon population biomass has declined by nearly 97% (Gustafson et al. 2010). In 1999, the biomass estimates were 418 metric tons[4]; and by 2010, had dropped to just 4 metric tons (Table 17). Abundance information is lacking for many coastal British Columbia subpopulations, but Gustafson et al. (2010) found that eulachon runs were universally larger in the past. Furthermore, the BRT was concerned that four out of seven coastal British Columbia subpopulations may be at risk of extirpation as a result of small population concerns such as Allee[5] effects and random genetic and demographic effects (Gustafson et al. 2010). Under SARA, Canada designated the Fraser River population as endangered in May 2011 due to a 98% decline in spawning stock biomass over the previous 10 years (COSEWIC 2011a). From 2012 through 2016, the Fraser River eulachon spawner population estimate is 2,518,835 adults (Table 17).

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

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

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

Year	Biomass estimate (metric tons)	Estimated spawner population[a]
2006	29	716,061
2007	41	1,012,363
2008	10	246,918
2009	14	345,685
2010	4	98,767
2011	31	765,445
2012	120	2,963,013
2013	100	2,469,177
2014	66	1,629,657
2015	317	7,827,292
2016	44	1,086,438
2012-2016[b]	**102**	**2,518,835**

[a] Estimated population numbers are calculated as 11.2 eulachon per pound.

[b] Five-year geometric mean of eulachon biomass estimates (2012-2016).

The Columbia River and its tributaries support the largest known eulachon run. Although direct estimates of adult spawning stock abundance are limited, commercial fishery landing records begin in 1888 and continue as a nearly uninterrupted data set to 2010 (Gustafson et al. 2010). From about 1915 to 1992, historic commercial catch levels were typically more than 500 metric tons, occasionally exceeding 1,000 metric tons. In 1993, eulachon catch levels began to decline and averaged less than five metric tons from 2005-2008 (Gustafson et al. 2010). Persistent low eulachon returns and landings in the Columbia River from 1993 to 2000 prompted the states of Oregon and Washington to adopt a Joint State Eulachon Management Plan (WDFW and ODFW 2001). From 2011 through 2013, all recreational and commercial fisheries for eulachon were closed in Washington and Oregon; but the fisheries were reopened in 2014. Beginning in 2011, ODFW and Washington Department of Fish and Wildlife (WDFW) began eulachon biomass surveys similar to those conducted on the Fraser River. From 2013 through 2015, eulachon abundance increased with a peak of over 186 million eulachon spawners in 2014. Since that 2014 peak, eulachon numbers have decreased annually with the lowest run totals, since the surveys began in 2011, expected in 2017 (pers. comm., R. Gustafson, June 8, 2017). From 2012 through 2016, the estimated eulachon spawner estimate for the Columbia River and its tributaries is 87,719,042 eulachon spawning adults (Table 18).

Table 18. Southern DPS eulachon spawning estimates for the lower Columbia River and tributaries (unpublished data, R. Gustafson, NWFSC, June 8, 2017).

Year	Biomass Estimate (metric tons)	Estimated spawner population[a]
2011	1,495	36,926,400
2012	1,451	35,825,440
2013	4,377	108,074,400

Year	Biomass Estimate (metric tons)	Estimated spawner population[a]
2014	7,544	186,279,520
2015	5,165	127,540,000
2016	2,287	56,460,342
2012-2016[b]	**3,553**	**87,719,042**

[a] Estimated population numbers are calculated as 11.2 eulachon per pound.
[b] Five-year geometric mean of mean eulachon biomass estimates (2012-2016).

In Northern California, no long-term eulachon monitoring programs exist. In the Klamath River, large eulachon spawning aggregations once regularly occurred but eulachon abundance has declined substantially (Fry 1979, Moyle et al. 1995, Larson and Belchik 1998, Hamilton et al. 2005). Recent reports from Yurok Tribal fisheries biologists have revealed small runs of adult eulachon ranging from 7 (2011) to ~1,000 (2014) individuals in presence/absence surveys using seines and dip nets (Gustafson et al. 2016).

Beacham et al. (2005) reported that marine sampling by trawl showed that eulachon from different rivers mix during their 2 to 3 years of pre-spawning life in offshore marine waters, but not thoroughly. Their samples from southern British Columbia comprised a mix of fish from multiple rivers, but were dominated by fish from the Columbia and Fraser River populations. The combined spawner estimate from the Columbia and Fraser rivers is 90.24 million eulachon.

Limiting Factors

Climate Change

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

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

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

Commercial and Recreational Harvest

In the past, commercial and recreational harvests likely contributed to eulachon decline. The best available information for catches comes from the Columbia River, where from 1938 to 1993 landings have averaged almost 2 million pounds per year (approximately 24.6 million fish), and have been as high as 5.7 million pounds in a single year (approximately 70 million fish) (Wydoski and Whitney 2003, Gustafson et al. 2010). Between 1994 and 2010, no catch exceeded one million pounds (approximately 12.3 million fish) annually and the median catch was approximately 43,000 pounds (approximately 529,000 fish), which amounts to a 97.7% reduction in catch (WDFW and ODFW 2001, JCRMS 2011). Catch from recreational eulachon fisheries was also high historically (Wydoski and Whitney 2003); and at its height in popularity, the fishery would draw thousands of participants annually. Commercial and recreational fisheries continued through the 2009-2010 season, and then were closed until 2014 (Gustafson et al. 2016). Beginning in 2014, ODFW and WDFW worked with NMFS to reopen their commercial and recreational eulachon fisheries (JCRMS 2014). Based upon their 2001 Eulachon Management Plan, both state agencies now manage their eulachon fisheries using scientific surveys to estimate spawner abundance and set fishery locations, dates, times, and limits by classifying their fisheries into one of three levels from most (level one) to least conservative (three) (WDFW and ODFW 2001). Since 2014, the combined commercial, recreational, and tribal eulachon fisheries have harvested 2.7 (2014), 3.5 (2015), and 1.6 (2016) million eulachon in the Columbia, Cowlitz, and Sandy rivers (Gustafson et al. 2016).

In British Columbia, the Fraser River supports the only commercial eulachon fishery that is within the range of the southern DPS. This fishery has been essentially closed since 1997, only opening briefly in 2002 and 2004 when only minor catches were landed (DFO 2008, Gustafson et al. 2016).

Shrimp Fishery Bycatch

Historically, bycatch of eulachon in the pink shrimp fishery along the U.S. and Canadian coasts has been very high (composing up to 28% of the total catch by weight; Hay and McCarter 2000, DFO 2008). Prior to the mandated use of bycatch-reduction devices (BRDs) in the pink shrimp fishery, 32–61% of the total catch in the pink shrimp fishery consisted of non-shrimp biomass, made up mostly of Pacific hake, various species of smelt including Pacific eulachon, yellowtail rockfish, sablefish, and lingcod (*Ophiodon elongatus*) (Hannah and Jones 2007). Reducing bycatch in this fishery has long been an active field of research (Hannah et al. 2003, Hannah and Jones 2007, Frimodig 2008) and great progress has been made in reducing bycatch. As of 2005, following required implementation of BRDs, the total bycatch by weight had been reduced to about 7.5% of the total catch and osmerid smelt bycatch was reduced to an estimated average of 0.73% of the total catch across all BRD types (Hannah and Jones 2007). From 2004 through 2011, eulachon bycatch in the California, Oregon, and Washington state shrimp fishery peaked at 1.0 million eulachon in 2010

(Al-Humaidhi et al. 2012). However, from 2012 through 2015, eulachon bycatch greatly increased ranging from 42.6 (2012) to 68.8 (2014) million eulachon annually (Gustafson et al. 2017). Although BRDs were being used, it is believed that they may operate at reduced efficiency when eulachon reach higher densities (Gustafson et al. 2017). Recent experimentation with using green LED lights on the trawl lines of shrimp trawl nets have shown a reduction in eulachon bycatch by 91% (p=0.0001) when compared to control nets (Hannah et al. 2015). In 2017, ODFW, in collaboration with the Pacific States Marine Fisheries Commission (PSMFC), will continue to test the use of green LEDs on shrimp trawls nets on reducing fish bycatch (Groth et al. 2017).

Other Factors

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

Status Summary

Adult spawning abundance of the southern DPS of eulachon has clearly increased since the listing occurred in 2010 (Gustafson et al. 2015). The improvement in estimated abundance in the Columbia River, relative to the time of listing, reflects both changes in biological status and improved monitoring. The documentation of eulachon returning to the Naselle, Chehalis, Elwha, and Klamath rivers over the 2011–2015 also likely reflects both changes in biological status and improved monitoring. Although eulachon abundance in monitored populations has generally improved, especially in the 2013–2015 return years, recent poor ocean conditions and the likelihood that these conditions will persist into the near future suggest that population declines may be widespread in the upcoming return years (Gustafson et al. 2015). Since the 2014 eulachon spawner peak, eulachon runs have decreased each year with the 2017 Columbia River run being the smallest since the eulachon surveys began in 2011 (pers. comm., R. Gustafson, June 8, 2017).

2.2.2.5 Southern Green Sturgeon

Description and Geographic Range

On April 7, 2006, NMFS listed the southern DPS of North American green sturgeon (hereafter referred to as “green sturgeon”) as a threatened species (71 FR 17757). The southern DPS consists of coastal and Central Valley populations south of the Eel River, with the only known spawning population in the Sacramento River. Information on their oceanic distribution and behavior indicates that green sturgeon make generally northern migrations—even occurring in numbers off Vancouver Island (NMFS 2005c). A mixed stock assessment assigned about 70% to 90% of the green sturgeon present in the Columbia River estuary and Willapa Bay to the southern DPS. The stock composition in Grays Harbor is about 40% southern DPS (Israel et al. 2009).

Green sturgeon—like all sturgeon—is a long-lived, slow-growing species. Adult green sturgeon typically migrate into fresh water beginning in late February and spawn from March to July. Green sturgeon females produce 60,000-140,000 eggs. Green sturgeon larvae are different from all other sturgeon because they lack a distinct swim-up or post-hatching stage and are distinguished from white sturgeon by their larger size, light pigmentation, and size and shape of the yolk sac. First feeding occurs 10 days after they hatch, and metamorphosis to juveniles is complete at 45 days. The larvae grow fast, reaching a length of 66 mm and a weight of 1.8 grams in three weeks of exogenous feeding. Larvae hatched in the laboratory are photonegative and exhibit hiding behaviors after the onset of exogenous feeding. The larvae and juveniles are nocturnal. Juveniles appear to spend one to three years in freshwater before they enter the ocean (NMFS 2005c).

Green sturgeon disperse widely in the ocean between their freshwater life stages. In the Klamath River, Nakamoto et al. (1995) found a lack of females from ages 3 to 13 and males from ages 3 to 9 suggesting an entirely marine existence during those ages. Green sturgeon reach maturity at 14 years for males and 16 years for females (Van Eenennaam et al. 2006) with maximum ages of 60 to 70 years or longer (Moyle 2002). Mature females return every two to four years to spawn (Erickson and Webb 2007). Lindley et al. (2008) found that green sturgeon make rapid, long distance season migrations along the continental shelf of North America from central California to central British Columbia. In the fall, green sturgeon move northward to or past the northern end of Vancouver Island, stay there for the winter, and then return southward during the spring. In an acoustic transmitter study, Moser and Lindley (2007) found that green sturgeon were routinely detected in Willapa Bay during the summer when estuarine water temperatures were greater than the coastal temperatures. However, green sturgeon were not detected in Willapa Bay during the winter when temperatures were below 10° C.

Spatial Structure and Diversity

Green sturgeon are composed of two DPS with two geographically distinct spawning locations. The northern DPS spawn in rivers north of and including the Eel River in Northern California with known spawning occurring in the Eel, Klamath, and Trinity rivers in California and the Rogue and Umpqua rivers in Oregon. The southern DPS spawn in rivers south of the Eel River which is now restricted to the Sacramento River. Historic spawning grounds were blocked by the construction of Shasta Dam (1938-1945) and Keswick Dam (1941-1950) on the Sacramento River and Oroville Dam (1961-1968) on the Feather River. Spawning grounds became limited to an area downstream of Shasta Dam that was impacted by high temperatures until the construction of a temperature control device in Shasta Dam in 1997 (Adams et al. 2007).

The CDFW reported that Oroville Dam limits access to potential spawning habitat, and warm water releases from the Thermalito Afterbay reservoir may increase temperatures to levels unsuitable for green sturgeon spawning and incubation in the Feather River (CDFG 2002). Adult green sturgeons have also been captured in the San Joaquin River delta (Adams et al. 2002). Moyle et al. (1992) suggested that green sturgeon presence in the delta is evidence that green sturgeon are spawning in the San Joaquin River. But, there are no documented observations of green sturgeon in the San Joaquin River upstream of the delta.

Diversity in sturgeon populations can range in scale from genetic differences within and among populations to complex life-history traits. One of the leading factors affecting the diversity of green sturgeon is the loss of habitat due to impassable barriers such as dams. As described above, several tributaries to the Sacramento River have been blocked and have therefore almost certainly reduced the DPS's diversity. Although this DPS migrates over long distances, its spawning locations are small and have been greatly affected by human activities.

Abundance and Productivity

Since 2006, research conducted and published has enhanced the understanding of S green sturgeon biology and life history, including reproductive characteristics (NMFS 2015). S green sturgeon typically spawn every three to four years (range two to six years) and primarily in the Sacramento River (Brown 2007; Poytress et al. 2012). Adult S green sturgeon enter San Francisco Bay in late winter through early spring and spawn from April through early July, with peaks of activity influenced by factors including water flow and temperature (Heublein et al. 2009; Poytress et al. 2011). Spawning primarily occurs in the cool sections of the upper mainstem Sacramento River in deep pools containing small to medium sized gravel, cobble or boulder substrate (NMFS 2015). Eggs incubate for a period of seven to nine days and remain near the hatching area for 18 to 35 days prior to dispersing (Van Eenennaam et al. 2001; Deng et al. 2002; Poytress et al. 2012). Based on length of juvenile sturgeon captured in the San Francisco Bay Delta, S green sturgeon migrate downstream toward the estuary between 6 months and 2 years of age (Radtke et al. 1966; NMFS 2015).

Since 2010, Dual Frequency Identification Sonar (DIDSON) surveys of aggregating sites in the upper Sacramento River for S green sturgeon have been conducted. Results from these surveys combined with the observed three to four year spawning cycle for S green sturgeon resulted in an estimate of 1,348 adults (Table 19; NMFS 2015). There are no estimates for juvenile S green sturgeon.

Table 19. Green sturgeon adult spawner numbers from DIDSON surveys in the upper Sacramento River and ESU estimate (NMFS 2015).

Year	Adult green sturgeon	95% Confidence Interval
2010	164	117 - 211
2011	220	178 - 262
2012	329	272 - 386
2013	338	277 - 399
2014	526	462 - 590
ESU abundance[a]	**1,348**	**824 – 1,872**

[a] ESU abundance for S green sturgeon numbers calculated from returning spawners in the Sacramento River and the observed spawning three to four year spawning cycle.

Limiting Factors

Many of the principle factors considered when listing Southern DPS green sturgeon as threatened are relatively unchanged (NMFS 2015). Recent studies confirm that the spawning area utilized by S green sturgeon is small. Confirmation of Feather River spawning is encouraging and the decommissioning of Red Bluff Diversion Dam and breach of Shanghai Bench makes spawning conditions more favorable, although S green sturgeon still encounter impassible barriers in the Sacramento, Feather and other rivers that limit their spawning range. The relationship between altered flows and temperatures in spawning and rearing habitat and S green sturgeon population productivity is uncertain. Entrainment as well as stranding in flood diversions during high water events also negatively impact S green sturgeon. The prohibition of retention in commercial and recreational fisheries has eliminated a known threat and likely had a very positive effect on the overall population, although recruitment indices are not presently available (NMFS 2015).

Status Summary

New information allows preliminary calculation of baseline information on spawning adult population abundance, although uncertainties exist because of the preliminary nature of the data (NMFS 2015). Since the current time series is temporally limited, there is no basis for examining trends over time. Annual DIDSON surveys could serve to track S green sturgeon spawning populations into the future. Additional future work utilizing this and other data sources (e.g. Beamesderfer et al. 2007) to look at abundance within a modeling framework would be useful and could provide a baseline for understanding the impact of various sources of Southern DPS take. Studies measuring fisheries by-catch mortality by gear type would assist in measuring the impact of bycatch of S green sturgeon in state and federal fisheries. Information gathered through the FMEP process will assist in understanding and limiting fisheries impacts (NMFS 2015).

Evaluation of new information generated since the last review does not suggest a significant change in the status of S green sturgeon. With respect to threats, the available information indicates that some threats, such as those posed by fisheries and impassable barriers, have been reduced. The emerging threat posed by nearshore and offshore energy development requires continued attention into the future. Since many of the threats cited in the original listing still exist, the Threatened status is still applicable.

2.2.2.6 Puget Sound/Georgia Basin Bocaccio and Yelloweye Rockfish

Description and Geographic Range

On April 27, 2010, NMFS listed the PS/GB DPS of bocaccio as endangered and PS/GB DPS of yelloweye rockfish as threatened (75 FR 22276). The geographic range of the listed PS/GB DPS rockfish is Puget Sound, Georgia Basin, Strait of Georgia, and Strait of Juan de Fuca east of Victoria Sill. The Victoria Sill, running from east of Port Angeles to Victoria, is a submerged terminal moraine that restricts water flow through the Strait of Juan de Fuca (Masson 2002). Puget Sound, a fjord system of submerged glacier valleys formed during a previous ice age, is an estuary located in northwest Washington State and covers an area of about 2,330 square km (900 square miles), including 4,000 km (2,500 miles) of shoreline. The Georgia Basin is a large fjord estuary situated between southern Vancouver Island and the mainland Washington State and British Columbia coasts. Puget Sound can be subdivided into five interconnected basins separated by shallow sills: (1) the San Juan/Strait of Juan de Fuca Basin (also referred to as “North Puget Sound”), (2) Main Basin, (3) Whidbey Basin, (4) South Puget Sound, and (5) Hood Canal. Each basin differs in features such as temperature regimes, water residence and circulation, biological conditions, depth profiles and contours, species, and habitats (Drake et al. 2010). We will use the term 'Puget Sound Proper' to refer to all of these basins except North Puget Sound.

Bocaccio

NMFS has determined that the PS/GB DPS of bocaccio is currently in danger of extinction throughout all of its range. Bocaccio are one of 28 rockfish species that reside in Puget Sound (Palsson et al. 2009). Bocaccio are elongate, laterally compressed fish with very large mouths (Love et al. 2002). Their appearance often varies among individuals, with several common color variations.

Bocaccio life-history includes a larval/pelagic juvenile stage followed by a nearshore juvenile stage, and sub-adult and adult stages. In contrast to the majority of bony fishes, rockfish fertilize their eggs internally, and the young are extruded as larvae. Bocaccio produce from 20,000 to 2,298,000 eggs; and as bocaccio grow and age, the number of young produced per female increases (Love et al. 2002). Larval release timing varies throughout the geographic range. Along the Washington state coast, female bocaccio release larvae between January and April (Love et al. 2002). Larvae are observed under free-floating algae, seagrass, and detached kelp (Shaffer et al. 1995, Love et al. 2002) but are also distributed throughout the water column (Weis 2004). Larvae can make small local movements to pursue food immediately after birth (Tagal et al. 2002), but are likely passively distributed with prevailing currents. Bocaccio larvae are planktivores that feed on larval krill, diatoms, and dinoflagellates (Love et al. 2002). Unique oceanographic conditions within Puget Sound proper (sills regulating water exchange from one basin to the next) likely result in most larvae staying within the basin where they are released (e.g., the South Sound) rather than being broadly dispersed (Drake et al. 2010).

Most bocaccio remain pelagic for 3.5 months prior to settling in shallow areas, although some may remain pelagic as long as 5.5 months. Several weeks after settlement, fish move to deeper waters, and settle onto shallow nearshore waters in rocky or cobble substrates with or without kelp (Love et al. 1991, 2002). These habitat features offer a beneficial mix of warmer temperatures, food, and refuge from predators (Love et al. 1991). Young-of-the-year are often found in shallow, nearshore waters over rocky bottoms associated with algae, within and near kelp canopies, and in 18 to 30 m deep waters associated with rocky reefs and high relief areas (Feder et al. 1974, Carr 1983, Sakuma and Ralston 1995, Johnson 2006, Love and Yoklavich 2008). Pelagic juveniles are opportunistic feeders, taking fish larvae, copepods, krill, and other prey. Larger juveniles and adults are primarily piscivores, eating other rockfishes, hake, sablefish, anchovies, lanternfishes, and squid. Chinook salmon, terns, and harbor seals predate upon smaller bocaccio (Love et al. 2002).

Bocaccio mature between ages three and eight years, at lengths from 32 cm to 61 cm (Wyllie-Echeverria 1987, Love et al. 2002). Evidence suggests that bocaccio may begin to mature at earlier ages in declining populations (MacCall 2002). Sub-adult and adult bocaccio typically utilize habitats with moderate to extreme steepness, complex bathymetry, and rock and boulder-cobble complexes (Love et al. 2002). Within Puget Sound proper, bocaccio have been documented in areas of high relief rocky and non-rocky substrates such as sand, mud, and other unconsolidated sediments (Washington 1977, Miller and Borton 1980). Bocaccio have large home ranges, move long distances, and spend time suspended in the water column (Love et al. 2002). Adult bocaccio inhabit waters from 12-478 m while being most common at depths of 50 to 250 m (Feder et al. 1974, Orr et al. 2000, Love et al. 2002). Some adults are semi-pelagic and form schools above rocky areas, while some are non-schooling, solitary benthic individuals (Yoklavich et al. 2000). Solitary bocaccio have been associated with large sea anemones, as well as under ledges and in crevices of isolated rock outcrops (Yoklavich et al. 2000). Though difficult to age, adults may live as long as 54 years (Drake et al. 2010). Their natural annual mortality is approximately eight percent (Palsson et. al 2009).

Yelloweye Rockfish

NMFS has determined that the PS/GB yelloweye rockfish is likely to become in danger of extinction in the foreseeable future throughout all of its range. The yelloweye rockfish life-history includes a larval/pelagic juvenile stage followed by a nearshore juvenile stage, and sub-adult and adult stages. Yelloweye rockfish may store sperm for several months until fertilization occurs, commonly between September and April, though fertilized individuals may be found year-round, depending on location (Wyllie-Echeverria 1987). In Puget Sound, yelloweye rockfish are believed to fertilize eggs during the winter to summer months and give birth in early spring to late summer (Washington et al. 1978). Fecundity ranges from 1.2 to 2.7 million eggs, considerably more than many other rockfish species (Love et al. 2002). Although yelloweye rockfish are generally thought to spawn once a year (MacGregor 1970), a Puget Sound study offered evidence of at least two spawning periods per year (Washington et al. 1978).

Larvae can make small local movements to pursue food immediately after birth (Tagal et al. 2002), but are likely passively distributed with prevailing currents. Larvae are observed under free-floating algae, seagrass, and detached kelp (Shaffer et al. 1995, Love et al. 2002) but are also distributed throughout the water column (Weis 2004). Unique oceanographic conditions within Puget Sound proper (sills regulating water exchange from one basin to the next) likely result in most larvae staying within the basin where they are released (e.g., the South Sound) rather than being broadly dispersed (Drake et al. 2010). Larval yelloweye rockfish remain pelagic for up to three months.

When yelloweye rockfish reach sizes of 2.5 to 10 cm (1 to 4 in.), they settle primarily in shallow, high relief zones, caves, crevices and areas with sponge gardens (Richards et al. 1985, Love et al. 1991). Juveniles have been documented as shallow as 15 m and generally move deeper as they get older (Love et al. 2002). Though not typically occupying intertidal waters (Love et al. 1991, Studebaker et al. 2009), juvenile yelloweye rockfish eventually settle in 30 to 40 m (98 to 131 ft.) of water near the upper depth range of adults (Yamanaka and Lacko 2001).

Yelloweye rockfish are among the largest rockfish, weighing up to 11 kg (25 lbs.) and are easily recognizable by their bright yellow eyes and red-orange color (Love et al. 2002). Yelloweye rockfish reach 50 percent maturity at sizes around 40 to 50 cm (16 to 20 in.) and ages of 15 to 20 years (Rosenthal et al. 1982, Yamanaka and Kronlund 1997). Sub-adult and adult yelloweye rockfish typically utilize habitats with moderate to extreme steepness, complex bathymetry, and rock and boulder-cobble complexes (Love et al. 2002). As they grow and move to deeper waters, adults utilize rocky, high relief areas that include caves, crevices, rocky pinnacles, and boulder fields (Carlson and Straty 1981, Richards 1986, Love et al. 1991, O'Connell and Carlisle 1993, Yoklavich et al. 2000). Within Puget Sound proper, yelloweye rockfish have been documented in areas of high relief rocky and non-rocky substrates such as sand, mud, and other unconsolidated sediments (Washington 1977, Miller and Borton 1980). In waters less than 90 m deep, adult yelloweye rockfish were observed at a mean depth of 45.8 m (Johnson et al. 2003). Overall, yelloweye rockfish adults are most commonly found between 40 to 250 m (131 to 820 ft.) and have small home ranges (Orr et al. 2000, Love et al. 2002).

Yelloweye rockfish adults do not move much and are generally considered to be relatively site-attached (Coombs 1979, DeMott 1983). Yelloweye rockfish are generally solitary, demersal residents with small home ranges but can be found infrequently in aggregations (Coombs 1979, DeMott 1983, Love et al. 2002). They are opportunistic feeders, targeting different food sources during different phases of their life history, with the early life stages having typical rockfish diets that include sand lance, gadids, flatfishes, shrimps, crabs, and gastropods (Love et al. 2002, Yamanaka et al. 2006). Due to their large sizes, they are able to handle much larger prey, including smaller yelloweye rockfish, and are preyed upon less frequently (Rosenthal et al. 1982). Yelloweye rockfish predators include salmon and orcas (Ford et al. 1998, Love et al. 2002). Yelloweye rockfish are among the longest lived rockfish, living up to at least 118 years (Love 1996, Love et al. 2002) with natural mortality rates estimated from 2 to 4.6 percent (Yamanaka and Kronlund 1997, Wallace 2007).

Spatial Structure and Diversity

A population's spatial structure depends on habitat quality, spatial configuration, and dynamics as well as dispersal characteristics of individuals within the population (McElhaney et al. 2000). In spatially and temporally varying environments, the three general reasons why diversity is important for species and population viability are: (1) diversity allows a species to use a wider array of environments, (2) it protects a species against short-term spatial and temporal changes in the environment, and (3) genetic diversity provides the raw material for surviving long-term environmental changes.

Bocaccio

Prior to contemporary fishery removals, all major basins likely hosted PS/GB bocaccio populations (Washington 1977, Washington et al. 1978, Moulton and Miller 1987). Historically, they were most abundant in the Central and South Sound (Drake et al. 2010). In North Puget Sound, bocaccio have always been rare in recreational fishery surveys. In the Strait of Georgia, bocaccio have been documented in some inlets; but records are sparse, isolated, and often based on anecdotal reports (COSEWIC 2002). This wide distribution allowed bocaccio to utilize the full suite of available habitats to maximize their abundance and demographic characteristics and, thereby, enhance their resilience (Hamilton 2008). This also enabled bocaccio to potentially exploit ephemerally good habitat conditions or, in turn, receive protection from smaller-scale and negative environmental fluctuations. These fluctuations may change prey abundance for various life stages and/or environmental characteristics that influence annual recruitment numbers. However, Puget Sound basin connectivity is naturally restricted by relatively shallow sills located at Deception Pass, Admiralty Inlet, the Tacoma Narrows, and in Hood Canal (Burns 1985) which most likely moderates rockfish larvae movement (Drake et al. 2010).

The steep reduction in PS/GB bocaccio abundance (and consequent fragmentation) has led to concerns about their viability (Drake et al. 2010). In the 1970's, size-frequency distributions for bocaccio included a wide range of sizes, with recreationally caught individuals from 25 to 85 cm (9.8 to 33.5 in.) and a bi-modal distribution (most captured bocaccio were either 30 cm or 70 cm)

(Drake et al. 2010). This broad size distribution suggests a spread of ages, with some successful recruitment over many years. In the 1980’s, a similar size range was still evident in the catch data, but the distribution was flat across length. By the 2000s, no bocaccio size distribution data were available. The temporal trend in bocaccio size distributions also suggests size truncation of the population, with larger fish becoming less common over time. So as the mature fish density has decreased, productivity may have also been impacted by Allee effects despite the propensity of some individuals to move long distances and potentially reestablish aggregations in formerly occupied habitat (Drake et al. 2010).

The BRT concluded there was no available information to support a conclusion of individual bocaccio populations within the DPS. The factors supporting that conclusion include: (1) similarity in age structure, (2) wide distribution of mature reproductive age adults, (3) widespread suitable habitat in a pattern that allows for movement, and (4) bocaccio adults are able to move over relatively long distances (75 FR 22276). Further, the potential loss of diversity for PS/GB bocaccio, in combination with their relatively low productivity, may result in a mismatch with habitat conditions and further reduce population viability (Drake et al. 2010). The unique oceanographic features and relative isolation of some of its basins may have led to unique adaptations, such as larvae release timing (Drake et al. 2010). Rockfish diversity characteristics include fecundity, larvae release timing, larvae condition, morphology, age at reproductive maturity, physiology, and molecular genetic characteristics. Leading factors affecting diversity include: (1) relatively small home ranges of juveniles and subadults (Love et al. 2002) and (2) low population size for all life stages. Results from a recent genetic study comparing bocaccio individuals from within the PS/GB DPS (n=2) to those outside the DPS (n=9) was insignificant due to insufficient sample size (Tonnes et al. 2016).

Yelloweye Rockfish

Prior to contemporary fishery removals, each major basin in the DPS likely hosted relatively large yelloweye rockfish populations (Washington 1977, Washington et al. 1978, Moulton and Miller 1987). This distribution allowed yelloweye rockfish to utilize the full suite of available habitats to maximize their abundance and demographic characteristics and, thereby, enhance their resilience (Hamilton 2008). This distribution also enabled them to potentially exploit ephemerally good habitat conditions or, in turn, receive protection from smaller-scale and negative environmental fluctuations. These fluctuations may change prey abundance for various life stages and/or may change environmental characteristics that influence annual recruit numbers. Yelloweye rockfish are probably most abundant within the San Juan Basin, but the likelihood of juvenile recruitment from this basin to adjacent basins is naturally low because of the generally retentive circulation patterns that.

The apparent steep reduction of ESA-listed rockfish in Puget Sound proper (and their consequent fragmentation) has led to concerns about the viability of these populations (Drake et al. 2010). Recreationally caught yelloweye rockfish in the 1970s spanned a broad size range. By the 2000s, fewer older fish in the population were observed (Drake et al. 2010). However, overall fish numbers in the database were also much lower, making it difficult to determine if clear size truncation occurred. With age truncation, the reproductive burden may have shifted to younger and smaller fish. This could alter larval release timing and condition, which may create a mismatch with habitat conditions and potentially reduce offspring viability (Drake et al. 2010).

Spatial distribution provides a protective measure from larger scale anthropogenic changes that damage habitat suitability, such as oil spills or hypoxia, which can occur within one basin but not necessarily the other basins. When localized depletion of rockfish occurs, it can reduce stock resiliency, especially when exacerbated by the natural hydrologic constrictions within Puget Sound (Levin 1998, Hilborn et al. 2003, Hamilton 2008). Combining this with limited adult movement, yelloweye rockfish population viability may be highly influenced by the probable localized loss of populations within the DPS, thus decreasing spatial structure and connectivity.

Rockfish diversity characteristics include fecundity, larvae release timing, larvae condition, morphology, age at reproductive maturity, physiology, and molecular genetic characteristics. The leading factors affecting diversity are the relatively small home ranges of juveniles and subadults (Love et al. 2002) and low population size of all life stages. Yelloweye rockfish spatial structure and connectivity are likely threatened by the apparently severe reduction of fish numbers throughout Hood Canal and South Puget Sound. At 2,330 square km, Puget Sound is a small geographic area compared with the entire yelloweye rockfish range in the northeastern Pacific.

Results from a recent genetic study comparing yelloweye rockfish individuals from within the PS/GB DPS (n=52) to those outside the DPS (n=52) provided multiple results (Tonnes et al. 2016). First, yelloweye rockfish in inland Canadian waters as far north as Johnstone Strait were genetically similar to those within the PS/GB DPS. Currently, these areas are not included within the boundaries of the DPS. Second, a significant genetic difference exists between individuals (1) outside the DPS and (2) within the DPS and north of the DPS in inland Canadian waters to as far north as Johnstone Strait. Lastly, individuals within Hood Canal are genetically differentiated from the rest of the DPS; thereby indicating a previous unknown degree of population differentiation within the DPS (Tonnes et al. 2016).

Abundance and Productivity

Short- and long-term abundance trends serve as primary risk indicators in natural populations. Trends may be calculated from a variety of quantitative data, including catch, catch per unit of effort (CPUE), and survey data. However, no single reliable historic or contemporary population estimate exists for PS/GB bocaccio and yelloweye rockfish (Drake et al. 2010). Despite this limitation, there is clear evidence all of these species' abundance has declined dramatically (Drake et al. 2010).

With historic fisheries reducing larger, older, more mature rockfish abundance, maternal effects can have a greater influence upon populations. Maternal effects for rockfish show up in numerous traits. Larger and older rockfish females, of various species, have higher weight-specific fecundity (larvae per unit of female weight) (Boehlert et al. 1982, Bobko and Berkeley 2004, Sogard et al. 2008). Several studies have shown that larger or older rockfish females release larvae earlier in the season when compared to smaller or younger females (Nichol and Pikitch 1994, Sogard et al. 2008). Larval birth timing can be crucial in terms of corresponding with favorable oceanographic conditions because most larvae are released on only one day each year, with a few exceptions in southern coastal populations (Washington et al. 1978). Further, larger or older females provide more nutrients to larvae by developing a larger oil globule released at parturition, which provides energy to the developing larvae (Berkeley et al. 2004, Fisher et al. 2007), and in black rockfish enhances early growth rates (Berkeley et al. 2004).

In 2008, WDFW conducted fishery-independent population abundance estimates using spatially and temporally limited research trawls, drop camera surveys, and underwater remotely operated vehicle (ROV) surveys (Pacunski et al. 2013). The trawl surveys were conducted on the bottom to assess marine fish abundance for a variety of species. The drop camera surveys sampled habitats less than 36.6 m (120 ft.), which is potential habitat for bocaccio juveniles. In the San Juan Basin, rocky habitats were mapped and a randomized survey of these areas assessing species assemblages and estimating abundances was conducted. The ROV surveys were conducted exclusively within these rocky habitats and represent the best available abundance estimates because of their survey area, number of transects, and stratification methods. WDFW conducted 200 transects and stratified each rocky habitat survey as either "shallower than" and "deeper than" 36.6 m (120 ft.). The total area surveyed within each stratum was calculated using the average transect width multiplied by the transect length. The mean densities were calculated by dividing the species counts within each stratum by the area surveyed. Population estimates were calculated by multiplying density estimates by the total survey area within each stratum (Pacunski et al. 2013). Additional ROV surveys by WDFW have been conducted in 2010, 2012, and 2013; but results from these surveys have not been published (Tonnes et al. 2016). Further, there are no estimates for juveniles for any of the PS/GB listed rockfish (Tonnes et al. 2016).

Bocaccio

Though bocaccio were never a predominant segment of the multi-species rockfish population within the Puget Sound/Georgia Basin (Drake et al. 2010), their present-day abundance is likely a fraction of their pre-contemporary fishery abundance. These trawls generally sampled over non-rocky substrates where bocaccio are less likely to occur compared to steep-sloped, rocky habitat (Drake et al. 2010). Based on these surveys, the WDFW estimates 4,606 bocaccio are present in the San Juan Islands basin of the DPS (Table 20). This estimate only includes the non-rocky habitats of the San Juan Island basin and, therefore, is likely to be a conservative estimate of the actual PS/GB bocaccio rockfish abundance.

Table 20. WDFW population estimates for bocaccio and yelloweye rockfish (Pacunski et al. 2013).

		Population Estimate	
DPS	**Survey Method**	**North Sound**	**Puget Sound proper**
PS/GB bocaccio	Bottom Trawl	Not Detected	Not Detected
	Drop Camera	Not Detected	Not Detected
	Remote Operated Camera	4,606 (San Juan Basin)	
	Total Population Estimate	**4,606**	
PS/GB yelloweye rockfish	Bottom Trawl	Not Detected	600
	Drop Camera	Not Detected	Not Detected
	Remove Operated Camera	47,407 (San Juan Basin)	
	Total Population Estimate	**47,407** [a]	

[a] The bottom trawl estimate is an incomplete estimate and is therefore not included in the total population estimate.

This information is limiting for PS/GB bocaccio. The total rockfish population in the Puget Sound region is estimated to have declined around three percent per year for the past several decades, which corresponds to an approximate 70 percent decline from the 1965 to 2007 time period (Drake et al. 2010). Relative to other rockfish species, bocaccio have declined in frequency in Puget Sound. Bocaccio declined from 4.63% of the total rockfish catch (1975-1979) to 0.24% of the total rockfish catch (1980-1989) (Drake et al. 2010). From 1996 to 2007, bocaccio were not observed in any of the 2,238 rockfish identified in the dockside surveys of the recreational catches. In a sample this large, the probability of observing at least one bocaccio would be 99.5% assuming it was at the same frequency (0.24%) as in the 1980s (Drake et al. 2010). In 2008 and 2009, some bocaccio were reported by recreational anglers in the Central Sound (WDFW 2011).

Though the bottom trawl and drop camera surveys did not detect bocaccio in Puget Sound proper, bocaccio have been historically present there and have been caught in recent recreational fisheries. Factors for the lack of bocaccio detections in Puget Sound proper include: (1) bocaccio populations are depleted, (2) the general lack of rocky benthic areas in Puget Sound proper may lead to bocaccio densities that are naturally less than the San Juan Basin, and (3) the study design or effort may not have been sufficiently powerful to detect bocaccio.

Productivity measures a population’s growth rate through all or a portion of its life-cycle. Bocaccio life-history traits suggest generally low inherent productivity levels because they are long-lived, mature slowly, and have sporadic episodes of successful reproduction (Tolimieri and Levin 2005, Drake et al. 2010). PS/GB bocaccio have a very low intrinsic rate of population growth of 1.01, even in the absence of a targeted fishery (Tolimieri and Levin 2005).

Bocaccio populations do not follow consistent growth trajectories, and sporadic recruitment drives population structure (Drake et al. 2010). Productivity is driven by high fecundity and episodic recruitment events, largely correlated with rare climatic and oceanographic conditions. Tolimieri and Levin (2005) estimated that these environmental conditions occur only about 15% of the time. When these conditions occur, large year-classes may be produced, which can sustain the population during years of reproductive failure. Demographically, this species demonstrates some of the highest recruitment variability among rockfish species, with many years of failed recruitment being the norm (Tolimieri and Levin 2005). This so-called year class strength is present in some fishes but extreme in rockfish (Ralston and Howard 1995).

Yelloweye Rockfish

Yelloweye rockfish were 2.4 percent of the rockfish harvest in the North Sound during the 1960s, 2.1 percent of the harvest during the 1980s, and further decreased to an average of one percent from 1996 to 2002 (Palsson et al. 2009). In Puget Sound proper, yelloweye rockfish were 4.4 percent of the rockfish harvest during the 1960s, 0.4 percent during the 1980s, and 1.4 percent from 1996 to 2002 (Palsson et al. 2009). By the 2000s, evidence of fewer older fish in the population prevailed. Since overall fish numbers in the database were also much lower, it is difficult to determine if size truncation occurred.

In 2008, fishery-independent estimate surveys conducted by WDFW estimated that 47,407 yelloweye rockfish are present in the in the San Juan Islands basin (Table 20). Since this estimate only includes the San Juan Island basin, this estimate is considered a conservative estimate of actual PS/GB yelloweye rockfish abundance. Though yelloweye rockfish were detected via bottom trawl surveys in Puget Sound proper, we do not consider the WDFW estimate of 600 fish to be a complete estimate and were not included. Since juvenile yelloweye rockfish are less dependent on rearing in shallow nearshore environments than bocaccio, the drop camera surveys were not expected to result in any detections.

Productivity measures a population's growth rate through all or a portion of its life-cycle. Yelloweye rockfish life-history traits suggest generally low inherent productivity levels because they are long-lived, mature slowly, and have sporadic episodes of successful reproduction (Tolimieri and Levin 2005, Drake et al. 2010). Adult yelloweye rockfish typically occupy relatively small ranges (Love et al. 2002) and may not move to find suitable mates. So as the density of mature fish has decreased, productivity may have also been impacted by Allee effects. Further, past commercial and recreational fishing may have depressed the DPS to a threshold beyond which optimal productivity is unattainable (Drake et al. 2010). Also, historic over-fishing may have had dramatic impacts on population size or age structure.

Limiting Factors

Several factors, both population- and habitat-related, have caused the listed PS/GB rockfish to decline to the point that NMFS has listed them. Their low intrinsic productivity, combined with continuing threats from bycatch in commercial and recreational harvest, non-native species introductions, loss and degradation of habitat, and chemical contamination increase the extinction risk.

Over the last century in the Puget Sound and Georgia Basin, human activities have introduced a variety of toxins that may affect rockfish populations or their prey. Although few studies have investigated toxin effects on rockfish ecology or physiology, other Puget Sound fish have shown a substantial impact, including reproductive dysfunction of some sole species (Landahl et al. 1997). Contaminants such as polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and chlorinated pesticides appear in rockfish collected in urban areas (Palsson et al. 2009). Though the highest contamination levels occur in urban areas, toxins can be found in the tissues of fish throughout Puget Sound (West et al. 2001). Several urban embayments have high heavy metal and organic compound levels (Palsson et al. 2009). When organisms living or eating in these sediments are consumed, contaminants are transferred up the food web to higher level predators like rockfishes and a wider geographic area. Rockfish reproductive function is also likely affected by contaminants (Palsson et al. 2009) and other life-history stages may be as well (Drake et al. 2010). Also, Puget Sound water quality is impacted by sewage, animal waste, and nutrient inputs.

Present-day abundance is influenced by bycatch from several commercial and recreational fisheries. Though rockfish may no longer be retained in these fisheries, released fish are often injured or killed by barotrauma. Physoclist fish (such as rockfish) lack the duct connection to the esophagus (Hallacher 1974) and are dependent upon passive gas exchange through their blood in the *rete mirabile* within their swim bladders (Alexander 1966). This allows them to become buoyant at much deeper depths than physotome fish (such as salmon), but rendering them unable to offload gases quickly during a rapid ascent. So when rockfish are brought from depths greater than 18.3 m (60 ft.), rapid decompression occurs (Parker et al. 2006, Jarvis and Lowe 2008, Palsson et al. 2009). During rapid decompression, swim bladder gases expand exponentially which is further exasperated by temperature increases. This results in swim bladder expansion; reduction in body cavity space; and displacement, eversion, and/or injury to the heart, kidneys, stomach, liver, and other internal organs (Rogers et al. 2008, Pribyl et al. 2009, Pribyl et al. 2011). Further, expanding gas can rupture and escape from the swim bladder filling the orbital space behind the eyes, stretching the optic nerve, and causing exophthalmia (Rogers et al. 2008). Once on the surface, rockfish can become positively buoyant, being unable to return to their previous water depth, and make them susceptible to predation (Starr et al. 2002, Hannah et al. 2008, Jarvis and Lowe 2008).

Future climate-induced changes to rockfish habitat could alter their productivity (Drake et al. 2010). Harvey (2005) created a generic bioenergetic model for rockfish, showing that rockfish productivity is highly influenced by climate conditions. For instance, El Niño-like conditions generally lowered growth rates and increased generation time. The negative effect of the warm water conditions associated with El Niño appear to be common across rockfishes (Moser et al. 2000). Rockfish recruitment appears to be correlated at large scales. Field and Ralston (2005) hypothesized that such synchrony was the result of large-scale climate forcing. Exactly how climate influences rockfish in Puget Sound is unknown; however, given the general importance of climate to rockfish recruitment, it is likely that climate strongly influences the dynamics of ESA-listed rockfish population viability (Drake et al. 2010).

Status Summary

Bocaccio

PS/GB bocaccio likely exist at very low abundance; however, observations are rare. Results from a recent genetic study comparing bocaccio individuals from within the PS/GB DPS to those outside the DPS were inconclusive due to an insufficient sample size (Tonnes et al. 2016). Their low intrinsic productivity, combined with continuing threats from bycatch in commercial and recreational harvest, non-native species introductions, loss and degradation of habitat, and chemical contamination, increase the extinction risk. NMFS has determined that this DPS is currently in danger of extinction throughout all of its range; and in its 2016 status review (Tonnes et al. 2016), NMFS has recommended no change in the PS/GB bocaccio's endangered classification.

Yelloweye Rockfish

PS/GB yelloweye rockfish abundance is much less than it was historically. The fish face several threats including bycatch in commercial and recreational harvest, non-native species introductions, and habitat degradation. Results from a recent genetic study comparing yelloweye rockfish individuals from within the PS/GB DPS to those outside the DPS concluded that a significant genetic difference exists between individuals (1) outside the DPS and (2) within the DPS and north of the DPS in inland Canadian waters to as far north as Johnstone Strait (Tonnes et al. 2016). Further, individuals within Hood Canal are genetically differentiated from the rest of the PS/GB DPS; thereby indicating a previous unknown degree of population differentiation within the DPS (Tonnes et al. 2016). NMFS has determined that this DPS is likely to be in danger of extinction in the foreseeable future throughout all of its range; and in its 2016 status review (Tonnes et al. 2016), NMFS has recommended no change in the PS/GB yelloweye rockfish's threatened classification.

2.2.3 Status of the Species' Critical Habitat

We review the status of designated critical habitat affected by the proposed action by examining the condition and trends of essential physical and biological features throughout the designated area.

These features are essential to the conservation of the listed species because they support one or more of the species' life stages (e.g., sites with conditions that support spawning, rearing, migration, and foraging).

For salmon and steelhead, NMFS ranked watersheds within designated critical habitat at the scale of the fifth-field hydrologic unit code (HUC5) in terms of the conservation value they provide to each listed species they support[6]; the conservation rankings are high, medium, or low. To determine the conservation value of each watershed to species viability, NMFS' critical habitat analytical review teams (CHARTs; NOAA Fisheries 2005) evaluated the quantity and quality of habitat features (for example, spawning gravels, wood and water condition, side channels), the relationship of the area compared to other areas within the species' range, and the significance to the species of the population occupying that area. Thus, even a location that has poor quality of habitat could be ranked with a high conservation value if it were essential due to factors such as limited availability (e.g., one of a very few spawning areas), a unique contribution of the population it served (e.g., a population at the extreme end of geographic distribution), or the fact that it serves another important role (e.g., obligate area for migration to upstream spawning areas).

2.2.3.1 Puget Sound Chinook Salmon

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

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

PS Chinook salmon populations inhabit rivers and streams flowing into Puget Sound including the Straits of Juan De Fuca from the Elwha River, eastward. This includes rivers and streams flowing into Hood Canal, South Sound, North Sound, and the Strait of Georgia in Washington. This region

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

experiences reduced rainfalls (50-120 cm) from the rainshadow effect of the Coast Mountains. The area is generally flat with high hills (600 m) at the southern margin of the ecoregion. Soils are composed of alluvial and lacustrine deposits. These deposits are glacial in origin north of Centralia, Washington. This area tends to have large groundwater resources, with groundwater from the bordering mountain ranges helping sustain river flows during drought periods. Peak river flow varies from December to June depending on the contribution of snowpack to surface runoff for each river system. Rivers tend to have sustained flows (five to eight months of flows at 50% of the peak or more), and low flows are generally 10-20% or more of the peak flows (Myers et al. 1998).

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

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

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

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

2.2.3.2 Hood Canal Summer-run Chum Salmon

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

As part of the designation process, NMFS convened Critical Habitat Analytical Review Teams (CHART) to evaluate the current habitat status and identify habitat health threats. The Puget Sound CHART's assessment of habitat quality and identification of habitat threats is available on our website at http://www.westcoast.fisheries.noaa.gov/publications/protected_species/salmon_steelhead/critical_habitat/chart_report/2005_chart_hc_chum.pdf. In determining the areas eligible for critical habitat designation, the PS CHART identified the PBFs essential for species conservation. PBFs for HCS chum salmon are those sites and habitat components that support one or more life stages including freshwater spawning sites, freshwater rearing sites, freshwater migration corridors, and nearshore marine areas. Designated critical habitat includes 34 miles of spawning/rearing sites, one mile of rearing/migration sites, 36 miles of migration corridors, and eight miles of unoccupied but essential habitat to ESU conservation. The 377 miles of designated nearshore marine habitats contain rearing and migration PBFs. There are 12 watersheds within the range of this ESU. Three watersheds received a medium rating and nine received a high rating of conservation value to the ESU. Five nearshore marine areas also received a rating of high conservation value.

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

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

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

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

2.2.3.3 Puget Sound Steelhead

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

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

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

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

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

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

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

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

2.2.3.4 Southern Eulachon

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

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

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

2.2.3.5 Southern Green Sturgeon

Critical habitat was designated for green sturgeon on October 9, 2009, when NMFS published a final rule in the *Federal Register* (74 FR 52300). This rule designates approximately 320 miles of freshwater river habitat, 897 square miles of estuarine habitat, 11,421 square miles of marine habitat, 487 miles of habitat in the Sacramento-San Joaquin Delta, and 135 square miles of habitat within the Yolo and Sutter bypasses (Sacramento River, CA) as critical habitat for the Southern DPS of green sturgeon. Areas designated for critical habitat include coastal U.S. marine waters within 60 fathoms depth from Monterey Bay, California north to Cape Flattery, Washington, including the Strait of Juan de Fuca, Washington, to its United States boundary; the lower Columbia River estuary; and certain coastal bays and estuaries in Washington (Willapa Bay and Grays Harbor). For Washington state, areas excluded from critical habitat designation include the lower Columbia River from river kilometer 74 to the Bonneville Dam, Puget Sound, and particular areas that would impact national security and Indian lands.

As part of the designation process NMFS convened a Critical Habitat Review Team (CHRT) to evaluate the current status of the habitat and identify threats to habitat health. The CHRT's assessment of habitat quality and identification of habitat threats is available on our website at http://swr.nmfs.noaa.gov/gs/GS_Critical_habitat_files/GSCHD_Final4b2Rpt.pdf. In determining what areas are eligible for critical habitat designation, the CHRT identified the primary constituent elements (PCEs) that are essential for the conservation of the species. Based on the best available scientific information, the CHRT identified PCEs for freshwater riverine systems, estuarine areas, and nearshore marine waters (74 FR 52300). For freshwater riverine systems, the specific PCEs for species conservation are (1) food resources, (2) substrate type or size, (3) water flow, (4) water quality, (5) migratory corridor, (6) water depth, and (7) sediment quality. For estuarine areas, the specific PCEs for species conservation are (1) food resources, (2) water flow, (3) water quality, (4) migratory corridor, (5) water depth, and (6) sediment quality. For coastal marine areas, the specific PCEs for species conservation are (1) migratory corridor, (2) water quality, and (3) food resources.

From analyses of the identified PCEs and examination of economic activities, NMFS verified that at least one activity in each specific area may threaten at least one PCE such that special management considerations or protection may be required (NMFS 2009). Major categories of habitat-related activities include: (1) dams, (2) water diversions, (3) dredging and disposal of dredged material, (4) in-water construction or alterations, (5) National Pollutant Discharge Elimination System (NPDES) activities and activities generating non-point source pollution, (6) power plants, (7) commercial shipping, (8) aquaculture, (9) desalination plants, (10) proposed alternative energy hydrokinetic projects, (11) Liquefied Natural Gas (LNG) projects, (12) habitat restoration, and (13) bottom trawl fisheries.

2.2.3.6 Puget Sound/Georgia Basin Bocaccio and Yelloweye Rockfish

Critical habitat was designated for PS/GB bocaccio and yelloweye rockfish on November 13, 2014, when NMFS published a final rule in the *Federal Register* (79 FR 68042). The critical habitat in the U.S. is spread amongst five interconnected, biogeographic basins (San Juan/Strait of Juan de Fuca basin, Main basin, Whidbey basin, South Puget Sound, and Hood Canal) based upon presence and distribution of adult and juvenile rockfish, geographic conditions, and habitat features.

NMFS has designated 590.4 sq. miles (1,529 sq. km.) of nearshore habitat in Puget Sound, Washington as PS/GB bocaccio critical habitat. Nearshore critical habitat consists of underwater substrates such as sand, rock, and/or cobble compositions from extreme high water out to 30m deep (the limit of the photic zone in Puget Sound). This critical habitat supports kelp, enables forage opportunities and refuge from predators, and enables behavioral and physiological changes needed for juveniles to occupy deeper adult habitats. These nearshore habitats need to provide: (1) quantity, quality, and availability of prey species to support individual growth, survival, reproduction, and feeding opportunities and (2) water quality and sufficient levels of dissolved oxygen to support growth, survival, reproduction, and feeding opportunities.

Further, NMFS has designated 414.1 sq. miles (1,072.5 sq. km.) of deepwater habitat in Puget Sound, Washington as PS/GB bocaccio and PS/GB yelloweye critical habitat. Deepwater critical habitat consists of benthic habitats or sites deeper than 30m that possess or are adjacent to areas of complex bathymetry consisting of rock and/or highly rugose habitat. This habitat is essential to conservation because these features support growth, survival, reproduction, and feeding opportunities by providing the structure for rockfish to avoid predation, seek food, and persist for decades. These deepwater habitats need to provide: (1) quantity, quality, and availability of prey species to support individual growth, survival, reproduction, and feeding opportunities; (2) water quality and sufficient levels of dissolved oxygen to support growth, survival, reproduction, and feeding opportunities; and (3) the type and amount of structure and rugosity that supports feeding opportunities and predator avoidance.

As part of the designation process, NMFS evaluated the current status of the habitat and identified threats to habitat health. The assessment of habitat quality and identification of habitat threats is available on our website at http://www.westcoast.fisheries.noaa.gov/protected_species/rockfish/critical_habitat_info.html. Benthic habitat degradation within these waters is a threat to listed rockfish and includes derelict fishing gear, eelgrass and kelp loss, non-native species introduction, and water quality degradation.

Derelict fishing gear is considered a threat (75 FR 22276) with up to 117,000 derelict nets and pots estimated to lie beneath the waters of Puget Sound (WDFW, unpublished data). As of June 30, 2015, the Northwest Straits Initiative had removed 5,667 derelict fishing nets, 3,634 derelict crab pots, and 58 derelict shrimp pots from Puget Sound with over 460,000 animals found entangled in the derelict gear from waters less than 32 m deep (105 ft.) (data from www.derelictgear.org). Sixty-two fish species have been identified entangled in derelict nets including canary rockfish, Chinook salmon, and chum salmon (data from www.derelictgear.org). Most derelict gillnets were recovered from high-relief habitats featuring rocky ledges and boulders (Drake et al. 2010) which are habitats frequently used by subadult and adult rockfish (Love et al. 2002). Some derelict nets have a tendency to remain stretched open with piles of bones beneath the nets suggesting that entanglement and mortality rates may not decline to negligible rates (Drake et al. 2010). Gilardi et al. (2010) estimated from their Puget Sound study of derelict gillnets that 0.275 fish become entangled daily per net with a mean decomposition rate of 16.8 days and a mean drop-out rate of 31.6% during net recovery.

Kelp coverage is highly variable and has shown long-term declines in some regions, though some kelp beds have increased in areas where artificial substrate provides additional kelp habitat (Palsson et al. 2009). Kelp and eelgrass are stressed by light availability (e.g. turbidity), nutrient levels (e.g. water stratification, eutrophication), toxics (e.g. oil, metals, sulfides), and physical disturbance (e.g. propellers, boat wake) (Mumford 2007). Kelp and eelgrass habitats are important for larval and young juvenile rockfish (Love et al. 2002).

Non-indigenous species are an emerging threat to the native Puget Sound biotic habitat. *Sargassum muiticum*, an introduced brown algae common throughout much of Puget Sound, is a competitor of kelp and eelgrass (Mumford 2007). Several nonindigenous tunicate species, primitive marine animals with firm, flexible bodies enclosed in tough outer coverings, have been identified in Puget Sound. For example, the sea squirt, *Ciona savignyi*, originally found in one location in 2004 has spread to 86% of Hood Canal survey sites within two years (Puget Sound Action Team 2007). Invasive tunicates impacts on rockfish or their habitats is unknown, but results from other regions (e.g., Levin et al. 2002) suggest the potential for widespread impacts on rocky-reef fish populations.

Low dissolved oxygen levels have been an increasing concern. Since the mid-1990s, Hood Canal has seen persistent and increasing areas of low dissolved oxygen with recent fish kill events occurring in 2002, 2003, 2004, 2006, and 2010 (Newton et al. 2012). Typically, rockfish move out of areas with dissolved oxygen less than 2 mg/l; however, when low dissolved oxygen waters were quickly upwelled to the surface in 2003, about 26% of the rockfish population was killed (Palsson et al. 2009). In addition to Hood Canal, Palsson et al. (2009) reported those periods of low dissolved oxygen are becoming more widespread in waters south of Tacoma Narrows.

2.3 Action Area

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

In all cases, the proposed research activities would take place in individually very small sites. For example, the researchers might electrofish a few hundred feet of river, deploy a beach seine covering only a few hundred square feet of stream, or operate a screw trap in a few tens of square feet of habitat. Many of all the proposed actions would take place in designated critical habitat. More detailed habitat information (i.e., migration barriers, physical and biological habitat features, and special management considerations) for species considered in this opinion may be found in the Federal Register notices designating critical habitat for HCS chum salmon and PS Chinook salmon (70 FR 52630), S green sturgeon (74 FR 52300), S eulachon (76 FR 65324), PS/GB bocaccio and PS/GB yelloweye rockfish (79 FR 68042), and PS steelhead (81 FR 9252).

2.4 Environmental Baseline

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

2.4.1 Summary for all Listed Species

2.4.1.1 Factors Limiting Recovery

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

Table 21 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 21. Major factors limiting recovery.

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

For detailed information on how various factors have degraded PBFs, please see any of the following: Busby et al. 1996, Good et al. 2005, Moyle et al. 2008, Drake et al. 2010, Gustafson et al. 2010, Ford 2011, NMFS 2016, NWFSC 2016, and sections 2.2.3.1-2.2.3.6.

Research Effects

Although not identified as a factor for decline or a threat preventing recovery, scientific research and monitoring activities have the potential to affect the species' survival and recovery by killing listed salmonids—whether intentionally or not. For the year 2017, NMFS has issued numerous research section 10(a)(1)(A) scientific research permits allowing lethal and non-lethal take of listed species, along with the state scientific research programs under ESA section 4(d) and tribal 4(d) research. Table 22 displays the total take for the ongoing research authorized under ESA sections 4(d) and 10(a)(1)(A).

Table 22. Take allotments for research on listed species in 2017.

Species	Life Stage	Origin[a]	Total Take	Percent of Abundance	Lethal Take	Percent of ESU/DPS killed
PS Chinook salmon[b]	Adult	LHAC	1,680	19.69216%	86	0.80133%
		LHIA	802		15	
		Natural	873	4.63228%	33	0.17510%
	Juvenile	LHAC	145,454	0.40295%	11,166	0.03093%
		LHIA	158,614	2.63603%	5,164	0.08582%
		Natural	449,302	17.85779%	8,691	0.34543%
HCS chum salmon	Adult	LHIA	0	0.00000%	0	0.00000%
		Natural	2,011	7.87331%	29	0.11354%
	Juvenile	LHIA	135	0.09000%	3	0.00200%
		Natural	706,572	17.59911%	2,847	0.07091%
PS steelhead[c]	Adult	LHAC	32	9.15813%	4	0.19171%
		LHIA	11		0	
		Natural	1,629		31	
	Juvenile	LHAC	4,828	8.01594%	107	0.17765%
		LHIA	751	0.66167%	12	0.01057%
		Natural	61,016	2.93807%	1,177	0.05668%
S eulachon[d]	Adult	Natural	35,588	0.03950%	32,493	0.03601%
	Juvenile	Natural	55		6	
S green sturgeon	Adult	Natural	70	5.19288%	0	0.00000%
PS/GB bocaccio[d]	Adult	Natural	12	1.08554%	7	0.19540%
	Juvenile	Natural	38		2	
PS/GB yelloweye rockfish[d]	Adult	Natural	65	0.25313%	28	0.07383%
	Juvenile	Natural	55		7	

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

[b] Abundances for adult hatchery PS Chinook are LHAC and LHIA combined.

[c] Abundances for all adult PS steelhead are combined

[d] Abundances for juvenile listed rockfish and eulachon are unknown; all take and mortalities will be analyzed as adults

Actual take levels associated with these activities are almost certain to be a good deal lower than the allowed levels. There are several reasons for this. First, the juvenile abundance estimates are deliberately designed to generate a conservative picture of abundance. Second, it is important to remember that estimates of lethal take for most of the proposed studies are purposefully inflated to account for potential accidental deaths and it is therefore very likely that fewer juveniles would be killed by the research than stated. In fact, for the vast majority of scientific research permits, history has shown that researchers generally take far fewer salmonids than the allotted number of salmonids every year (14.19% of requested take and 12.31% of requested mortalities were used in ID, OR, and WA Section 10a1A permits from 2008 to 2016). 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 eighth 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, eulachon, green sturgeon, or rockfish. 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 18ºC or dissolved oxygen is below saturation. Fish that are transferred to holding tanks can experience trauma if care is not taken in the transfer process, and fish can experience stress and injury from overcrowding in traps if the traps are not emptied regularly. Decreased survival of fish can result when stress levels are high because stress can be immediately debilitating and may also increase the potential for vulnerability to subsequent challenges (Sharpe et al. 1998). Debris buildup at traps can also kill or injure fish if the traps are not monitored and cleared regularly. The 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) will be followed in all electrofishing surveys. The guidelines require that field crews be trained in observing animals for signs of stress and shown how to adjust electrofishing equipment to minimize that stress. All areas are visually searched for fish before electrofishing may begin. Electrofishing is not done in the vicinity of redds or spawning adults. All electrofishing equipment operators are trained by qualified personnel to be familiar with equipment handling, settings, maintenance, and safety. Operators work in pairs to increase both the number of fish that may be seen and the ability to identify individual fish without having to net them. Working in pairs also allows the researcher to net fish before they are subjected to higher electrical fields. Only DC units are used, and the equipment is regularly maintained to ensure proper operating condition. Voltage, pulse width, and rate are kept at minimal levels and water conductivity is tested at the start of every electrofishing session so those minimal levels can be determined. Due to the low settings used, shocked fish normally revive instantaneously. Fish requiring revivification receive immediate, adequate care. In all cases, electrofishing is used only when other survey methods are not feasible.

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

External Tagging (Floy tags)

Fish can be externally tagged with floy tags. Floy tags provide an opportunity for a fish to be marked uniquely as individuals by using a polyolefin (plastic) tag that is designed to last the lifetime of the fish. In rockfish, floy tags are attached in the dorsal musculature between the pterygiophores (Dell 1968, Stanley et al. 1994, Rikardsen et al. 2002).

Mathews and Barker (1983) studied the impacts of floy tags upon rockfish. From 1975 to 1977, 700 rockfish were captured and floy tagged with all of them returned to the water except for 10 rockfish. These 10 rockfish were retained for up to two years with four dying before the end of the study and the other six sacrificed. All of the rockfish retained their tags and showed no necrosis at the tag insertion points upon examination. Of the 700 tagged and returned rockfish, 41 were recaptured in recreational and commercial fisheries up to six years after being tagged (Mathews and Barker 1983).

Gastric Lavage

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

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

Hook and Line

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

The available information assessing hook and release mortality of adult steelhead suggests that hook and release mortality is low. Hooton (1987) found catch and release mortality of adult winter steelhead to average 3.4% (127 mortalities of 3,715 steelhead caught) when using barbed and barbless hooks, bait, and artificial lures. Among 336 steelhead captured on various combinations of popular terminal gear in the Keogh River, the mortality of the combined sample was 5.1%. Natural bait had slightly higher mortality (5.6%) than did artificial lures (3.8%), and barbed hooks (7.3%) had higher mortality than barbless hooks (2.9%). Hooton (1987) concluded that catching and releasing adult steelhead was an effective mechanism for maintaining angling opportunity without negatively impacting stock recruitment. Reingold (1975) showed that adult steelhead hooked, played to exhaustion, and then released returned to their target spawning stream at the same rate as steelhead not hooked and played to exhaustion. Pettit (1977) found that egg viability of hatchery steelhead was not negatively affected by catch-and-release of pre-spawning adult female steelhead. Bruesewitz (1995) found, on average, fewer than 13% of harvested summer and winter steelhead in Washington streams were hooked in critical areas (tongue, esophagus, gills, eye). The highest percentage (17.8%) of critical area hookings occurred when using bait and treble hooks in winter steelhead fisheries.

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

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

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

Only a few reports are available that provide empirical evidence showing what the catch and release mortality is for Chinook salmon in freshwater. The ODFW has conducted studies of hooking mortality incidental to the recreational fishery for Chinook salmon in the Willamette River. A study of the recreational fishery estimates a per-capture hook-and-release mortality for wild spring Chinook in Willamette River fisheries of 8.6% (Schroeder et al. 2000), which is similar to a mortality of 7.6% reported by Bendock and Alexandersdottir (1993) in the Kenai River, Alaska.

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

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

Rockfish barotrauma

Fish have two different types of swim bladders: physotome (open swim bladder) and physoclist (closed swim bladder). Physostome fish (such as salmonids) have a swim bladder connected to the esophagus via the pneumatic duct that allows them to gulp air to fill their swim bladder or quickly release the air when necessary. Physoclist fish (such as rockfish) lack the duct connection to the esophagus (Hallacher 1974) and are dependent upon passive gas exchange through their blood in the rete mirabile within their swim bladders (Alexander 1966). This allows them to become buoyant at much deeper depths than physotome fish, but they are unable to offload gases quickly during a rapid ascent.

During rapid decompression, swim bladder gases expand exponentially which is further exacerbated by temperature increases. This results in swim bladder expansion; reduction in body cavity space; and displacement, eversion, and/or injury to the heart, kidneys, stomach, liver, and other internal organs (Rogers et al. 2008, Pribyl et al. 2009, Pribyl et al. 2011). Further, expanding gas can rupture and escape from the swim bladder filling the orbital space behind the eyes, stretching the optic nerve, and causing exophthalmia (Rogers et al. 2008). Once on the surface, rockfish can become positively buoyant, meaning they are unable to return to their previous water depth become susceptible to predation (Starr et al. 2002, Hannah et al. 2008, Jarvis and Lowe 2008).

Methods for reducing barotrauma impacts on rockfish include handling rockfish below the surface, decreasing handling time at the surface, and rapidly submerging them to their capture depth (Parker et al. 2006, Hannah and Matteson 2007, Hannah et al. 2008). Hannah et al. (2008) observed that rockfish that failed to submerge either (1) did not attempt to submerge or only made weak attempts to do so, or (2) vigorously attempted to submerge and failed, leading to his conclusion that buoyancy is not the sole cause of submergence failure. Starr et al. (2002) captured rockfish and brought them up to 20m below the surface (below the local thermocline) where divers surgically implanted sonic tags in rockfish, placed them in a recovery cage, and released them. Because they observed no mortalities or abnormal swimming when these methods were employed, Starr et al. (2002) deduced that reducing surface handling time appears to improve survivorship. Jarvis and Lowe (2008) noted a 78% survivorship rate after recompression for rockfish released within 10 minutes of landing, which increased to 83% when the fish were released within 2 minutes. Another method for increasing survival for captured rockfish involves rapidly submerging the rockfish after capture and handling. Though the rockfish do not avoid effects of barotrauma when handled in this manner, the immediate impacts of decompression will stop when they are returned to their capture depth. Hochhalter and Reed (2011) compared submergence success of yelloweye rockfish released at the surface and at depth in a mark-recapture study. Though 91% of the individuals showed external signs of barotrauma after capture, the 17-day survival rate was 98.8% after resubmergence, though survival was size-dependent. Yelloweye rockfish released at the surface successfully submerged only 22.1% of the time and had an unknown survivorship rate. In a different study, Hannah and Matteson (2007) researched nine different rockfish different species from six different sites off the Oregon coast. After being captured, rockfish were briefly handled (less than two minutes), placed in a release cage with a video camera, and returned to capture depth/neutral buoyancy. Release behavior was visually observed and scored for behavioral impairment. The behavioral effects of barotrauma appeared to be highly species-specific (probably due to anatomical differences among rockfish species) and health condition at the surface did not appear to be a good indicator of survivorship potential after recompression. In addition, barotrauma effects increase with capture depth.

Tissue Sampling / Marking

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

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

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

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

2.5.2 Species-specific Effects of Each Permit

In previous sections, we estimated the annual abundance of adult and juvenile listed salmonids, eulachon, green sturgeon, and rockfish. 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 effect at the species level. Table 23 displays the estimated annual abundance of the listed species.

Table 23. Estimated annual abundance of ESA listed fish.

Species	Origin[a]	Abundance	
		Adult	Juvenile
PS Chinook salmon	LHAC	12,604[b]	36,097,500
	LHIA		6,017,150
	Natural	18,846	2,516,000
HCS chum salmon	LHIA	1,910	150,000
	Natural	25,542	4,014,817
PS steelhead	LHAC	18,257[c]	60,230
	LHIA		113,500
	Natural		2,076,734
S eulachon[d]	Natural	90,237,877	-
S green sturgeon[d]	Natural	1,348	-
PS/GB bocaccio[d]	Natural	4,606	-
PS/GB yelloweye rockfish[d]	Natural	47,407	-

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

[b] Abundances for adult hatchery salmonids are LHAC and LHIA combined.

[c] Abundances for all adult PS steelhead are combined

[d] Abundances for juvenile listed rockfish, green sturgeon, and eulachon are unknown

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 15848-2R

As noted previously, issuing permit 15848-2R would authorize the WDFW to renew an existing permit that currently authorizes them to take listed adult and juvenile PS Chinook salmon, HCS chum salmon, PS steelhead, S eulachon, PS/GB bocaccio, and PS/GB yelloweye rockfish and adult S green sturgeon in the Puget Sound (Washington State). Using bottom trawls, the researchers would capture, handle, and release fish. Up to six listed natural-origin salmonids, nine listed rockfish, and 400 listed eulachon may die as a result of the research. The requested take is laid out in Table 24.

Table 24. Proposed take under permit 15848-2R.

ESU/DPS	Life Stage	Origin	Take Action	Requested Take	Requested Mortality
PS Chinook	Adult	LHAC	C/H/R	10	2/10
PS Chinook	Adult	Natural	C/H/R	5	1/5
PS Chinook	Juvenile	LHAC	C/H/R	10	2/10
PS Chinook	Juvenile	Natural	C/H/R	5	1/5

ESU/DPS	Life Stage	Origin	Take Action	Requested Take	Requested Mortality
HCS chum	Adult	Natural	C/H/R	2	1/2
HCS chum	Juvenile	Natural	C/H/R	3	1/3
PS steelhead	Adult	LHAC	C/H/R	2	1/2
PS steelhead	Adult	Natural	C/H/R	3	1/3
PS steelhead	Juvenile	LHAC	C/H/R	2	1/2
PS steelhead	Juvenile	Natural	C/H/R	3	1/3
S eulachon	Adult	Natural	C/H/R	300	300/300
S eulachon	Juvenile	Natural	C/H/R	100	100/100
PS/GB bocaccio	Adult	Natural	C/H/R	5	2/5
PS/GB bocaccio	Juvenile	Natural	C/H/R	15	5/15
PS/GB yelloweye rockfish	Adult	Natural	C/H/R	2	1/2
PS/GB yelloweye rockfish	Juvenile	Natural	C/H/R	3	1/3
S green sturgeon	Adult	Natural	C/H/R	1	0/1

C/H/R – Capture/Handle/Release

The fish mortality rate is expected to range from none (green sturgeon) to moderate (salmon, steelhead, rockfish) to high (eulachon) dependent upon fish size and physiology. This study researches bottomfish abundance, distribution, and biology. To capture these species, this study uses a bottom trawl at great depths, which may result in sub-lethal and lethal effects upon incidentally captured listed fish. Green sturgeon mortalities are neither expected nor requested. Salmonids and eulachon are susceptible to descaling, crushing, and trawl net-related injuries resulting in lethal effects. Rockfish are extremely susceptible to barotrauma, thus a moderate mortality rate is expected. To combat barotrauma, rockfish would be returned to the water via rapid submersion to their capture depths. The true effects of the proposed action are best seen in the context of the fish that are likely to be killed. To determine the effects of these losses, 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 the juvenile and adult abundances (Table 25).

Table 25. Comparison of possible lethal take to annual abundance at the ESU/DPS scale for Permit 15848-2R.

ESU/DPS	Life Stage	Origin	Percent of ESU/DPS
PS Chinook	Adult	LHAC	0.0159%
PS Chinook	Adult	Natural	0.0053%
PS Chinook	Juvenile	LHAC	<0.0001%
PS Chinook	Juvenile	Natural	<0.0001%
HCS chum	Adult	Natural	0.0039%
HCS chum	Juvenile	Natural	<0.0001%
PS steelhead	Adult	LHAC/Natural	0.0110%
PS steelhead	Juvenile	LHAC	0.0017%
PS steelhead	Juvenile	Natural	<0.0001%

ESU/DPS	Life Stage	Origin	Percent of ESU/DPS
S eulachon[a]	Adult/Juvenile	Natural	0.0004%
PS/GB bocaccio[a]	Adult/Juvenile	Natural	0.1520%
PS/GB yelloweye rockfish[a]	Adult/Juvenile	Natural	0.0042%

[a] Juvenile abundances for this species is unknown; therefore, requested juvenile mortalities will be analyzed as adults.

Since take activities would occur throughout the Puget Sound region where all populations could be present, the effect of that take cannot be examined at the population level. At the ESU/DPS levels, the permitted activities may kill at most 0.1520% of any natural-origin listed component (PS/GB bocaccio). Overall, 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. For this project over the past five years (2012-2016), only 5.99% of the requested take (136 of 2,270) and 6.27% of the requested mortalities (136 of 2,170) occurred. Take and mortality of one juvenile PS/GB yelloweye rockfish occurred while no take of PS/GB bocaccio or any listed salmonids occurred.

An effect of the research that cannot be quantified is the conservation benefit to the species resulting from the research. The purpose of this research is to estimate the relative numerical and biomass abundance of bottomfish in Puget Sound and collect information on the distribution and biology of key marine vertebrate and invertebrate resources. The research would benefit the affected species by providing the WDFW with information on encounter rates and species distributions, which can be used by fisheries managers to promulgate effective regulations to protect and promote the recovery of listed species and to properly manage non-listed fishery resources.

Permit 15890-2R

As noted previously, issuing permit 15890-2R would authorize the WDFW to renew an existing permit that currently authorizes them to take listed adult and juvenile PS Chinook salmon, HCS chum salmon, PS steelhead, S eulachon, PS/GB bocaccio, and PS/GB yelloweye rockfish in the Puget Sound (Washington State). Using midwater trawls, the researchers would capture, handle, measure, sample fins and scales (salmonids and rockfish only), and release fish. Up to 16 listed natural-origin salmonids, four listed rockfish, and 350 listed eulachon may die as a result of the research. The requested take is laid out in Table 26.

Table 26. Proposed take under permit 15890-2R.

ESU/DPS	Life Stage	Origin	Take Action	Requested Take	Requested Mortality
PS Chinook salmon	Adult	LHAC	C/M,T,S/R	5	1/5
PS Chinook salmon	Adult	Natural	C/M,T,S/R	5	1/5
PS Chinook salmon	Juvenile	LHAC	C/M,T,S/R	100	25/100
PS Chinook salmon	Juvenile	Natural	C/M,T,S/R	50	5/50
HCS chum salmon	Adult	Natural	C/M,T,S/R	5	1/5
HCS chum salmon	Juvenile	Natural	C/M,T,S/R	50	5/50

ESU/DPS	Life Stage	Origin	Take Action	Requested Take	Requested Mortality
PS steelhead	Adult	LHAC	C/M,T,S/R	1	0/1
PS steelhead	Adult	Natural	C/M,T,S/R	1	0/1
PS steelhead	Juvenile	LHAC	C/M,T,S/R	10	2/10
PS steelhead	Juvenile	Natural	C/M,T,S/R	10	2/10
S eulachon	Adult	Natural	C/H/R	200	200/200
S eulachon	Juvenile	Natural	C/H/R	150	150/150
PS/GB bocaccio	Adult	Natural	C/M,T,S/R	1	1/1
PS/GB bocaccio	Juvenile	Natural	C/M,T,S/R	1	1/1
PS/GB yelloweye rockfish	Adult	Natural	C/M,T,S/R	1	1/1
PS/GB yelloweye rockfish	Juvenile	Natural	C/M,T,S/R	1	1/1

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

The fish mortality rate is expected to range from moderate (salmon and steelhead) to high (eulachon and rockfish) dependent upon fish size and physiology. This study researches pelagic fish species demographics. To capture these species, this study uses a mid-water trawl, which may result in sub-lethal and lethal effects upon incidentally captured listed fish. Salmonids and eulachon are susceptible to descaling, crushing, and trawl net-related injuries resulting in lethal effects. Rockfish are extremely susceptible to barotrauma, thus a high mortality rate is expected. To combat barotrauma, rockfish would be returned to the water via rapid submersion to their capture depths. The true effects of the proposed action are best seen in the context of the fish that are likely to be killed. To determine the effects of these losses, 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 the juvenile and adult abundances (Table 27).

Table 27. Comparison of possible lethal take to annual abundance at ESU/DPS scale for Permit 15890-2R.

ESU/DPS	Life Stage	Origin	Percent of ESU/DPS
PS Chinook	Adult	LHAC	0.0079%
PS Chinook	Adult	Natural	0.0053%
PS Chinook	Juvenile	LHAC	<0.0001%
PS Chinook	Juvenile	Natural	0.0002%
HCS chum	Adult	Natural	0.0039%
HCS chum	Juvenile	Natural	0.0001%
PS steelhead	Juvenile	LHAC	0.0033%
PS steelhead	Juvenile	Natural	<0.0001%
S eulachon[a]	Adult/Juvenile	Natural	0.0004%
PS/GB bocaccio[a]	Adult/Juvenile	Natural	0.0434%
PS/GB yelloweye rockfish[a]	Adult/Juvenile	Natural	0.0042%

[a] Juvenile abundances for this species is unknown; therefore, requested juvenile mortalities will be analyzed as adults.

Since take activities would occur throughout the Puget Sound region where all populations could be present, the effect of that take cannot be examined at the population level. At the ESU/DPS levels, the permitted activities may kill at most 0.0434% of any listed component (PS/GB bocaccio). 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. For this project over the past five years (2012-2016), only 5.25% of the requested take (31 of 590) and 7.50% of the requested mortalities (30 of 400 requested mortalities) occurred. No take or mortality of any listed rockfish or salmonids occurred.

An effect of the research that cannot be quantified is the conservation benefit to the species resulting from the research. The purpose of this study is to estimate abundance and determine other important demographic information for pelagic forage fish in key areas of Puget Sound, thus providing a comparison of stock abundance over time and demographic information about the populations including growth, mortality, and recruitment. The research would benefit both listed and non-listed species by monitoring their relative abundance in Puget Sound and obtaining information on the spatial and temporal locations of all pelagic species in the region.

Permit 16021-2R

As noted previously, issuing permit 16021-2R would authorize the WDFW to renew an existing permit that currently authorizes them to take listed adult and juvenile PS Chinook salmon, PS/GB bocaccio, and PS/GB yelloweye rockfish and adult S eulachon and S green sturgeon in the Puget Sound (Washington State). Using hook and line and live capture traps, the researchers would collect, handle, measure, fin clip (rockfish only), floy tag (rockfish only), and release fish. Up to two listed, natural-origin PS Chinook; 10 listed eulachon; and four listed rockfish may die as a result of the research. The requested take is laid out in Table 28.

Table 28. Proposed take under permit 16021-2R.

ESU/DPS	Life Stage	Origin	Take Action	Requested Take	Requested Mortality
PS Chinook salmon	Adult	LHAC	C/H/R	5	1/5
PS Chinook salmon	Adult	Natural	C/H/R	5	1/5
PS Chinook salmon	Juvenile	LHAC	C/H/R	5	1/5
PS Chinook salmon	Juvenile	Natural	C/H/R	5	1/5
S eulachon	Adult	Natural	C/H/R	10	10/10
PS/GB bocaccio	Adult	Natural	C/M,T,S/R	1	1/1
PS/GB bocaccio	Juvenile	Natural	C/M,T,S/R	1	1/1
PS/GB yelloweye rockfish	Adult	Natural	C/M,T,S/R	1	1/1
PS/GB yelloweye rockfish	Juvenile	Natural	C/M,T,S/R	1	1/1
S green sturgeon	Adult	Natural	C/H/R	1	0/1

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

The fish mortality rate is expected to range from none (green sturgeon) to moderate (salmon) to high (eulachon and rockfish) dependent upon fish size and physiology. This study researches groundfish stock structure, life history, biology, geographic distribution, habitat use, and food web relationships. To capture these species, this study uses hook and line at great depths, which may result in sub-lethal and lethal effects upon incidentally captured listed fish. Green sturgeon mortalities are neither expected nor requested. For salmonids and eulachon, capture depth may result in a higher than normal mortality rate. Rockfish are extremely susceptible to barotrauma, thus a high mortality rate is expected. To combat barotrauma, rockfish would be returned to the water via rapid submersion to their capture depths. The true effects of the proposed action are best seen in the context of the fish that are likely to be killed. To determine the effects of these losses, 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 the juvenile and adult abundances (Table 29).

Table 29. Comparison of possible lethal take to annual abundance at the ESU/DPS scale for Permit 16021-2R.

ESU/DPS	Life Stage	Origin	Percent of ESU/DPS
PS Chinook salmon	Adult	LHAC	0.0079%
PS Chinook salmon	Adult	Natural	0.0053%
PS Chinook salmon	Juvenile	LHAC	<0.0001%
PS Chinook salmon	Juvenile	Natural	<0.0001%
S eulachon[a]	Adult/Juvenile	Natural	<0.0001%
PS/GB bocaccio[a]	Adult/Juvenile	Natural	0.0434%
PS/GB yelloweye rockfish[a]	Adult/Juvenile	Natural	0.0042%

[a] Juvenile abundances for this species is unknown; therefore, requested juvenile mortalities will be analyzed as adults.

Since take activities would occur throughout the Puget Sound region where all populations could be present, the effect of that take cannot be examined at the population level. At the ESU/DPS level, the permitted activities may kill at most 0.0434% of any natural-origin listed component (PS/GB bocaccio). Overall, 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. For this project over the past five years (2012-2016), only 5.00% of the requested take (5 of 100; four juvenile and one adult PS Chinook) and none of the requested mortalities (0 of 50 requested mortalities) occurred.

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 improve the understanding of groundfish stock structure, life history, biology, geographic distribution, habitat use, and food web relationships. The research would benefit the affected species by providing data critical for population modeling, leading to improved management of Puget Sound groundfish resources.

Permit 16091-2R

As noted previously, issuing permit 16091-2R would authorize the WDFW to renew an existing permit that currently authorizes them to take listed adult and juvenile PS Chinook salmon, HCS chum salmon, PS steelhead, S eulachon, PS/GB bocaccio, and PS/GB yelloweye rockfish and adult S green sturgeon in the Puget Sound (Washington State). Using bottom trawls, the researchers would capture, handle, and release fish. Up to 18 listed, natural-origin juvenile salmonids, 160 listed eulachon, and 20 listed rockfish may die as a result of the research. The requested take is laid out in Table 30.

Table 30. Proposed take under permit 16091-2R.

ESU/DPS	Life Stage	Origin	Take Action	Requested Take	Requested Mortality
PS Chinook	Adult	LHAC	C/H/R	6	2/6
PS Chinook	Adult	Natural	C/H/R	6	2/6
PS Chinook	Juvenile	LHAC	C/H/R	200	50/200
PS Chinook	Juvenile	Natural	C/H/R	50	12/50
HCS chum	Adult	Natural	C/H/R	1	1/1
HCS chum	Juvenile	Natural	C/H/R	1	1/1
PS steelhead	Adult	LHAC	C/H/R	1	1/1
PS steelhead	Adult	Natural	C/H/R	1	1/1
PS steelhead	Juvenile	LHAC	C/H/R	1	1/1
PS steelhead	Juvenile	Natural	C/H/R	1	1/1
S eulachon	Adult	Natural	C/H/R	60	60/60
S eulachon	Juvenile	Natural	C/H/R	100	100/100
PS/GB bocaccio	Adult	Natural	C/H/R	5	5/5
PS/GB bocaccio	Juvenile	Natural	C/H/R	5	5/5
PS/GB yelloweye rockfish	Adult	Natural	C/H/R	5	5/5
PS/GB yelloweye rockfish	Juvenile	Natural	C/H/R	5	5/5
S green sturgeon	Adult	Natural	C/H/R	1	0/1

C/H/R – Capture/Handle/Release

The fish mortality rate is expected to range from none (green sturgeon) to moderate (salmon, steelhead) to high (eulachon, rockfish) dependent upon fish size and physiology. This study researches bottomfish abundance, distribution, and biology. To capture these species, this study uses a bottom trawl at great depths, which may result in sub-lethal and lethal effects upon incidentally captured listed fish. Green sturgeon mortalities are neither expected nor requested. Salmonids and eulachon are susceptible to descaling, crushing, and trawl net-related injuries resulting in lethal effects. Rockfish are extremely susceptible to barotrauma, thus a high mortality rate is expected. To combat barotrauma, rockfish would be returned to the water via rapid submersion to their capture depths. The true effects of the proposed action are best seen in the context of the fish that are likely to be killed. To determine the effects of these losses, 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 the juvenile and adult abundances (Table 31).

Table 31. Comparison of possible lethal take to annual abundance at the ESU/DPS scale for Permit 16091-2R.

ESU/DPS	Life Stage	Origin	Percent of ESU/DPS
PS Chinook	Adult	LHAC	0.0159%
PS Chinook	Adult	Natural	0.0106%
PS Chinook	Juvenile	LHAC	0.0001%
PS Chinook	Juvenile	Natural	0.0005%
HCS chum	Adult	Natural	0.0039%
HCS chum	Juvenile	Natural	<0.0001%
PS steelhead	Adult	LHAC	0.0110%
PS steelhead	Adult	Natural	<0.0001%
PS steelhead	Juvenile	LHAC	0.0017%
PS steelhead	Juvenile	Natural	<0.0001%
S eulachon[a]	Adult/Juvenile	Natural	0.0002%
PS/GB bocaccio[a]	Adult/Juvenile	Natural	0.2171%
PS/GB yelloweye rockfish[a]	Adult/Juvenile	Natural	0.0211%

[a] Juvenile abundances for this species is unknown; therefore, requested juvenile mortalities will be analyzed as adults.

Since take activities would occur throughout the Puget Sound region where all populations could be present, the effect of that take cannot be examined at the population level. At the ESU/DPS levels, the permitted activities may kill at most 0.2171% of any natural-origin listed component (PS/GB bocaccio). 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. For this project over the past five years (2012-2016), only 0.56% of the requested take (6 of 1,075; all eulachon) and 0.51% of the requested mortalities (5 of 985 requested mortalities; all eulachon) occurred.

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 capture English sole throughout the Salish Sea to monitor tissue levels of toxic chemical contaminants, frequency of pathological disorders, and biomarkers signifying biological effects. The research would benefit the listed species as well as the target species is better understanding of toxic contaminant impacts on the benthic food web, measuring changes in toxic contaminant levels on a local level, and the potential to prioritize cleanup efforts to maximize advances towards the recovery and protection of Puget Sound.

Permit 20535-2M

As noted previously, issuing permit 20535-2M would authorize the USACE to modify an existing permit that currently authorizes them to take juvenile PS Chinook salmon and PS steelhead and adult S eulachon in the lower Duwamish River (King County, Washington). The modification is necessary due to higher than expected juvenile PS Chinook salmon take and mortality at the study location. Besides an increase in take and mortality, alterations were made to the methods and timing to reduce possible interactions with PS Chinook. Using beach seines, the researchers would capture, handle, and release fish. For the modification, up to an additional five listed, natural-origin PS Chinook salmon may die as a result of the research. The requested additional take is laid out in Table 32.

Table 32. Proposed additional take under the modification request for Permit 20535-2M.

ESU/DPS	Life Stage	Origin	Take Action[b]	Original Permit[a] Issued Take	Original Permit[a] Issued Mortality	Modified Permit Requested Take	Modified Permit Requested Mortality	Analyzed for this opinion Take	Analyzed for this opinion Mortality
PS Chinook	Juvenile	LHAC	C/H/R	30	1/30	45	6/45	15	5/15
PS Chinook	Juvenile	Natural	C/H/R	30	1/30	45	6/45	15	5/15
PS steelhead	Juvenile	LHAC	C/H/R	30	1/30	30	1/30	-	-
PS steelhead	Juvenile	Natural	C/H/R	30	1/30	30	1/30	-	-
S eulachon	Adult	Natural	C/H/R	15	3/15	15	3/15	-	-

[a] From Consultation WCR/2016/5949

[b] C/H/R – Capture/Handle/Release

Because the majority of the fish that would be captured are expected to recover with no ill effects, the true effects of the proposed action are best seen in the context of the fish that are likely to be killed. To determine the effects of these losses, 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 33).

Table 33. Comparison of possible lethal take to annual abundance at the population (Duwamish sub-basin) and ESU/DPS scale in the modification request for Permit 20535-2M.

ESU	Life Stage	Origin	Percent of Population	Percent of ESU/DPS
PS Chinook salmon	Juvenile	LHAC	0.0002%	<0.0001%
PS Chinook salmon	Juvenile	Natural	0.0029%	0.0002%

At the population level, the permitted activities may kill at most 0.0029% of natural-origin listed PS Chinook salmon. At the ESU/DPS level, the permitted activities may kill at most 0.0002% of natural-origin listed PS Chinook salmon. Therefore, the research would be a very small impact on the species' abundance, a likely similar impact on their productivity, and no measureable effect on their spatial structure or diversity. Since approved research projects rarely use all of the take and mortalities authorized to them, 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 collect starry flounder, shiner surfperch, English sole, and Pacific staghorn sculpin for tissue sampling and PCB congener analysis. The research would benefit the listed species by enhancing the understanding of contaminant partitioning within the food web near the Lower Duwamish Waterway Superfund Site.

Permit 21061

As noted previously, issuing permit 21061 would authorize the WE to take listed juvenile and adult PS Chinook salmon and PS steelhead and juvenile PS/GB bocaccio and PS/GB yelloweye rockfish in the lower Duwamish River (King County, Washington). Using otter trawls and crab traps, the researchers would capture, handle, and release fish. Up to two listed, natural-origin juvenile salmonids (one PS Chinook salmon and one PS steelhead) may die as a result of the research. The requested take is laid out in Table 34.

Table 34. Proposed take under Permit 21061.

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	20	1/20
PS Chinook salmon	Juvenile	Natural	C/H/R	20	1/20
PS steelhead	Adult	LHAC	C/H/R	2	0/2
PS steelhead	Adult	Natural	C/H/R	2	0/2
PS steelhead	Juvenile	LHAC	C/H/R	20	1/20
PS steelhead	Juvenile	Natural	C/H/R	20	1/20
PS/GB bocaccio	Juvenile	Natural	C/H/R	1	0/1
PS/GB yelloweye rockfish	Juvenile	Natural	C/H/R	1	0/1

C/H/R – Capture/Handle/Release

Because the majority of the fish that would be captured are expected to recover with no ill effects, the true effects of the proposed action are best seen in the context of the fish that are likely to be killed. To determine the effects of these losses, 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 salmonid abundances (Table 35).

Table 35. Comparison of possible lethal take to annual abundance at the population (Duwamish sub-basin) and ESU/DPS scale for Permit 21061.

ESU	Life Stage	Origin	Percent of Population	Percent of ESU/DPS
PS Chinook salmon	Juvenile	LHAC	<0.0001%	<0.0001%
PS Chinook salmon	Juvenile	Natural	0.0006%	<0.0001%
PS steelhead	Juvenile	LHAC	0.0020%	0.0017%
PS steelhead	Juvenile	Natural	0.0009%	<0.0001%

At the population level, the permitted activities may kill at most 0.0009% of any natural-origin listed component (juvenile PS steelhead). At the ESU/DPS level, the permitted activities may kill at most less than 0.0001% of any natural-origin listed component. 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. Since approved research projects rarely use all of the take and mortalities authorized to them, 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 establish baseline tissue chemical concentrations for English sole, starry flounder, shiner surfperch, Dungeness crab, and graceful crab in the lower Duwamish River to assess the progress toward meeting the target tissue chemical concentrations identified in EPA's Record of Decision (ROD). The research would benefit the affected species by confirmation of contaminated areas and minimization of exposure to contaminated sediments through sediment remediation engineered to protect aquatic wildlife.

Permit 21185

As noted previously, issuing permit 21185 would authorize the WFC to take listed juvenile PS Chinook salmon and PS steelhead in the Deschutes River subbasin and Kitsap Peninsula (Washington State). Using backpack electrofishing, the researchers would capture, handle, fin clip (PS steelhead only), and release fish. Up to two listed, natural-origin juvenile PS steelhead may die as a result of the research. The requested take is laid out in Table 36.

Table 36. Proposed take under Permit 21185.

ESU	Life Stage	Origin	Take Action	Requested Take	Requested Mortality
PS Chinook salmon	Juvenile	Natural	C/H/R	7	0/7
PS steelhead	Juvenile	Natural	C/M,T,S/R	40	2/40

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 ill effects, the true effects of the proposed action are best seen in the context of the fish that are likely to be killed. To determine the effects of these losses, 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 salmonid abundances (Table 37).

Table 37. Comparison of possible lethal take to annual abundance at the population (Deschutes and Kitsap sub-basins) and ESU/DPS scale for Permit 21185.

ESU	Life Stage	Origin	Percent of Deschutes sub-basin Population[a]	Percent of Kitsap sub-basin Population[a]	Percent of ESU/DPS
PS steelhead	Juvenile	Natural	-	-	<0.0001%

[a] PS steelhead found in this sub-basin is not recognized as part of any steelhead population.

Any mortality at the authorized locations for this permit cannot be attributed to any specific PS steelhead population and, therefore, cannot be analyzed at the population level. At the DPS level, the permitted activities may kill at most less than 0.0001% of any natural-origin listed component. Overall, 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. Since approved research projects rarely use all of the take and mortalities authorized to them, 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 water type existing channel classifications in selected sub-basins and floodplain areas to validate and correct Washington Department of Natural Resources (WDNR) classifications. The research would benefit the listed species by filling data gaps regarding fish passage impediments (i.e., tidegates, culverts) and fish species composition and distribution – information needed to responsibly identify, prioritize, and implement effective and science-based restoration projects.

Permit 21330

As noted previously, issuing permit 21330 would authorize the FWS to take juvenile PS Chinook salmon and PS steelhead in Jim Creek (South Fork Stillaguamish River watershed; Snohomish County, Washington). 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 when recovered. Up to six listed, natural-origin juvenile salmonids (one PS Chinook and five PS steelhead) may die as a result of the research. The requested take is laid out in Table 38.

Table 38. Proposed take under Permit 21330.

ESU	Life Stage	Origin	Take Action	Requested Take	Requested Mortality
PS Chinook salmon	Juvenile	Natural	C/H/R	5	1/5
PS steelhead	Juvenile	Natural	C/H/R	250	5/250

C/H/R – Capture/Handle/Release

Because the majority of the fish that would be captured are expected to recover with no ill effects, the true effects of the proposed action are best seen in the context of the fish that are likely to be killed. To determine the effects of these losses, 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 percentage of juvenile listed salmonid abundances (Table 39).

Table 39. Comparison of possible lethal take to annual abundance at the population (Stillaguamish sub-basin) and ESU/DPS scale for Permit 21330.

ESU	Life Stage	Origin	Percent of Population	Percent of ESU/DPS
PS Chinook salmon	Juvenile	Natural	0.0162%	<0.0001%
PS steelhead	Juvenile	Natural	0.0092%	0.0002%

At the population level (Stillaguamish sub-basin), the permitted activities may kill at most 0.0162% of any natural-origin listed component (juvenile PS Chinook salmon). At the ESU/DPS level, the permitted activities may kill at most 0.0002% of any natural-origin listed component (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. Since approved research projects rarely use all of the take and mortalities authorized to them, 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 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, PS steelhead, and bull trout (*Salvelinus confluentus*).

2.5.3 Effects on Critical Habitat

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

2.6 Cumulative Effects

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

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

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

Because the action area falls within navigable waters, the vast majority of future actions in the region will undergo section 7 consultation with one or more of the Federal entities with regulatory jurisdiction over water quality, flood management, navigation, or hydroelectric generation. In almost all instances, proponents of future actions will need government funding or authorization to carry out a project that may affect salmon or its habitat; and therefore, the effects such a project may have on salmon and steelhead will be analyzed when the need arises.

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

Non-Federal actions are likely to continue affecting listed species. The cumulative effects in the action area are difficult to analyze because of this opinion's geographic scope, the different resource authorities in the action area, the uncertainties associated with government and private actions, and the changing economies of the region. Whether these effects will increase or decrease is a matter of speculation; however, based on the trends identified in the baseline, the adverse cumulative effects are likely to increase. From 1960 through 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 eight 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 40), (b) add the take proposed by the researchers in this opinion to the take that has already been authorized in the region (Table 41), and then (c) compare those totals to the estimated annual abundance of each species under consideration (Table 42).

Table 40. 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 Abundance	Lethal Take	Percent of ESU/DPS killed
PS Chinook salmon[b]	Adult	LHAC	28	0.22215%	6	0.04760%
		LHIA	0		0	
		Natural	23	0.12204%	5	0.02653%
	Juvenile	LHAC	380	0.00105%	85	0.00024%
		LHIA	0	0.00000%	0	0.00000%
		Natural	187	0.00743%	27	0.00107%
HCS chum salmon	Adult	LHIA	0	0.00000%	0	0.00000%
		Natural	8	0.03132%	3	0.01175%
	Juvenile	LHIA	0	0.00000%	0	0.00000%
		Natural	54	0.00135%	7	0.00017%
PS steelhead[c]	Adult	LHAC	6	0.07121%	2	0.02191%
		LHIA	0		0	
		Natural	7		2	
	Juvenile	LHAC	63	0.10460%	6	0.00996%
		LHIA	0	0.00000%	0	0.00000%
		Natural	354	0.01705%	13	0.00063%
S eulachon[d]	Adult	Natural	585	0.00104%	573	0.00102%
	Juvenile	Natural	350		350	
S green sturgeon	Adult	Natural	3	0.22255%	0	0.00000%
PS/GB bocaccio[d]	Adult	Natural	12	0.75988%	9	0.45593%
	Juvenile	Natural	23		12	
PS/GB yelloweye rockfish[d]	Adult	Natural	9	0.04219%	8	0.03375%
	Juvenile	Natural	11		8	

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

[b] Abundances for adult hatchery salmonids are LHAC and LHIA combined.

[c] Abundances for all adult PS steelhead are combined

[d] Abundances for juvenile listed rockfish and eulachon are unknown; all take and mortalities will be analyzed as adults

Table 41. Total expected take of the ESA listed species for scientific research and monitoring already approved for 2017.

Species	Life Stage	Origin[a]	Total Take	Percent of Abundance	Lethal Take	Percent of ESU/DPS killed
PS Chinook salmon[b]	Adult	LHAC	1,680	19.69216%	86	0.80133%
		LHIA	802		15	
		Natural	873	4.63228%	33	0.17510%
	Juvenile	LHAC	145,454	0.40295%	11,166	0.03093%
		LHIA	158,614	2.63603%	5,164	0.08582%
		Natural	449,302	17.85779%	8,691	0.34543%
HCS chum salmon	Adult	LHIA	0	0.00000%	0	0.00000%
		Natural	2,011	7.87331%	29	0.11354%
	Juvenile	LHIA	135	0.09000%	3	0.00200%
		Natural	706,572	17.59911%	2,847	0.07091%
PS steelhead[c]	Adult	LHAC	32	9.15813%	4	0.19171%
		LHIA	11		0	
		Natural	1,629		31	
	Juvenile	LHAC	4,828	8.01594%	107	0.17765%
		LHIA	751	0.66167%	12	0.01057%
		Natural	61,016	2.93807%	1,177	0.05668%
S eulachon[d]	Adult	Natural	35,588	0.03950%	32,493	0.03601%
	Juvenile	Natural	55		6	
S green sturgeon	Adult	Natural	70	5.19288%	0	0.00000%
PS/GB bocaccio[d]	Adult	Natural	12	1.08554%	7	0.19540%
	Juvenile	Natural	38		2	
PS/GB yelloweye rockfish[d]	Adult	Natural	65	0.25313%	28	0.07383%
	Juvenile	Natural	55		7	

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

[b] Abundances for adult hatchery salmonids are LHAC and LHIA combined.

[c] Abundances for all adult PS steelhead are combined

[d] Abundances for juvenile listed rockfish and eulachon are unknown; all take and mortalities will be analyzed as adults

Table 42. Total expected take of the ESA listed species for scientific research and monitoring already approved for 2017 plus the permits covered in this Biological Opinion.

Species	Life Stage	Origin[a]	Total Take	Percent of Abundance	Lethal Take	Percent of ESU/DPS killed
PS Chinook salmon[b]	Adult	LHAC	1,708	19.91431%	92	0.84894%
		LHIA	802		15	
		Natural	896	4.75432%	38	0.20163%
	Juvenile	LHAC	145,834	0.40400%	11,251	0.03117%
		LHIA	158,614	2.63603%	5,164	0.08582%
		Natural	449,489	17.86522%	8,718	0.34650%
HCS chum salmon	Adult	LHIA	0	0.00000%	0	0.00000%
		Natural	2,019	7.90463%	32	0.12528%
	Juvenile	LHIA	135	0.09000%	3	0.00200%
		Natural	706,626	17.60045%	2,854	0.07109%
PS steelhead[c]	Adult	LHAC	38	9.22934%	6	0.21362%
		LHIA	11		0	

Species	Life Stage	Origin[a]	Total Take	Percent of Abundance	Lethal Take	Percent of ESU/DPS killed
		Natural	1,636		33	
	Juvenile	LHAC	4,891	8.12054%	113	0.18761%
		LHIA	751	0.66167%	12	0.01057%
		Natural	61,370	2.95512%	1,190	0.05730%
S eulachon[d]	Adult	Natural	36,173	0.04054%	33,066	0.03704%
	Juvenile	Natural	405		356	
S green sturgeon	Adult	Natural	73	5.41543%	0	0.00000%
PS/GB bocaccio[d]	Adult	Natural	24	1.84542%	16	0.65132%
	Juvenile	Natural	61		14	
PS/GB yelloweye rockfish[d]	Adult	Natural	74	0.29532%	36	0.10758%
	Juvenile	Natural	66		15	

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

[b] Abundances for adult hatchery salmonids are LHAC and LHIA combined.

[c] Abundances for all adult PS steelhead are combined

[d] Abundances for juvenile listed rockfish and eulachon are unknown; all take and mortalities will be analyzed as adults

Salmonids

For juvenile salmonids, the total amount of estimated natural-origin, lethal take for the proposed research would be 27 PS Chinook salmon, 7 HCS chum salmon, and 13 PS steelhead. This is the maximum amount of lethal take contemplated in this biological opinion; if the various permits are granted and exercised, a lesser amount of take is expected to actually occur. Overall, these numbers represent very small fractions of the expected natural-origin abundances and may kill at most 0.0011% of any natural-origin listed component (PS Chinook salmon) (Table 40).

For adult salmonids, the total amount of estimated natural-origin, lethal take for the proposed research would be five PS Chinook salmon, three HCS chum salmon, and two PS steelhead. This is the maximum amount of lethal take contemplated in this biological opinion; if the various permits are granted and exercised, a lesser amount of take is expected to actually occur. Overall, this number represents a very small fraction of the expected natural-origin abundances and may kill at most 0.0265% of any natural-origin listed component (PS Chinook salmon) (Table 40).

When combined with scientific research and monitoring permits already approved (Section 10 (a)(1)(A) and state/tribal 4(d) permits) (Table 41), the total take and mortalities are low (Table 42). For example, approximately 17.87% of juvenile natural origin, PS Chinook salmon would be taken. However, and as noted previously, the majority of salmonids handled subsequently recover shortly after handling with no long-term ill effects. For natural-origin PS Chinook salmon juvenile take, only 1.94% of the requested take is authorized as lethal take (8,718 of 449,489); thus, we estimate that a maximum of 0.3465% of natural-origin PS Chinook salmon juvenile take for the ESU would be killed. And for the vast majority of scientific research permits, history has shown that researchers generally take far fewer salmonids than the allotted number of salmonids every year (14.19% of requested take and 12.31% of requested mortalities were used in ID, OR, and WA Section 10a1A permits from 2008 to 2016). Thus, the activities contemplated in this opinion would add only very small fractions to those already low numbers.

Thus, as Tables 40-42 demonstrate, all the mortalities, even taken together, represent very small fractions 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. First, the juvenile abundance estimates are deliberately designed to generate a conservative picture of abundance. Second, it is important to remember that estimates of lethal take for most of the proposed studies are purposefully inflated to account for potential accidental deaths; and it is, therefore, very likely that fewer juveniles would be killed by the research than stated. As mentioned in the previous paragraph, approximately one-seventh of the authorized take and one-eighth of the authorized mortalities has been used from 2008 through 2016. 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 eighth of the values given in the tables.

Rockfish, Eulachon, and Green Sturgeon

For listed rockfish, eulachon, and green sturgeon, all the mortalities, even taken together, represent very small fractions of the various species' abundances. Since no directed mortality is requested for any of these permits within this Opinion, it is important to remember that lethal take estimates exist only to account for potential accidental deaths.

For the listed PS/GB bocaccio and PS/GB yelloweye rockfish, the total amount of listed rockfish lethal take for the proposed research would be 17 adults (9 bocaccio and 8 yelloweye rockfish) and 20 juveniles (12 bocaccio and 8 yelloweye rockfish). Since there is no known juvenile abundance estimates for listed PS/GB rockfish species, all rockfish lifestages will be analyzed as adults (which will result in an overestimate of the impact to the species). This is the maximum amount of lethal take contemplated in this biological opinion. Overall, these numbers represent small fractions of the abundances for listed rockfish (0.4559% for bocaccio, 0.0338% for yelloweye rockfish) (Table 40). If the various permits are granted and exercised, a lesser amount of take is expected to actually occur. For the vast majority of scientific research permits, history has shown that researchers generally take fewer rockfish than the allotted number of rockfish every year (18.82% of requested take and 0.62% of requested mortalities were used in WA Section 10a1A permits from 2009 to 2016).

For the listed S eulachon, the total amount of estimated lethal take for the proposed research would be 573 adults and 350 juveniles. Since there is no known juvenile abundance estimates for listed S eulachon, all eulachon lifestages will be analyzed as adults (which will result in an overestimate of the impact to the species). This is the maximum amount of lethal take contemplated in this biological opinion. Overall, these numbers represent very small fractions of the abundances for eulachon (0.0010%) (Table 40). If the various permits are granted and exercised, a lesser amount of take is expected to actually occur. For the vast majority of scientific research permits, history has shown that researchers generally take fewer eulachon than the allotted number of eulachon every year (25.63% of requested take and 26.03% of requested mortalities were used in OR and WA Section 10a1A permits from 2009 to 2016).

For listed S green sturgeon, there is no requested lethal take for the proposed research.

Thus, as Tables 40-42 demonstrate, all the mortalities, even taken together, represent very small fractions 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. First, there is no known juvenile abundance estimates for the listed rockfish or eulachon species, so all of the lifestages were analyzed as adults. Since the impacts were based solely on adult abundance, this will inflate the displayed percentages. 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 individuals would be killed by the research than stated. As mentioned in the previous paragraphs, approximately one-hundredth of the authorized rockfish mortalities and one-quarter of the authorized eulachon mortalities have been used from 2009 through 2016. Thus, the detrimental effect of the research activities contemplated in this opinion—even when they are added to the effects already contemplated in the region—are expected to be minimal. Because these effects are so small, the actions would have only a slight negative effect on the species' abundance and productivity. And because that slight impact is in most cases distributed throughout the entire listing units, it would be so attenuated as to have no appreciable effect on spatial structure or diversity. Moreover, as shown in each permit description, all the research actions are expected to generate lasting benefits for the listed fish.

Critical Habitat

As noted earlier, we do not expect the individual actions to have any appreciable effect on any listed species' critical habitat. This is true for all the 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, while somewhat unpredictable, are too small to be effectively gauged as an additional increment of harm over the time span considered in this analysis. Moreover, the actions would in no way contribute to climate change (even locally), and in any case the proposed actions would actually help monitor the effects of climate change by noting stream temperatures, flows, marine conditions, etc. So while we can expect both cumulative effects and climate change to continue their negative trends, it is unlikely that any of the proposed actions would have any additive impact to the pathways by which those effects are realized (e.g., a slight reduction in salmonid abundance would have no effect on increasing stream temperatures or continuing land development).

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

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

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

2.8 Conclusion

After reviewing and analyzing the current status of the listed species and critical habitat, the environmental baseline within the action area, the effects of the proposed action, any effects of interrelated and interdependent activities, and cumulative effects, it is NMFS' biological opinion that the proposed actions are not likely to jeopardize the continued existence of PS Chinook salmon, HCS chum salmon, PS steelhead, S eulachon, S green sturgeon, PS/GB bocaccio, and PS/GB yelloweye rockfish. or destroy or adversely modify its designated critical habitat.

2.9 Incidental Take Statement

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

In this instance, and for the actions considered in this opinion, there is no incidental take at all. The reason for this is that all the take contemplated in this document would be carried out under 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 Eight ESA Section 10(a)(1)(A) Scientific Research Permits affecting Salmon, Steelhead, Eulachon, Green Sturgeon, and Rockfish 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 Southern Resident (SR) killer whale DPS composed of J, K, and L pods was listed as endangered under the ESA on November 18, 2005 (70 FR 69903). The final rule listing SR killer whales as endangered identified several potential factors that may have caused their decline or may be limiting recovery. These are: quantity and quality of prey, toxic chemicals which accumulate in top predators, and disturbance from sound and vessel traffic. The rule also identified oil spills as a potential risk factor for this species. The final recovery plan includes more information on these potential threats to SR killer whales (NMFS 2008a).

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

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

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

The proposed actions may affect SR killer whales indirectly by reducing availability of their primary prey, Chinook salmon. As described in the effects analysis for salmonids, up to 27 juvenile and five adult natural-origin Chinook salmon may be killed during proposed research activities.

Take of juvenile salmonids could affect prey availability to the whales in future years throughout their range, including designated critical habitat in inland waters of Washington. For the Puget Sound, average smolt to adult survival of both naturally produced and hatchery Chinook is 1%. If one percent of the 27 juvenile Chinook salmon taken by research activities were to survive to adulthood, this would translate to the effective loss of less than one 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). Additionally, these take estimates are likely an overestimate of the actual number of Chinook salmon that would be taken during research activities, and thus the actual reduction in prey available to the whales is likely smaller than the stated figure.

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

Future loss of Chinook salmon from Chinook salmon ESU populations could affect the prey PBF of designated critical habitat. As described above, however, considering the estimate of up to five adult equivalent natural-origin Chinook salmon (27 juveniles and five adults) that could be taken by the proposed actions, and the total amount of prey available in the critical habitat, the reduction would be insignificant and would not affect the conservation value of the critical habitat. Proposed research activities would have discountable effects on the water quality or passage PBFs for SR killer whales.

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

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

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

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

3.1 Essential Fish Habitat Affected by the Project

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

3.2 Adverse Effects on Essential Fish Habitat

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

3.3 Essential Fish Habitat Conservation Recommendations

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

3.4 Statutory Response Requirement

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

3.5 Supplemental Consultation

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

4. DATA QUALITY ACT DOCUMENTATION AND PRE-DISSEMINATION REVIEW

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

4.1 Utility

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

This ESA section 7 consultation on the issuance of the 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

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

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

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

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

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

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

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

April 7, 2006 (71 FR 17757). Final Rule: Endangered and Threatened Wildlife and Plants: Threatened Status for Southern Distinct Population Segment of North American Green Sturgeon.

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

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

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

October 9, 2009 (74 FR 52300). Final Rule: Endangered and Threatened Wildlife and Plants: Final Rulemaking To Designate Critical Habitat for the Threatened Southern Distinct Population Segment of North American Green Sturgeon.

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

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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.

November 13, 2014 (79 FR 68042). Final Rule: Endangered and Threatened Species; Designation of Critical Habitat for the Puget Sound/Georgia Basin Distinct Population Segments of Yelloweye Rockfish, Canary Rockfish and Bocaccio.

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.

June 15, 2017 (82 FR 27468). Notice: Endangered and Threatened Species; Take of Anadromous Fish.

5.2 Literature Cited

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