UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
1201 NE Lloyd Boulevard, Suite 1100
PORTLAND, OR 97232-1274

Refer to NMFS No:
WCRO-2018-00286

February 16, 2022

Daniel D. Opalski
Director
United States Environmental Protection Agency, Region 10
1200 Sixth Avenue, Suite 155
Seattle, Washington 98101-3123

Re: Reinitiation of Endangered Species Act Section 7(a)(2) Biological Opinion, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the Environmental Protection Agency's Approval of Washington State Department of Ecology's Sediment Management Standards (WAC 173-204-412) Regarding Marine Finfish Rearing Facilities.

Dear Mr. Opalski:

Thank you for your letter of October 1, 2018, requesting initiation of consultation with NOAA's National Marine Fisheries Service (NMFS) pursuant to Section 7 of the Endangered Species Act of 1973 (ESA) (16 U.S.C. 1531 et seq.) for reinitiation of ESA Section 7 consultation for the Environmental Protection Agency's Approval of Washington State Department of Ecology's (Ecology) Sediment Management Standards (WAC 173-204-412) regarding marine finfish rearing facilities in the Puget Sound (PS), signed April 8, 2011 (NMFS tracking number: 2010/06071). This consultation was conducted in accordance with the 2019 revised regulations that implement section 7 of the ESA (50 CFR 402, 84 FR 45016).

The enclosed document contains a biological opinion (opinion) that analyzes the effects of EPA's approval of Ecology's Sediment Management Standards regarding marine finfish rearing facilities. In this opinion, we conclude that the proposed action is not likely to jeopardize the continued existence of PS Chinook salmon (*Oncorhynchus tshawytscha*), PS steelhead (*O. mykiss*), Hood Canal summer-run chum (HCSRC; *O. keta)*, PS/Georgia Basin (PS/GB) yelloweye rockfish (*Sebastes ruberrimus*) or PS/GB bocaccio (*S. paucispinis*). Further, we conclude that the proposed action is not likely to result in the destruction or adverse modification of the designated critical habitats for any of the listed species.

The opinion includes an incidental take statement that describes reasonable and prudent measures we consider necessary or appropriate to minimize incidental take associated with this action. The take statement also sets forth terms and conditions, including reporting requirements that the United States Environmental Protection Agency (EPA) must comply with to carry out the reasonable and prudent measures. Incidental take from actions that meet these terms and conditions would be exempt from the ESA take prohibition.

NMFS also reviewed the likely effects of the proposed action on essential fish habitat (EFH), pursuant to section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. 1855(b)), and concluded that the action would adversely affect the EFH of Pacific Coast salmon, Pacific Coast groundfish and coastal pelagic species. Therefore, we have included the results of that review in Section 3 of this document.

We have included conservation recommendations to avoid, minimize, or otherwise offset potential adverse effects on EFH. These conservation recommendations are a subset of the ESA take statement's terms and conditions. Section 305(b) (4) (B) of the MSA requires federal agencies to provide a detailed written response to NMFS within 30 days after receiving the final recommendations.

If the response is inconsistent with the essential fish habitat conservation recommendations, the EPA must explain why the recommendations will not be followed, including the scientific justification for any disagreements over the effects of the action and the recommendations. In response to increased oversight of overall essential fish habitat program effectiveness by the Office of Management and Budget, NMFS established a quarterly reporting requirement to determine how many conservation recommendations are provided as part of each essential fish habitat consultation and how many are adopted by the action agency. Therefore, we request that, in your statutory reply to the essential fish habitat portion of this consultation, you clearly identify the conservation recommendations accepted.

Please contact Dr. Jeff Vanderpham with the Central PS Branch in Lacey, Washington, at (360) 753-5834 or Jeff.Vanderpham@NOAA.gov if you have any questions concerning this consultation, or if you require additional information.

Sincerely,

Kim W. Kratz, Ph.D
Assistant Regional Administrator
Oregon Washington Coastal Office

cc: Hanh Shaw
Lindsay Guzzo
Matthew Szelag

Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the

Reinitiation of Consultation for the Environmental Protection Agency's Approval of Washington State Department of Ecology's Sediment Management Standards (WAC 173-204-412) Regarding Marine Finfish Rearing Facilities

NMFS Consultation Number: WCRO-2018-00286

Action Agency: United States Environmental Protection Agency

Affected Species and NMFS' 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?
PS steelhead (*Oncorhynchus mykiss*)	Threatened	Yes	No	Yes	No
PS Chinook salmon (*O. tshawytscha*)	Threatened	Yes	No	Yes	No
Hood Canal summer-run chum salmon (*O. keta*)	Threatened	Yes	No	Yes	No
PS/GB bocaccio rockfish (*Sebastes paucispinis*)	Endangered	Yes	No	Yes	No
PS/GB yelloweye rockfish (*S. ruberrimus*)	Threatened	Yes	No	Yes	No
Southern DPS green sturgeon (*Acipenser medirostris*)	Threatened	No	No	No	No
Southern DPS eulachon (*Thaleichthys pacificus*)	Threatened	No	No	No	No
Mexico DPS humpback whale (*Megaptera novaeanglia*)	Threatened	No	No	No	No
Central America DPS humpback whale (*M. novaeanglia*)	Endangered	No	No	No	No
Southern resident killer whale (*Orcinus orca*)	Endangered	No	No	No	No

Fishery Management Plan That Identifies EFH in the Project Area	Does Action Have an Adverse Effect on EFH?	Are EFH Conservation Recommendations Provided?
Pacific Coast Salmon	Yes	Yes
Pacific Coast Groundfish	Yes	Yes
Coastal Pelagic Species	Yes	Yes

Consultation Conducted By: National Marine Fisheries Service
West Coast Region

Issued By:

Kim W. Kratz, Ph.D
Assistant Regional Administrator
Oregon Washington Coastal Office

Date: February 16, 2022

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1. INTRODUCTION

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

1.1 Background

The National Marine Fisheries Service (NMFS) prepared the biological opinion (opinion) and incidental take statement (ITS) portions of this document in accordance with section 7(b) of the Endangered Species Act (ESA) of 1973 (16 USC 1531 et seq.), and implementing regulations at 50 CFR 402, as amended.

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 within two weeks at the NOAA Library Institutional Repository (https://repository.library.noaa.gov/welcome). A complete record of this consultation is on file at the NMFS Oregon Washington Coastal Office.

1.2 Consultation History

This consultation is a reinitiation of a previous informal consultation signed April 8, 2011 (NMFS tracking number: 2010/06071). NMFS received a request to reinitiate ESA Section 7 formal consultation on October 1, 2018, following a failure and collapse of a commercial Atlantic salmon net pen (Cypress Island Site 2) in the Puget Sound (PS), and potential new information.

Numerous emails were exchanged and meetings held between NMFS and EPA to determine the extent of the proposed action and the information needed to complete the consultation. Several meetings also included staff from the Washington Department of Fish and Wildlife (WDFW) and the Washington Department of Ecology (Ecology), both with jurisdictional responsibilities related to PS net pens, as well as Cooke Aquaculture, Inc., the current operator of all commercial net pens within the PS. The focus of these meetings was to determine the reasonably likely consequences of the EPA action, including gathering information on existing and future net pen facilities and operations. Significant meetings included:

- October 11, 2018, preliminary meeting with NMFS and EPA to determine extent of proposed action and discuss consultation process;
- January 23, 2019, February 25, 2019, and April 9, 2020, meetings with NMFS and EPA to discuss potential effects of the proposed action, consultation timeline and information needs;

- July 31, 2019, May 14, 2020, and May 28, 2020, meetings with NMFS, EPA and Cooke Aquaculture, Inc. to discuss PS commercial net pen operations; and
- March 31, 2020, meeting with NMFS, EPA, Ecology and WDFW to discuss PS net pen operations, permitting and potential environmental effects.

On May 28, 2020, EPA provided to NMFS an "Addendum to the Updated Biological Evaluation Dated December 13, 2010, Regarding the EPA Clean Water Act Action on Washington's Marine Finfish Rearing Facility Provision Contained in the Sediment Management Standards at Washington Administrative Code (WAC) 173-204-412" (Biological Evaluation (BE) Addendum; EPA 2020). Previously, referenced EPA BEs include EPA (2008) and EPA (2010). A detailed consultation history can be found in the 2020 BE Addendum; (pages 2-5).

Upon review, we determined that the BE Addendum provided the necessary information to complete ESA Section 7 and EFH consultation, and the new consultation was initiated on May 28, 2020. This formal ESA Section 7 consultation is triggered by likely adverse effects to PS Chinook salmon, PS steelhead, HCSRC, PS/GB bocaccio and PS/GB yelloweye rockfish, and critical habitat for each of these species. The EFH portion of this consultation is triggered because the proposed action may adversely affect EFH for Pacific Coast groundfish, coastal pelagic species, and Pacific Coast salmon.

At the end of February 2021, NMFS provided EPA with a draft Opinion. NMFS and EPA met on March 18, 2021, to discuss EPA's review of the draft Opinion, and EPA provided NMFS with comments on the draft opinion on March 23, 2021. NMFS provided a revised draft Opinion to EPA on April 5, 2021, and a revised incidental take statements on June 16, 2021, and October 19, 2021.

1.3 Proposed Federal Action

Under the ESA, "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). Under the MSA, "Federal action" means any action authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken by a federal agency (50 CFR 600.910).

EPA proposes to approve specific revisions to Washington State's Sediment Management Standards (WAC 173-204) under the federal Clean Water Act. These revisions include: (1) the addition of a section for marine finfish rearing facilities (WAC 173-204-412); (2) defining "marine finfish rearing facilities" (WAC 173-204-200(13)); (3) describing the applicability of marine finfish rearing facilities (WAC-204-412); and (4) defining sediment monitoring requirements (WAC 173-204-412 (3)(a) and (3)(b)) and sediment impact zones for marine finfish rearing facilities (WAC 173-204-412 (4), (4)(a), (4)(a)(i), (4)(a)(ii) and (4)(b)).

The proposed action also includes the EPA's approval of the following Sediment Management Standards provisions that could affect aquatic life:

- WAC 173-204(1)(b)(ii). Juvenile polychaete chronic tests;

- WAC 173-204-315(2)(b). Larval performance standards for control and reference sediment biological test results;
- WAC 173-204-315(2)(d). Juvenile polychaete performance standards for control and reference sediment biological test results;
- WAC 173-204-320(3)(d). Juvenile polychaete biological effects criteria; and
- WAC 173-204-430(3)(c)(iv). Juvenile polychaete PS marine sediment impact zone maximum biological effects criteria.

The five provisions described in the bulleted list above direct laboratory quality of the control and reference sediment samples for juvenile polychaete growth and larval bivalve survivorship. Each provision serves to improve the reliability of test results.

The addition of the marine finfish rearing facilities section to the WAC exempts net pen facilities in PS from portions of Washington's sediment management standards, underneath and around the immediate area of the net pen. The section also states that sediment quality compliance and monitoring requirements of net pen facilities are addressed through the National Pollutant Discharge Elimination System (NPDES) permitting program. The section provides for a special sediment impact zone, by rule, within and including a distance of 100 feet from the outer edge of net pen facility structures. Consequently, such facilities and their associated discharges are exempt from the otherwise applicable marine sediment quality standards, the sediment impact zone maximum criteria, and the sediment impact zone standards, at WAC 173-204-415. The finfish specific section also allows Ecology to authorize sediment impact zones beyond 100 feet via NPDES permits or administrative actions, subject to increased monitoring.

NPDES permits are issued pursuant to the applicable WAC establish requirements to minimize effects on environmental conditions to protect aquatic life in PS. Ecology reviews and reissues NPDES permits every five years. The current NPDES permits for marine finfish rearing facilities in PS, which are governed in part by the sediment quality revisions of EPA's proposed action, include a variety of requirements (monitoring and conservation measures), including the following:

- Monitoring, record-keeping and reporting requirements
- Sediment sampling and analysis plan
- Dissolved oxygen profile survey
- Underwater photographic survey
- Antibiotic resistance monitoring
- Sediment impact zone closure requirements
- General operating requirements
- Disease control chemical use requirements
- Pollution prevention plan
- Fish release prevention and monitoring plan
- Accidental fish release response plan
- Structural monitoring and reporting

The Washington state sediment management standards (WAC Chapter 173-204) dictate allowable impact levels or variation from baseline conditions in the PS. The NPDES permits for the net pen facilities specify monitoring and reporting requirements, and establishes operating requirements to minimize discharge of pollutants (see individual permits at Ecology 2021). Discharges from a net pen facility must comply with Chapter 173-204 WAC Sediment Management Standards to protect biological resources and human health. The NPDES standards are set for the protection of benthic organisms and the surrounding marine environment. Benthic conditions outside of the SIZ (Sediment Impact Zone; area within 100-foot perimeter of net pens) must comply with sediment quality standards. These regulations require no net increase in benthic nutrients, and the NPDES permits require that fish be fed in a manner that minimizes the amount of uneaten food and maximizes ingestion by reared fish (see Ecology 2021). This includes the use of properly sized feed for the size of fish in each individual pen, feed free of excessive fines and that is highly digestible. Fish biomass and feed must also be monitored and reported monthly. A reduction in feeding rate may be required in response to any noncompliance in water quality or sediment management standards.

In this Opinion, we analyze the effects of EPA's approval of the Washington State Sediment Management Standards provisions and revisions described above. As required by the ESA, we look at all the consequences of the proposed action on ESA-listed species and designated critical habitat. Here consequences include sediment and water quality effects associated with marine finfish rearing (net pens) that would not occur but for the proposed action.

In this case, in light of the approach followed in past consultations on EPA's approval of these sediment management standards and the court's Order denying federal defendant's motion for judgment on the pleadings, *Wild Fish Conservancy v. United States Env't Prot. Agency*, 331 F. Supp. 3d 1210, 1220–21 (W.D. Wash. 2018), we are evaluating the effects stemming from four existing commercial net pen facilities as a consequence of EPA's proposed action. Here we assume that operations at those four facilities would cease if EPA did not approve the proposed water quality standards.
Other non-commercial net pen facilities and their operations, including the PS Tribal enhancement net pen facilities and the research net pens at the NOAA Manchester Research Facility, are regulated directly by EPA through a General Permit,[1] are not subject to the sediment standards evaluated here, and are discussed more in the Environmental Baseline Section 2.4.

Therefore, the effects or consequences of EPA's proposed action considered in this opinion include those directly stemming from the application of the proposed sediment standards provisions and revisions, as well as operations of four net pen facilities currently present in the PS that would not occur but for the proposed action. Any future, additional or expanded facilities and operations are too far downstream in the causal chain to be considered a consequence of this proposed action. Further, we know of no existing plans for any such activities, and any future facility or expansion would likely require new permits, for example Clean Water Act (Section 404) and Rivers and Harbors Act (Section 10) permits from the United States Army Corps of

1 NMFS completed consultation on the EPA's renewal of this general permit on the same day as it completed this consultation. *See* Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the NPDES General Permit for Tribal Enhancement and Federal Research Marine Net Pen Facilities Within Puget Sound, NPDES Permit No. WAG132000, WCRO-2021-03087.

Engineers, and be subject to a separate Section 7 or Section 10 (if no federal action) consultation at that time.

The scope of review for this opinion is the application of the sediment management standards revisions (the proposed action). Because we consider only the four existing facilities and their future operations to be reasonably certain to occur, our assessment of effects of the standards (proposed action) is limited to the effects of these facilities and operations. These facilities currently exist and fall within the NDPES permits that are governed in part by the sediment quality revisions that EPA now proposes to approve, and thus our effects analysis (Section 2.5) includes the structures and operations at these net pen sites.

The existing four commercial marine finfish rearing net pen facilities (that require NPDES permits from Washington state), which to date have been used for rearing (farming) of commercial Atlantic salmon (Table 1 and Figure 1), and which are all governed by the revised standards and definitions that the EPA proposes to approve. Several of these facilities are located in close proximity to each other, resulting in two general locations or “farms” – Hope Island (Hope Island facility), and Rich Passage (Clam Bay – Saltwater I, Fort Ward – Saltwater II, and Orchard Rocks – Saltwater IV facilities).

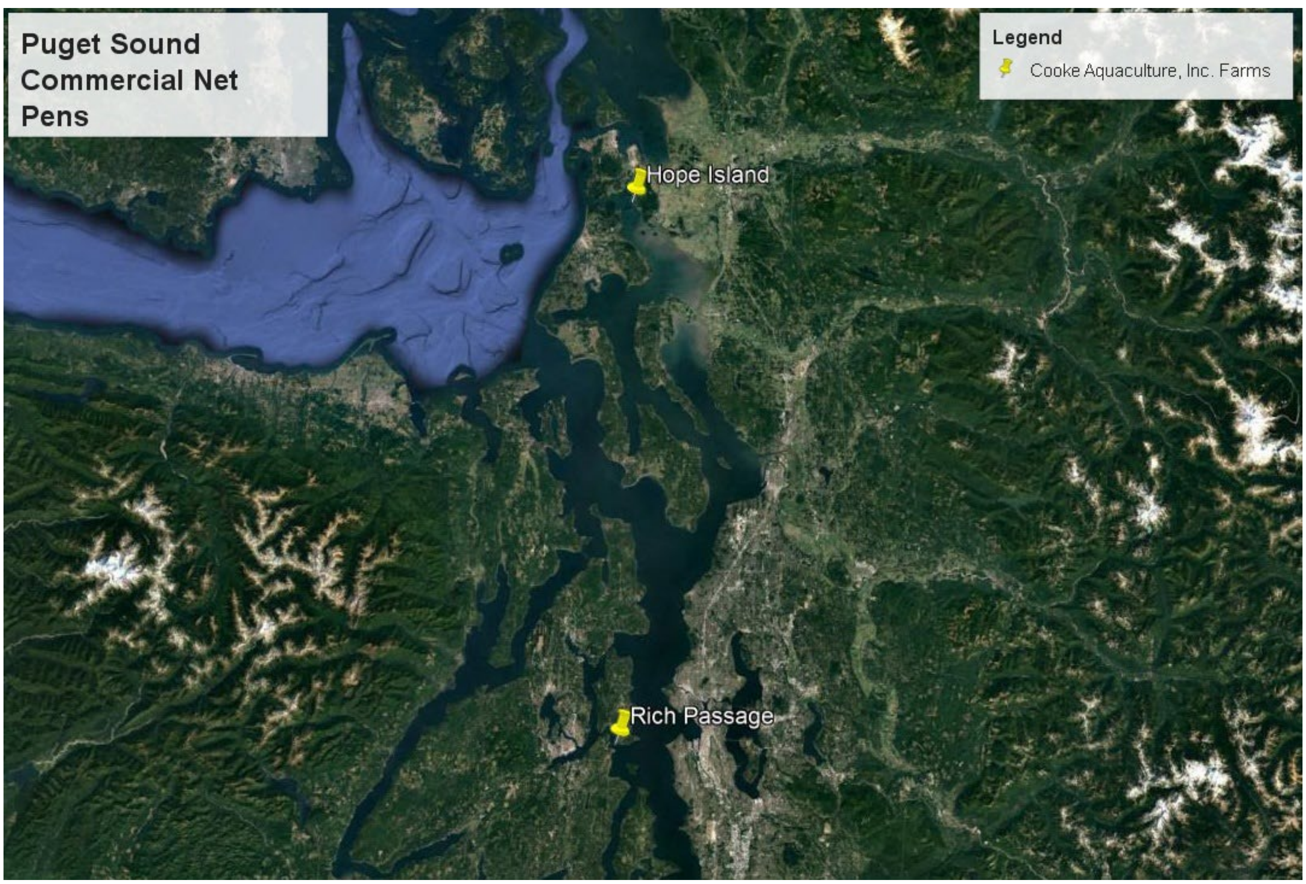

Figure 1. Map of approximate location of PS commercial net pens, indicating the two Cooke Aquaculture, Inc. farms; Rich Passage farm (Clam Bay—Saltwater I, Fort Ward—Saltwater II and Orchard Rocks—Saltwater IV sites) and Hope Island farm (Hope Island site).

On October 1, 2019, WDFW issued a Mitigated Determination of Non-significance for Cooke Aquaculture, Inc.'s proposed action to transition production from Atlantic salmon to all-female, triploid rainbow trout (*Oncorhynchus mykiss*) in existing PS net pen facilities. In January 2020, WDFW approved Cooke Aquaculture, Inc.'s application to farm all-female sterile (triploid) rainbow trout/steelhead in PS (WDFW 2020b). On January 6, 2021, Ecology issued modified NPDES permits for Cooke Aquaculture, Inc. to raise rainbow trout/steelhead (Ecology 2021).

Rainbow trout and steelhead are both the same species, but with different life histories, non-anadromous and anadromous, respectively (e.g., see Berejikian et al. 2014; Hodge et al. 2016). Although the source stock for the net pens may be non-anadromous rainbow trout, since they are reared in marine net pens they could be referred to as steelhead. For consistency in this Opinion, we refer to the triploid *O. mykiss* proposed for net pen rearing as rainbow trout/steelhead.

Additionally, based on information provided by Cooke Aquaculture, Inc. (e.g., K. Bright, personal communication, May 12, 2020), and a company press-release,[2] it is reasonably likely that sablefish (black cod; *Anoplopoma fimbria*) would also be reared in PS net pens in the near future (i.e., within the next 5 years). These operations would also require NPDES permits. We therefore anticipate net pen farming of sablefish and steelhead in the PS to be consequences of EPA's proposed action.

Farming of sablefish and rainbow trout/steelhead in PS is expected to occur for the foreseeable future. Atlantic salmon farming, which historically occurred within PS net pens, is required to end by 2022. Washington State House Bill 2957[3] (effective June 7, 2018) phases out non-native fish farming in Washington by prohibiting the issuance of any new leases. All existing leases end during or before the year 2022, and thus all Atlantic salmon net pen farming in the PS must cease by 2022. Cooke Aquaculture, Inc., is the only recent operator of Atlantic salmon net pens in the PS. Cooke Aquaculture, Inc. completed a scheduled phase-out (last harvest and all fish removed) of Atlantic salmon farming in the PS in October 2020. (K. Bright, personal communication, January 6, 2021). Cooke Aquaculture, Inc. reported on November 23, 2020, that all of their PS sites were void of cultured fish, and that there were no fish stock containment nets at any of the facilities (K. Bright, personal communication, November 23, 2020). Cooke Aquaculture, Inc. has no future plans to rear Atlantic salmon in the PS (K. Bright, personal communication, January 6, 2021).

As mentioned above, there are four current commercial net pen sites in the PS, with all facilities owned and operated by Cooke Aquaculture, Inc. These facilities have active DNR aquatic leases and NPDES permits. Based on existing regulations, approved NPDES permits from Ecology (2021) and the discussions with Cooke Aquaculture, Inc. as outlined above, it is reasonably likely that future rainbow trout/steelhead or sablefish net pen operations would occur at the four existing net pen sites.

[2]https://www.cookeseafood.com/2020/01/23/cooke-aquaculture-pacific-and-jamestown-sklallam-tribe-welcome-washington-state-approval-to-farm-trout/

[3] March 26, 2018. Washington State House Bill 2957. Nonnative Finfish—Marine Aquaculture—Escape. Chapter 179, Laws of 2018.

Cooke Aquaculture previously operated four additional net pen sites used for rearing Atlantic salmon in the PS. These sites are not currently in operation and do not have active DNR aquatic leases, as these were terminated by DNR in 2017 and 2018. As of November 2020, Cooke Aquaculture, Inc. had removed all net pen structures, associated facilities and mooring systems from the water at these inactive sites, with uncertainty whether facilities would be operating at these sites in the future (K. Bright, personal communication, November 23, 2020; K. Bright, personal communication, January 6, 2021). Thus, we do not consider it reasonably likely that commercial net pen facilities would be present or operating at these historical sites in the future. Any new installation of structures would require Clean Water Act Section 401 and Rivers and Harbors Act Section 10 permits from the United States Army Corps of Engineers. We expect such a permit to create a federal nexus and require individual ESA consultation.

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Table 1. PS commercial net pen site information.

Facility/Site	Farm	Number of cages	Surface area of aggregate net pen rearing area (square feet)	Cage depth from surface (feet)	Minimum water depth at MLLW (feet)	Distance to nearest shoreline at MLLW (feet)	Maximum current speed (cm/sec)*	Estimated mean current speed (cm/sec)*	Total maximum annual biomass (pounds)	Total number of stocked fish[a]	Currently operating (active DNR lease)?
Skagit Bay - Hope Island Site 4	Hope Island	10	85,500	45	60	2000	96	35	2,800,000	390,000	Yes
Clam Bay - Saltwater I	Rich Passage	22	186,850	49	65	1,500	90	15	5,800,000	800,000	Yes
Fort Ward - Saltwater II	Rich Passage	12	118,300	35	45	750	125	40	3,400,000	400,000	Yes
Orchard Rocks - Saltwater IV	Rich Passage	20	166,650	35	45	2,000	115	35	5,600,000	800,000	Yes

Notes: All facility information from Cooke 2019b, c, d, e, and Cooke 2020e, 2020f, 2020g 2020h;
MLLW = mean lower low water.
* measured midway between bottom of net pen and the sea floor.
[a] Proposed numbers provided by J. Parson, personal communication, June 23, 2021.

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 provide 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 ITS that specifies the impact of any incidental taking and includes reasonable and prudent measures (RPMs) and terms and conditions to minimize such impacts.

The EPA determined the proposed action is not likely to adversely affect Southern DPS green sturgeon (*Acipenser medirostris*) or its critical habitat, Southern DPS Pacific eulachon (*Thaleichthys pacificus*) or its critical habitat, Mexico DPS and Central America DPS humpback whale (*Megaptera novaeangliea*) or their critical habitat, and Southern Resident killer whale (*Orcinus orca*). Our rationale for our concurrence is documented in the "Not Likely to Adversely Affect" Determinations section (Section 2.10).

2.1 Analytical Approach

This biological opinion includes both a jeopardy analysis and an adverse modification analysis. The jeopardy analysis relies upon the regulatory definition of "jeopardize the continued existence of" a listed species, which is "to engage in an action that reasonably 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 as a whole for the conservation of a listed species" (50 CFR 402.02).

The designations of critical habitat for PS fish species use the term "primary constituent elements" (PCEs). The 2016 critical habitat regulations (50 CFR 424.12) replaced 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, as appropriate for the specific critical habitat.

The 2019 ESA regulations define effects of the action using the term "consequences" (50 CFR 402.02). As explained in the preamble to the regulations (84 FR 44977), that definition does not change the scope of our analysis and in this opinion we use the terms "effects" and "consequences" interchangeably. Consequences include activities caused by the proposed action.

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

- Evaluate the rangewide status of the species and critical habitat expected to be adversely affected by the proposed action.
- Evaluate the environmental baseline of the species and critical habitat.
- Evaluate the effects of the proposed action on individuals from listed species and on features of their habitat using an exposure-response approach. The individual effects are then evaluated for their influence on the populations they comprise, and the species as a whole.
- Evaluate cumulative effects.
- In the integration and synthesis, add the effects of the action and cumulative effects to the environmental baseline, and, in light of the status of the species and critical habitat, analyze whether the proposed action is likely to: (1) directly or indirectly 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; or (2) directly or indirectly result in an alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species.
- If necessary, suggest a reasonable and prudent alternative to the proposed action.

In addition, to help identify and weigh environmental risks of escapes of marine aquaculture fish to their wild conspecifics, the Offshore Mariculture Escapes Genetic/Ecological Assessment (OMEGA) model, developed by NOAA and ICF International (ICF) as a tool for use by scientists and resource managers to help with understanding the potential negative impact of farmed fish escapees on their wild conspecifics (OMEGA 2020a), was employed. This is further discussed in Section 2.5.3.

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' "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 function of the essential PBFs that help to form that conservation value.

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

During the last century, average regional air temperatures in the Pacific Northwest increased by 1-1.4°F as an annual average, and up to 2°F in some seasons (based on average linear increase per decade; Abatzoglou et al. 2014; Kunkel et al. 2013). Recent temperatures in all but two years since 1998 ranked above the 20th century average (Mote et al. 2014). Warming is likely to continue during the next century as average temperatures are projected to increase another 3 to 10°F, with the largest increases predicted to occur in the summer (Mote et al. 2014).

Decreases in summer precipitation of as much as 30 percent by the end of the century are consistently predicted across climate models (Mote et al. 2014). Precipitation is more likely to occur during October through March, less during summer months, and more winter precipitation will be rain than snow (ISAB 2007; Mote et al. 2013). Earlier snowmelt will cause lower stream flows in late spring, summer, and fall, and water temperatures will be warmer (ISAB 2007; Mote et al. 2014). Models consistently predict increases in the frequency of severe winter precipitation events (i.e., 20-year and 50-year events), in the western United States (Dominguez et al. 2012). The largest increases in winter flood frequency and magnitude are predicted in mixed rain-snow watersheds (Mote et al. 2014).

The combined effects of increasing air temperatures and decreasing spring through fall flows are expected to cause increasing stream temperatures; in 2015 this resulted in 3.5-5.3ºC increases in Columbia Basin streams and a peak temperature of 26ºC in the Willamette (NWFSC 2015). Overall, about one-third of the current cold-water salmonid habitat in the Pacific Northwest is likely to exceed key water temperature thresholds by the end of this century (Mantua et al. 2009).

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

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

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

Moreover, as atmospheric carbon emissions increase, increasing levels of carbon are absorbed by the oceans, changing the pH of the water. A 38 percent to 109 percent increase in acidity is projected by the end of this century in all but the most stringent CO_2 mitigation scenarios, and is essentially irreversible over a time scale of centuries (IPCC 2014). Regional factors appear to be amplifying acidification in Northwest ocean waters, which is occurring earlier and more acutely than in other regions and is already impacting important local marine species (Barton et al. 2012; Feely et al. 2012). Acidification also affects sensitive estuary habitats, where organic matter and nutrient inputs further reduce pH and produce conditions more corrosive than those in offshore waters (Feely et al. 2012; Sunda and Cai 2012).

Global sea levels are expected to continue rising throughout this century, with predicted likely increases of 10-32 inches by 2081-2100 (IPCC 2014). These changes will likely result in increased erosion and more frequent and severe coastal flooding, and shifts in the composition of nearshore habitats (Tillmann and Siemann 2011; Reeder et al. 2013). Estuarine-dependent salmonids such as chum and Chinook salmon are predicted to be impacted by significant reductions in rearing habitat in some Pacific Northwest coastal areas (Glick et al. 2007). Historically, warm periods in the coastal Pacific Ocean have coincided with relatively low abundances of salmon and steelhead, while cooler ocean periods have coincided with relatively high abundances, and therefore these species are predicted to fare poorly in warming ocean conditions (Scheuerell and Williams 2005; Zabel et al. 2006). This is supported by the recent observation that anomalously warm sea surface temperatures off the coast of Washington from 2013 to 2016 resulted in poor coho and Chinook salmon body condition for juveniles caught in those waters (NWFSC 2015). Changes to estuarine and coastal conditions, as well as the timing of seasonal shifts in these habitats, have the potential to impact a wide range of listed aquatic species (Tillmann and Siemann 2011; Reeder et al. 2013).

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

2.2.1 Status of the Species

For Pacific salmon, steelhead, and certain other species, we commonly use the four "viable salmonid population" (VSP) criteria (McElhany et al. 2000) to assess the viability of the populations that, together, constitute the species. These four criteria (spatial structure, diversity, abundance, and productivity) encompass the species' "reproduction, numbers, or distribution" as described in 50 CFR 402.02. 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.

"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 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 in 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, we assess 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).

The summaries that follow describe the status of the six ESA-listed species, and their designated critical habitats, that occur within the geographic area of this proposed action and are considered in this opinion. More detailed information on the status and trends of these listed resources, and their biology and ecology, are in the listing regulations and critical habitat designations published in the Federal Register. See Table 2.

Table 2. Listing status, status of critical habitat designations and protective regulations, and relevant Federal Register (FR) decision notices for ESA-listed species considered in this opinion. Listing status: 'T' means listed as threatened; 'E' means listed.

Species	Listing Status	Critical Habitat
Chinook salmon ***(Oncorhynchus tshawytscha)***		
Puget Sound	T 6/28/05; 70 FR 37160	9/02/05; 70 FR 52630
Chum salmon ***(O. keta)***		
Hood Canal summer-run	T 6/28/05; 70 FR 37160	9/02/05; 70 FR 52630
Steelhead **(*O. mykiss*)**		
Puget Sound	T 5/11/07; 72 FR 26722	2/24/16; 81 FR 9252
Yelloweye Rockfish ***(Sebastes ruberrimus)***		
Puget Sound/Georgia Basin	T 4/28/10; 75 FR 22276	2/11/15; 79 FR 68041
Bocaccio **(S. *paucispinis)***		
Puget Sound/Georgia Basin	T 4/28/10; 75 FR 22276	2/11/15; 79 FR 68041

Status of PS Chinook Salmon

The PS Chinook salmon evolutionarily significant unit (ESU) was listed as threatened on June 28, 2005 (70 FR 37160). We adopted the recovery plan for this ESU in January 2007. The recovery plan consists of two documents: the PS salmon recovery plan (Shared Strategy for PS 2007) and a supplement by NMFS (2006). The recovery plan adopts ESU and population level viability criteria recommended by the PS Technical Recovery Team (PSTRT) (Ruckelshaus et al. 2002). The PSTRT's biological recovery criteria will be met when all of the following conditions are achieved:

- The viability status of all populations in the ESU is improved from current conditions, and when considered in the aggregate, persistence of the ESU is assured;
- Two to four Chinook salmon populations in each of the five biogeographical regions of the ESU (Table 6) achieve viability, depending on the historical biological characteristics and acceptable risk levels for populations within each region;
- At least one population from each major genetic and life history group historically present within each of the five biogeographical regions is viable;
- Tributaries to PS not identified as primary freshwater habitat for any of the 22 identified populations are functioning in a manner that is sufficient to support an ESU-wide recovery scenario;
- Production of Chinook salmon from tributaries to PS not identified as primary freshwater habitat for any of the 22 identified populations occurs in a manner consistent with ESU recovery; and
- Populations that do not meet the viability criteria for all VSP parameters are sustained to provide ecological functions and preserve options for ESU recovery.

The most recent 5-year Status Review (NMFS 2017c) concluded that benefits from the many habitat actions identified in the recovery plan will take decades to produce significant improvement in natural population viability parameters.

Spatial Structure and Diversity. The PS Chinook salmon ESU includes all naturally spawning populations of Chinook salmon from rivers and streams flowing into PS including the Strait of Juan de Fuca (SJDF) from the Elwha River, eastward, including rivers and streams flowing into Hood Canal, South Sound, North Sound and the Strait of Georgia in Washington. The ESU also includes the progeny of numerous artificial propagation programs (NWFSC 2015). The PSTRT identified 22 extant populations, grouped into five major geographic regions, based on consideration of historical distribution, geographic isolation, dispersal rates, genetic data, life history information, population dynamics, and environmental and ecological diversity. The PSTRT distributed the 22 populations among five major biogeographical regions, or major population groups (MPG), that are based on similarities in hydrographic, biogeographic, and geologic characteristics (Table 3).

Between 1990 and 2014, the proportion of natural-origin spawners has trended downward across the ESU, with the Whidbey Basin the only MPG with consistently high fractions of natural-origin spawner abundance. All other MPG have either variable or declining spawning populations with high proportions of hatchery-origin spawners (NWFSC 2015, NMFS 2017c).

Table 3. Extant PS Chinook salmon populations in each biogeographic region and the 2-year trend (2012-2014) (Ruckelshaus et al. 2002, NWFSC 2015)

Biogeographic Region	Population (Watershed)	Population trend (% change)
Strait of Georgia	North Fork Nooksack River	Negative (-30)
	South Fork Nooksack River	Positive (+8)
Strait of Juan de Fuca	Elwha River	Positive (+93)
	Dungeness River	Negative (-6)
Hood Canal	Skokomish River	Positive (+34)
	Mid Hood Canal River	Positive (+257)
Whidbey Basin	Skykomish River	Negative (-31)
	Snoqualmie River	Negative (-42)
	North Fork Stillaguamish River	Negative (-1)
	South Fork Stillaguamish River	Negative (-15)
	Upper Skagit River	Negative (-32)
	Lower Skagit River	Negative (-35)
	Upper Sauk River	Positive (+67)
	Lower Sauk River	Negative (-24)
	Suiattle River	Positive (+38)
	Upper Cascade River	Positive (+1)
Central/South Puget Sound Basin	Cedar River	Positive (+31)
	North Lake Washington/ Sammamish River	Negative (-16)
	Green/Duwamish River	Negative (-32)
	Puyallup River	Negative (-41)
	White River	Negative (-35)
	Nisqually River	Positive (+31)

Abundance and Productivity. Available data on total abundance since 1980 indicate that although abundance trends have fluctuated between positive and negative for individual populations, there are widespread negative trends in natural-origin Chinook salmon spawner abundance across the ESU (NWFSC 2015). Productivity remains low in most populations, and hatchery-origin spawners are present in high fractions in most populations outside of the Skagit watershed. Available data now shows that most populations have declined in abundance over the past 7 to 10 years. Further, escapement levels for all populations remain well below the TRT planning ranges for recovery, and most populations are consistently below the spawner-recruit levels identified by the TRT as consistent with recovery (NWFSC 2015; NMFS 2017c).

The most recent final biological viability assessment update for Pacific salmon and steelhead (Ford 2022) provides similar findings. It concludes that all PS Chinook salmon populations continue to remain well below the TRT planning ranges for recovery escapement levels, and that most populations remain consistently below the spawner-recruit levels identified by the TRT as necessary for recovery. However, it also finds that most populations have increased somewhat in abundance since the last status review in 2016, but still have small negative trends over the past 15 years, with productivity remaining low in most populations (Ford 2022).

Limiting Factors. Limiting factors for this species include:

- Degraded floodplain and in-river channel structure
- Degraded estuarine conditions and loss of estuarine habitat
- Riparian area degradation and loss of in-river large woody debris
- Excessive fine-grained sediment in spawning gravel
- Degraded water quality and temperature
- Degraded nearshore conditions
- Impaired passage for migrating fish
- Altered flow regime

PS Chinook Salmon Recovery Plan. Nearshore areas serve as the nursery for juvenile PS Chinook salmon. Riparian vegetation, shade and insect production, and forage fish eggs along marine shorelines and river deltas help to provide food, cover and thermoregulation in shallow water habitats. Forage fish spawn in large aggregations along shorelines with suitable habitat, which produce prey for juvenile PS Chinook salmon. Juvenile salmon commonly occupy “pocket estuaries” where freshwater inputs provide salinity gradients that make adjusting to the marine environment less physiologically demanding. Pocket estuaries also provide refugia from predators. As the juvenile salmon grow and adjust, they move out to more exposed shorelines such as eelgrass, kelp beds and rocky shorelines where they continue to grow and migrate into the ocean environment. Productive shoreline habitats of PS are necessary for the recovery of PS salmon (Shared Strategy for PS 2007).

The PS Recovery Plan (Volumes 1 and 2) includes specific recovery actions for each of the 22 extant populations of PS Chinook salmon. General protection and restoration actions summarized from the plan include:

- Aggressively protect functioning drift cells and feeder bluffs that support eelgrass bands and depositional features;
- Counties should pass strong regulations and policies limiting increased armoring of these shorelines and offering incentives for protection;
- Aggressively protect areas, especially shallow water/low gradient habitats and pocket estuaries, within 5 miles of river deltas;
- Protect the forage fish spawning areas;
- Conduct limited beach nourishment on a periodic basis to mimic the natural sediment transport processes in select sections where corridor functions may be impaired by extensive armoring;
- Maintain the functioning of shallow, fine substrate features in and near 11 natal estuaries for Chinook salmon (to support rearing of fry);
- Maintain migratory corridors along the shores of PS;
- Maintain the production of food resources for salmon;
- Maintain functioning nearshore ecosystem processes (i.e., sediment delivery and transport; tidal circulation) that create and support the above habitat features and functions;
- Increase the function and capacity of nearshore and marine habitats to support key needs of salmon;
- Protect and restore shallow, low velocity, fine substrate habitats along marine shorelines, including eelgrass beds and pocket estuaries, especially adjacent to major river deltas;
- Protect and restore riparian areas;
- Protect and restore estuarine habitats of major river mouths;
- Protect and restore spawning areas and critical rearing and migration habitats for forage fish; and
- Protect and restore drift cell processes (including sediment supply, e.g., from feeder bluffs, transport, and deposition) that create and maintain nearshore habitat features such as spits, lagoons, bays, beaches.

Status of Hood Canal Summer-run Chum Salmon

We adopted a recovery plan for HCSRC salmon in May of 2007. The recovery plan consists of two documents: the Hood Canal and Eastern SJDF Summer Chum Salmon Recovery Plan (HCCC 2005) and a supplemental plan by NMFS (2007). The recovery plan adopts ESU and population level viability criteria recommended by the PS Technical Recovery Team (PSTRT) (Sands et al. 2007). The PSTRT's biological recovery criteria will be met when the following conditions are achieved:

- Spatial Structure: (1) Spawning aggregations are distributed across the historical range of the population. (2) Most spawning aggregations are within 20 km of adjacent aggregations. (3) Major spawning aggregations are distributed across the historical range of the population and are not more than approximately 40 km apart. Further, a viable population has spawning, rearing, and migratory habitats that function in a manner that is consistent with population persistence

- Diversity: Depending on the geographic extent and ecological context of the population, a viable population includes one or more persistent spawning aggregations from each of the two to four major ecological diversity groups historically present within the two populations (see also McElhany et al. 2000).
- Abundance and Productivity: Achievement of minimum abundance levels associated with persistence of HCSR chum ESU populations that are based on two assumptions about productivity and environmental response (Table 4).

Despite substantive gains towards meeting viability criteria in the Hood Canal and SJDF summer chum salmon populations, the ESU still does not meet all of the recovery criteria for population viability at this time (NWFSC 2015; NMFS 2017c; Ford 2022).

Table 4. HCSR chum salmon ESU abundance and productivity recovery goals (Sands et al. 2009).

Population	Low Productivity Planning Target for Abundance (productivity in parentheses)	High Productivity Planning Target for Abundance (productivity in parentheses)
SJDF	12,500 (1.0)	4,500 (5.0)
Hood Canal	24,700 (1.0)	18,300 (5.0)

<u>Spatial Structure and Diversity</u>. The ESU includes all naturally spawning populations of summer-run chum salmon in Hood Canal tributaries as well as populations in Olympic Peninsula rivers between Hood Canal and Dungeness Bay, Washington, as well as several artificial propagation programs. The PS Technical Recovery Team identified two independent populations for the Hood Canal summer chum, one which includes the spawning aggregations from rivers and creeks draining into the SJDF, and one which includes spawning aggregations within Hood Canal proper (Sands et al. 2009).

Spatial structure and diversity measures for the HCSRC recovery program have included the reintroduction and sustaining of natural-origin spawning in multiple small streams where summer chum spawning aggregates had been extirpated. 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). Spawning aggregations are present and persistent within five of the six major ecological diversity groups identified by the PSTRT (Table 5). As supplementation program goals have been met in most locations, they have been terminated except in the Lilliwaup and Tahuya River programs, where supplementation is anticipated to be discontinued in the next two years (NMFS 2022). Spatial structure and diversity viability parameters for each population have increased and nearly meet the viability criteria.

Table 5. Seven ecological diversity groups as proposed by the PSTRT for the HCSRC ESU by geographic region and associated spawning aggregation.

Geographic Region(population)	Spawning aggregations: Extant* and extinct**
Eastern SJDF	Dungeness R (unknown status)
	Jimmycomelately Cr* Salmon Cr* Snow Cr* Chimacum Cr**
Hood Canal	Unknown
	Big Quilcene R* Little Quilcene R*
	Dosewallips R* Duckabush R*
	Big Beef Cr** Seabeck Cr** Stavis Cr** Anderson Cr** Dewatto R** Tahuya R** Mission Cr** Union R*
	Hamma Hamma R* Lilliwaup Cr* Skokomish R*

Abundance and Productivity. Smoothed trends in estimated total and natural population spawning abundances for both Hood Canal and SJDF populations have generally increased over the 1980 to 2014 time period. The Hood Canal population had a 25 percent increase in abundance of natural-origin spawners from 2005 to 2009. The SJDF has had a 53 percent increase in abundance of natural-origin spawners during this time period (NWFSC 2015; NMFS 2017c).

Trends in population productivity, estimated as the log of the smoothed natural spawning abundance in year t minus the smoothed natural spawning abundance in year (t-4), increased from 2010 to 2015, and were above replacement rates in 2012 and 2013 (NWFSC 2015). However, productivity rates have been varied above and below replacement rates over the entire time period up to 2014. PNPTT and WDFW (2014) provide a detailed analysis of productivity for the ESU, each population, and by individual spawning aggregation, and report that 3 of the 11 stocks exceeded the co-manager's interim productivity goal of an average of 1.6 Recruit/Spawner over 8 years. They also report that natural-origin Recruit/Spawner rates have been highly variable in recent brood years, particularly in the SJDF population. Only one spawning aggregation (Chimacum) meets the co-manager's interim recovery goal of 1.2 recruits per spawner in six of the most recent eight years. Productivity of individual spawning aggregates shows only two of eight aggregates have viable performance. (NWFSC 2015; NMFS 2017c).

The 2022 biological viability assessment (Ford 2022) reported that natural-origin spawner abundance has increased since ESA-listing and spawning abundance targets in both populations have been met in some years. However, it found that productivity has been down for the last three years for the Hood Canal population, and for the last four years for the SJDF population, following prior increased productivity reported at the time of the last review (NWFSC 2015). Based on productivity of individual spawning aggregates, Ford (2022) identified viable performance for only two of eight aggregates. However, spatial structure and diversity viability parameters, as originally determined by the TRT have improved and nearly meet the viability criteria for both populations. Ford (2022) finds that although substantive gains have been made towards meeting viability criteria, the ESU still does not meet all of the recovery criteria for population viability. Therefore, Ford (2022) concludes that the HCSRC ESU remains at moderate risk of extinction, with viability largely unchanged from the prior review.

<u>Limiting factors.</u> Limiting factors for this species include (HCCC 2005):

- Reduced floodplain connectivity and function
- Poor riparian condition
- Loss of channel complexity (reduced large wood and channel condition, loss of side channels, channel instability)
- Sediment accumulation
- Altered flows and water quality

Mantua et al. (2010) suggested that the unique life history of HCSRC makes this ESU especially vulnerable to the climate change impacts because they spawn in small shallow streams in late summer, eggs incubate in the fall and early winter, and fry migrate to sea in late winter. Sensitivity during the adult freshwater stage and the early life history was ranked moderate. Predicted climate change effects for the low-elevation Hood Canal streams historically used by summer chum salmon include multiple negative impacts stemming from warmer water temperatures and reduced streamflow in summer, and the potential for increased redd-scouring from peak flow magnitudes in fall and winter. Exposure for stream temperature and summer water deficit were both ranked high, largely due to effects on returning adults and hatched fry. Likewise, sensitivity to cumulative life-cycle effects was ranked high.

<u>HCSRC Recovery Plan</u>. The 2005 recovery plan for HCSR chum salmon currently guides habitat protection and restoration activities for chum Salmon recovery (HCCC 2005; NMFS 2007). Human-caused degradation of HCSRC habitat has diminished the natural resiliency of Hood Canal/SJDF river deltas and estuarine habitats (HCCC 2005). Despite some improvement in habitat protection and restoration actions and mechanisms, concerns remain that given the pressures of population growth, 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 (Shared Strategy for PS 2007). The widespread loss of estuary and lower floodplain habitat was noted by the PSTRT as a continuing threat to ESU spatial structure and connectivity (PSTRT 2004; 69 FR 33134).

The HCSRC recovery plan includes specific recovery actions for each stream (HCCC 2005). General protection and restoration actions summarized from those streams include:

- Incorporate channel migration zones within the protected areas of the Shoreline Master Plans of local governments.
- Acquire high priority spawning habitat
- Set back or remove levees in the lower rivers and in river deltas
- Restore upstream ecosystem processes to facilitate delivery of natural sediment and large wood features to lower river habitats
- Remove armoring along the Hood Canal shoreline, including private bulkheads, roadways, and railroad grades
- Restore large wood to river deltas and estuarine habitats
- Restore salt marsh habitats

Status of PS Steelhead

The PS Steelhead TRT produced viability criteria, including population viability analyses (PVAs), for 20 of 32 demographically independent populations (DIPs) and three major population groups (MPGs) in the DPS (Hard et al. 2015). It also completed a report identifying historical populations of the DPS (Myers et al. 2015). The DIPs are based on genetic, environmental, and life history characteristics. Populations display winter, summer, or summer/winter run timing (Myers et al. 2015). The TRT concludes that the DPS is currently at "very low" viability, with most of the 32 DIPs and all three MPGs at "low" viability.

The designation of the DPS as "threatened" is based upon the extinction risk of the component populations. Hard (2015), identifies several criteria for the viability of the DPS, including that a minimum of 40 percent of summer-run and 40 percent of winter-run populations historically present within each of the MPGs must be considered viable using the VSP-based criteria. For a DIP to be considered viable, it must have at least an 85 percent probability of meeting the viability criteria, as calculated by Hard et al. (2015).

On December 27, 2019, we published a final recovery plan for PS steelhead (84 FR 71379) (NMFS 2019a). The plan indicates that within each of the three MPGs, at least fifty percent of the populations must achieve viability, *and* specific DIPs must also be viable:

- <u>Central and South PS MPG</u>: Green River Winter-Run; Nisqually River Winter-Run; Puyallup/Carbon Rivers Winter-Run, or the White River Winter-Run; and at least one additional DIP from this MPG: Cedar River, North Lake Washington/Sammamish Tributaries, South PS Tributaries, or East Kitsap Peninsula Tributaries.
- <u>Hood Canal and SJDF MPG</u>: Elwha River Winter/Summer-Run; Skokomish River Winter-Run; One from the remaining Hood Canal populations: West Hood Canal Tributaries WinterRun, East Hood Canal Tributaries Winter-Run, or South Hood Canal Tributaries WinterRun; and One from the remaining SJDF populations: Dungeness Winter-Run, SJDF Tributaries Winter-Run, or Sequim/Discovery Bay Tributaries Winter-Run.
- <u>North Cascades MPG:</u> Of the eleven DIPs with winter or winter/summer runs, five must be viable: One from the Nooksack River Winter-Run; One from the Stillaguamish River Winter-Run; One from the Skagit River (either the Skagit River Summer-Run and

Winter-Run or the Sauk River Summer-Run and Winter-Run); One from the Snohomish River watershed (Pilchuck, Snoqualmie, or Snohomish/Skykomish River Winter-Run); and One other winter or summer/winter run from the MPG at large.

Of the five summer-run DIPs in this MPG, three must be viable representing in each of the three major watersheds containing summer-run populations (Nooksack, Stillaguamish, Snohomish Rivers); South Fork Nooksack River Summer-Run; One DIP from the Stillaguamish River (Deer Creek Summer-Run or Canyon Creek Summer-Run); and One DIP from the Snohomish River (Tolt River Summer-Run or North Fork Skykomish River Summer-Run).

Spatial Structure and Diversity**.** The PS steelhead DPS is the anadromous form of *O. mykiss* that occur in rivers, below natural barriers to migration, in northwestern Washington state that drain to PS, Hood Canal, and the SJDF between the U.S./Canada border and the Elwha River, inclusive. The DPS also includes six hatchery stocks that are considered no more than moderately diverged from their associated natural-origin counterparts: Green River natural winter-run; Hamma Hamma winter-run; White River winter-run; Dewatto River winter-run; Duckabush River winter-run; and Elwha River native winter-run (USDC 2014). Steelhead are the anadromous form of *Oncorhynchus mykiss* that occur in rivers, below natural barriers to migration, in northwestern Washington state (Ford 2011). Non-anadromous ‘‘resident’’ *O. mykiss* occur within the range of PS steelhead but are not part of the DPS due to marked differences in physical, physiological, ecological, and behavioral characteristics (Hard et al. 2007).

DIPs can include summer steelhead only, winter steelhead only, or a combination of summer and winter run timing (e.g., winter run, summer run or summer/winter run). Most DIPs have low viability criteria scores for diversity and spatial structure, largely because of extensive hatchery influence, low breeding population sizes, and freshwater habitat fragmentation or loss (Hard et al. 2007). In the Central and South PS and Hood Canal and SJDF MPGs, nearly all DIPs are not viable (Hard et al. 2015). More information on PS steelhead spatial structure and diversity can be found in NMFS' technical report (Hard et al. 2015).

Abundance and Productivity. Abundance of adult steelhead returning to nearly all PS rivers has fallen substantially since estimates began for many populations in the late 1970s and early 1980s. Smoothed trends in abundance indicate modest increases since 2009 for 13 of the 22 DIPs. Between the two most recent five-year periods (2005-2009 and 2010-2014), the geometric mean of estimated abundance increased by an average of 5.4 percent. For seven populations in the Northern Cascades MPG, the increase was 3 percent; for five populations in the Central & South PS MPG, the increase was 10 percent; and for six populations in the Hood Canal & SJDF MPG, the increase was 4.5 percent. However, several of these upward trends are not statistically different from neutral, and most populations remain small. Inspection of geometric means of total spawner abundance from 2010 to 2014 indicates that 9 of 20 populations evaluated had geometric mean abundances fewer than 250 adults and 12 of 20 had fewer than 500 adults. The 5-year status review identified increases in abundance of 10 to 100 percent for several populations during the two preceding 5-year periods (2005-2009 and 2010-2014), but about half have remained in decline (NWFSC 2015; NMFS 2017c). Long-term (15-year) trends in natural spawners are predominantly negative (NWFSC 2015; Ford 2022).

There are some signs of modest improvement in steelhead productivity since the 2011 review, at least for some populations, especially in the Hood Canal & SJDF MPG. However, these modest changes must be sustained for a longer period (at least two generations) to lend sufficient confidence to any conclusion that productivity is improving over larger scales across the DPS. Moreover, several populations are still showing dismal productivity, especially those in the Central & South PS MPG (NWFSC 2015; NMFS 2017c).

The 2022 biological viability assessment (Ford 2022) identified a slight improvement in the viability of the PS steelhead DPS since the PS steelhead technical review team 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). Ford (2022) reported observed increases in spawner abundance in a number of populations over the last five years, which were disproportionately found within the South and Central PS and SJDF and Hood Canal MPGs, and primarily among smaller populations. Fifteen-year trends continue to be largely negative for PS steelhead (Ford 2022). The 2022 assessment concluded that recovery efforts in conjunction with improved ocean and climatic conditions have resulted in an increasing 5-year viability trend for the PS steelhead DPS, although the extinction risk remains moderate.

Little or no data is available on summer-run populations to evaluate extinction risk or abundance trends. Because of their small population size and the complexity of monitoring fish in headwater holding areas, summer steelhead have not been broadly monitored.

<u>Limiting factors.</u> In our 2013 proposed rule designating critical habitat for this species (USDC 2013, 78 FR 2725), and maintained in the 2016 final rule (81 FR 9251, February 24, 2006), we noted that the following factors for decline for PS steelhead persist as limiting factors:

- The continued destruction and modification of steelhead habitat
- Widespread declines in adult abundance (total run size), despite significant reductions in harvest in recent years
- Threats to diversity posed by use of two hatchery steelhead stocks (Chambers Creek and Skamania)
- Declining diversity in the DPS, including the uncertain but weak status of summer run fish
- A reduction in spatial structure
- Reduced habitat quality through changes in river hydrology, temperature profile, downstream gravel recruitment, and reduced movement of large woody debris
- In the lower reaches of many rivers and their tributaries in PS where urban development has occurred, increased flood frequency and peak flows during storms and reduced groundwater-driven summer flows, with resultant gravel scour, bank erosion, and sediment deposition
- Dikes, hardening of banks with riprap, and channelization, which have reduced river braiding and sinuosity, increasing the likelihood of gravel scour and dislocation of rearing juveniles.

Table 6. Extant PS Steelhead populations in each biogeographic region and the percent change 1990-2014 (Ruckelshaus et al. 2002, NWFSC 2015).

Biogeographic Region	Population (Watershed)	Population trend (% change)
Hood Canal and SJDF	East Hood Canal Tributaries	Negative (-3)
	Sequim/Discovery Bay Tributaries	Positive (+12)
	Elwha River	-
	Dungeness River	-
	Skokomish River	Positive (+65)
	South Hood Canal Tributaries	Negative (-43)
	West Hood Canal Tributaries	Negative (-50)
	SJDF Tributaries	Negative (-40)
Northern Cascades	Snohomish/Skykomish River	Negative (-70)
	Snoqualmie River	Negative (-46)
	Stillaguamish River	Positive (+20)
	Nooksack River	-
	Skagit River	Positive (+7)
	Pilchuck River	Positive (+3)
	Sammish/Bellingham Bay Tributaries	Positive (+58)
	Tolt River	Positive (44)
Central/South PS Basin	Cedar River	Negative (-67)
	North Lake Washington/ Sammamish River	-
	Green River	Negative (-23)
	Puyallup/Carbon River	Negative (-42)
	White River	Positive (+136)
	Nisqually River	Positive (+18)

PS steelhead Recovery Plan. Juvenile PS steelhead are less dependent on nearshore habitats for early marine rearing than Chinook or Chum Salmon; nevertheless, nearshore, estuarine, and shoreline habitats provide important features necessary for the recovery of steelhead. PS steelhead spend only a few days to a few weeks migrating through the large fjord, but mortality rates during this life stage are critically high (Moore et al. 2010; Moore and Berejikian 2017). Early marine mortality of PS steelhead is recognized as a primary limitation to the species' survival and recovery (NMFS 2019a). Factors in the marine environment influencing steelhead survival include predation, access to prey (primarily forage fish), contaminants (toxics), disease and parasites, migration obstructions (e.g., the Hood Canal Bridge), and degraded habitat conditions which exacerbate these factors.

The PS steelhead recovery plan identifies ten ecological concerns that directly impact salmon and steelhead:

- Habitat quantity (anthropogenic barriers, natural barriers, competition);
- Injury and mortality (predation, pathogens, mechanical injury, contaminated food);
- Food (altered primary productivity, food-competition, altered prey species composition and diversity);
- Riparian condition (riparian condition, large wood recruitment);

- Peripheral and transitional habitats (side channel and wetland condition, estuary conditions, nearshore conditions);
- Channel structure and form (bed and channel form, instream structural complexity);
- Sediment conditions (decreased sediment quantity, increased sediment quantity);
- Water quality (temperature, oxygen, gas saturation, turbidity, pH, salinity, toxic contaminants);
- Water quantity (increased water quality, decreased water quality, altered flow timing); and
- Population-level effects (reduced genetic adaptiveness, small population effects, demographic changes, life history changes).

The PS steelhead recovery plan and associated appendix 3 includes specific recovery actions for the marine environment. General protection and restoration actions summarized from the plan include:

- Continue to improve the assessments of harbor seal predation rates on juvenile steelhead;
- Remove docks and floats which act as artificial haul-out sites for seals and sea lions;
- Consistent with the MMPA, test acoustic deterrents and other hazing techniques to reduce steelhead predation from harbor seals;
- Develop non-lethal actions for “problem animals and locations” to deter predation;
- Increase forage fish habitat to increase abundance of steelhead prey;
- Remove bulkheads and other shoreline armoring to increase forage fish;
- Acquire important forage fish habitat to protect high forage fish production areas;
- Add beach wrack to increase forage fish egg survival;
- Protect and restore aquatic vegetation (e.g., eelgrass and kelp);
- Remove creosote pilings to reduce mortality of herring eggs;
- Increase the assessment of migratory blockages, especially the Hood Canal bridge, where differential mortality has been documented;
- Identify and remedy sources of watershed chemical contaminants (e.g., PBDEs and PCBs).

Status of PS/GB Rockfish

Detailed assessments of yelloweye rockfish and bocaccio can be found in the recovery plan (NMFS 2017a) and the 5-year status review (NMFS 2016e), and are summarized here. We describe the status of yelloweye rockfish and bocaccio with nomenclature referring to specific areas of PS. PS is the second largest estuary in the United States, located in northwest Washington state and covering an area of about 900 square miles (2,330 square km), including 2,500 miles (4,000 km) of shoreline. PS is part of a larger inland waterway, the Georgia Basin, situated between southern Vancouver Island, British Columbia, Canada, and the mainland coast of Washington State. We subdivide the PS into five interconnected basins because of the presence of shallow areas called sills: (1) the San Juan/SJDF Basin (also referred to as “North Sound”), (2) Main Basin, (3) Whidbey Basin, (4) South Sound, and (5) Hood Canal. We use the term “PS proper” to refer to all of these basins except the San Juan/SJDF Basin.

The PS/GB DPS of yelloweye rockfish is listed under the ESA as threatened, and bocaccio are listed as endangered (75 FR 22276, April 28, 2010). On January 23, 2017, we issued a final rule to remove the PS/GB canary rockfish (*Sebastes pinniger*) DPS from the Federal List of Threatened and Endangered Species and remove its critical habitat designation. We proposed these actions based on newly obtained samples and genetic analysis that demonstrates that the PS/GB canary rockfish population does not meet the DPS criteria and therefore does not qualify for listing under the Endangered Species Act. Within the same rule, we extended the yelloweye rockfish DPS area further north in the Johnstone Strait area of Canada. This extension was also the result of new genetic analysis of yelloweye rockfish. The final rule was effective March 24, 2017.

The DPSs include all yelloweye rockfish and bocaccio found in waters of PS, the Strait of Georgia, and the SJDF east of Victoria Sill (Figure 2 and Figure 3). Yelloweye rockfish and bocaccio are 2 of 28 species of rockfish in PS (Palsson et al. 2009).

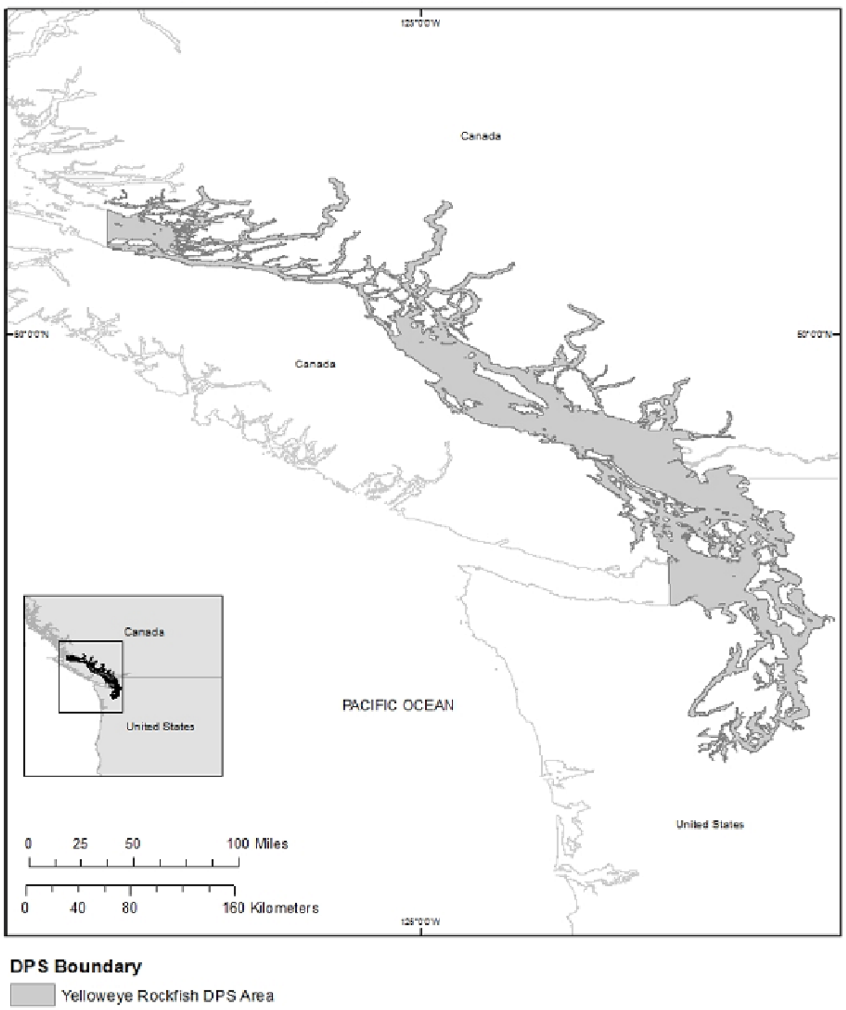

Figure 2. Yelloweye rockfish DPS area.

Figure 3. Bocaccio DPS area.

The life histories of yelloweye rockfish and bocaccio include a larval/pelagic juvenile stage followed by a juvenile stage, and subadult and adult stages. Much of the life history and habitat use for these two species is similar, with important differences noted below. Rockfish fertilize their eggs internally and the young are extruded as larvae. Individual mature female yelloweye rockfish and bocaccio produce from several thousand to over a million eggs each breeding cycle (Love et al. 2002; NMFS 2017a). The timing of larval release for each species varies throughout their geographic range (see NMFS 2017a). In the PS, there is some evidence that yelloweye larvae are extruded in early spring to late summer (Washington et al. 1978) and in British Columbia between April and September with a peak in May and June (Yamanaka et al. 2006). Along the coast of Washington State, bocaccio release larvae between January and April (Love et al. 2002).

Larvae can make small local movements to pursue food immediately after birth (Tagal et al. 2002), but are likely initially passively distributed with prevailing currents until they are large enough to progress toward preferred habitats. 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 PS proper 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). A study of rockfish in PS found that larval rockfish appeared to occur in two peaks (early spring, late summer) that coincide with the main primary production peaks in PS. Both measures indicated that rockfish ichthyoplankton essentially disappeared from the surface waters by the beginning of November. Densities also tended to be lower in the more northerly basins (Whidbey and Rosario), compared to Central and South Sound (Greene and Godersky 2012).

When bocaccio reach sizes of 1 to 3.5 inches (3 to 9 centimeters (cm)) (approximately 3 to 6 months old), they settle onto shallow nearshore waters in rocky or cobble substrates with or without kelp (Love et al. 1991; Love et al. 2002). These habitat features offer a beneficial mix of warmer temperatures, food, and refuge from predators (Love et al. 1991). Areas with floating and submerged kelp species support the highest densities of most juvenile rockfish (Carr 1983; Halderson and Richards 1987; Matthews 1990; Hayden-Spear 2006). Unlike bocaccio, juvenile and young-of year yelloweye rockfish do not typically occupy intertidal waters (Love et al. 1991; Studebaker et al. 2009; NMFS 2017a), but settle in 98 to 131 feet (30 to 40 meters (m) of water near the upper depth range of adults (Yamanaka and Lacko 2001).

Subadult and adult yelloweye rockfish and bocaccio typically utilize habitats with moderate to extreme steepness, complex bathymetry, and rock and boulder-cobble complexes (Love et al. 2002). Within PS proper, each species has 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). Yelloweye rockfish remain near the bottom and have small home ranges, while bocaccio have larger home ranges, move long distances, and spend time suspended in the water column (Love et al. 2002). Adults of each species are most commonly found between 131 to 820 feet (40 to 250 m) (Orr et al. 2000; Love et al. 2002).

Yelloweye rockfish are one of the longest-lived of the rockfishes, with some individuals reaching more than 100 years of age. They reach 50 percent maturity at sizes around 16 to 20 inches (40 to 50 cm) and ages of 15 to 20 years (Rosenthal et al. 1982; Yamanaka and Kronlund 1997). The maximum age of bocaccio is unknown, but may exceed 50 years, and they reach reproductive maturity near age 6.

In the following section, we summarize the condition of yelloweye rockfish and bocaccio at the DPS level according to the following demographic viability criteria: abundance and productivity, spatial structure/connectivity, and diversity. These viability criteria are outlined in McElhany et al. (2000) and reflect concepts that are well founded in conservation biology and are generally applicable to a wide variety of species. These criteria describe demographic risks that individually and collectively provide strong indicators of extinction risk (Drake et al. 2010). There are several common risk factors detailed below at the introduction of each of the viability criteria for each listed rockfish species. Habitat and species limiting factors can affect abundance, spatial structure and diversity parameters, and are described.

Abundance and Productivity

There is no single reliable historical or contemporary population estimate for the yelloweye rockfish or bocaccio within the full range of the PS/GB DPSs (Drake et al. 2010). Despite this limitation, there is clear evidence each species' abundance has declined dramatically, largely due to recreational and commercial fisheries that peaked in the early 1980's (Drake et al. 2010;

Williams et al. 2010). Analysis of SCUBA surveys, recreational catch, and WDFW trawl surveys indicated total rockfish populations in the PS region are estimated to have declined between 3.1 and 3.8 percent per year for the past several decades, which corresponds to a 69 to 76 percent decline from 1977 to 2014 (NMFS 2016e).

Catches of yelloweye rockfish and bocaccio have declined as a proportion of the overall rockfish catch (Palsson et al. 2009; Drake et al. 2010). Yelloweye rockfish were 2.4 percent of the harvest in North Sound during the 1960s, occurred in 2.1 percent of the harvest during the 1980s, but then decreased to an average of 1 percent from 1996 to 2002 (Palsson et al. 2009). In PS proper, yelloweye rockfish were 4.4 percent of the harvest during the 1960s, only 0.4 percent during the 1980s, and 1.4 percent from 1996 to 2002 (Palsson et al. 2009).

Bocaccio consisted of 8 to 9 percent of the overall rockfish catch in the late 1970s and declined in frequency, relative to other species of rockfish, from the 1970s to the 1990s (Drake et al. 2010). From 1975 to 1979, bocaccio averaged 4.6 percent of the catch. From 1980 to 1989, they were 0.2 percent of the 8,430 rockfish identified (Palsson et al. 2009). In the 1990s and early 2000s, bocaccio were not observed by WDFW in the dockside surveys of the recreational catches (Drake et al. 2010), but a few have been observed in recent remotely operated vehicle (ROV) surveys and other research activities.

Productivity is the measurement of a population’s growth rate through all or a portion of its life cycle. Life history traits of yelloweye rockfish and bocaccio suggest generally low levels of inherent productivity because they are long-lived, mature slowly, and have sporadic episodes of successful reproduction (Tolimieri and Levin 2005; Drake et al. 2010). Overfishing can have dramatic impacts on the size or age structure of the population, with effects that can influence ongoing productivity. When the size and age of females decline, there are negative impacts on reproductive success. These impacts, termed maternal effects, are evident in a number of traits. Larger and older females of various rockfish species have a higher weight-specific fecundity (number of larvae per unit of female weight) (Boehlert et al. 1982; Bobko and Berkeley 2004; Sogard et al. 2008). A consistent maternal effect in rockfishes relates to the timing of parturition. The timing of larval birth can be crucial in terms of corresponding with favorable oceanographic conditions because most larvae are released typically once annually, with a few exceptions in southern coastal populations and in yelloweye rockfish in PS (Washington 1978). Several studies of rockfish species have shown that larger or older females release larvae earlier in the season compared to smaller or younger females (Nichol and Pikitch 1994; Sogard et al. 2008). 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).

Contaminants such as polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and chlorinated pesticides appear in rockfish collected in urban areas (Palsson et al. 2009). While the highest levels of contamination occur in urban areas, toxins can be found in the tissues of fish throughout PS (West et al. 2001). Although few studies have investigated the effects of toxins on rockfish ecology or physiology, other fish in the PS region that have been studied do show a substantial impact, including reproductive dysfunction of some sole species

(Landahl et al. 1997). Reproductive function of rockfish is also likely affected by contaminants (Palsson et al. 2009) and other life history stages may be affected as well (Drake et al. 2010).

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 their 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). Recruitment of all species of rockfish 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 PS is unknown; however, given the general importance of climate to rockfish recruitment, it is likely that climate strongly influences the dynamics of listed rockfish population viability (Drake et al. 2010), although the consequences of climate change to rockfish productivity during the course of the proposed action would likely be small.

Yelloweye Rockfish Abundance and Productivity

Yelloweye rockfish within the PS/GB (in U.S. waters) are very likely the most abundant within the San Juan Basin. The San Juan Basin has the most suitable rocky benthic habitat (Palsson et al. 2009) and historically was the area of greatest numbers of angler catches (Moulton and Miller 1987; Olander 1991).

Productivity for yelloweye rockfish is influenced by long generation times that reflect intrinsically low annual reproductive success. Natural mortality rates have been estimated from 2 to 4.6 percent (Yamanaka and Kronlund 1997; Wallace 2007). Productivity may also be particularly impacted by Allee effects, which occur as adults are removed by fishing and the density and proximity of mature fish decreases. Adult yelloweye rockfish typically occupy relatively small ranges (Love et al. 2002) and it is unknown the extent they may move to find suitable mates.

In Canada, yelloweye rockfish biomass is estimated to be 12 percent of the unfished stock size on the inside waters of Vancouver Island (DFO 2011). There are no analogous biomass estimates in the U.S. portion of the yelloweye rockfish DPS. However, WDFW has generated several population estimates of yelloweye rockfish in recent years. ROV surveys in the San Juan Island region in 2008 (focused on rocky substrate) and 2010 (across all habitat types) estimated a population of 47,407±11,761 and 114,494±31,036 individuals, respectively. A 2015 ROV survey of that portion of the DPSs south of the entrance to Admiralty Inlet encountered 35 yelloweye rockfish, producing a preliminary population estimate of 66,998±7,370 individuals (WDFW 2017). For the purposes of this analysis we use the an abundance scenario derived from the combined WDFW ROV survey in the San Juan Islands in 2010, and the 2015 ROV survey in PS proper. We chose the 2010 survey in the San Juan Islands because it occurred over a wider range of habitat-types than the 2008 survey. We use the lower confidence intervals for each survey to form a precautionary analysis and total yelloweye population estimate of 143,086 fish within the U.S. portion of the DPS.

Bocaccio Abundance and Productivity

Bocaccio in the PS/GB were historically most common within the South Sound and Main Basin (Drake et al. 2010). Though bocaccio were never a predominant segment of the multi-species rockfish abundance within the PS/GB (Drake et al. 2010), their present-day abundance is likely a fraction of their pre-contemporary fishery abundance. Bocaccio abundance may be very low in large segments of the PS/GB. Productivity is driven by high fecundity and episodic recruitment events, largely correlated with environmental conditions. Thus, bocaccio populations do not follow consistent growth trajectories and sporadic recruitment drives population structure (Drake et al. 2010).

Natural annual mortality is approximately 8 percent (Palsson et al. 2009). Tolimieri and Levin (2005) found that the bocaccio population growth rate is around 1.01, indicating a very low intrinsic growth rate for this species. 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). Given their severely reduced abundance, Allee effects may be particularly acute for bocaccio, even considering the propensity of some individuals to move long distances and potentially find mates.

In Canada, the median estimate of bocaccio biomass is 3.5 percent of its unfished stock size (though this included Canadian waters outside of the DPS's area) (Stanley et al. 2012). There are no analogous biomass estimates in the U.S. portion of the bocaccio DPS. However, The ROV survey of the San Juan Islands in 2008 estimated a population of 4,606±4,606 (based on four fish observed along a single transect), but no estimate could be obtained in the 2010 ROV survey because this species was not encountered. A single bocaccio encountered in the 2015 ROV survey produced a statistically invalid population estimate for that portion of the DPS lying south of the entrance to Admiralty Inlet and east of Deception Pass. Several bocaccio have been caught in genetic surveys and by recreational anglers in PS proper in the past several years.

In summary, though abundance and productivity data for yelloweye rockfish and bocaccio is relatively imprecise, both abundance and productivity have been reduced largely by fishery removals within the range of each PS/GB DPSs.

Spatial Structure and Connectivity

Spatial structure consists of a population's geographical distribution and the processes that generate that distribution (McElhany et al. 2000). A population's spatial structure depends on habitat quality, spatial configuration, and dynamics as well as dispersal characteristics of individuals within the population (McElhany et al. 2000). Prior to contemporary fishery removals, each of the major basins in the range of the DPSs likely hosted relatively large populations of yelloweye rockfish and bocaccio (Washington 1977; Washington et al. 1978; Moulton and Miller 1987). This distribution allowed each species to utilize the full suite of available habitats to maximize their abundance and demographic characteristics, thereby enhancing their resilience (Hamilton 2008). This distribution also enabled each species to potentially exploit ephemerally good habitat conditions, or in turn receive protection from smaller-scale and negative environmental fluctuations. These types of fluctuations may change prey abundance for various life stages and/or may change environmental characteristics that influence the number of annual recruits. Spatial distribution also provides a measure of protection from larger scale anthropogenic changes that damage habitat suitability, such as oil spills or hypoxia that can occur within one basin but not necessarily the other basins. Rockfish population resilience is sensitive to changes in connectivity among various groups of fish (Hamilton 2008). Hydrologic connectivity of the basins of PS is naturally restricted by relatively shallow sills located at Deception Pass, Admiralty Inlet, the Tacoma Narrows, and in Hood Canal (Burns 1985). The Victoria Sill bisects the SJDF and runs from east of Port Angeles north to Victoria, and regulates water exchange (Drake et al. 2010). These sills regulate water exchange from one basin to the next, and thus likely moderate the movement of rockfish larvae (Drake et al. 2010). When localized depletion of rockfish occurs, it can reduce stock resiliency (Hilborn et al. 2003; Hamilton 2008). The effects of localized depletions of rockfish are likely exacerbated by the natural hydrologic constrictions within PS.

Yelloweye Rockfish Spatial Structure and Connectivity

Yelloweye rockfish spatial structure and connectivity is threatened by the reduction of fish within each basin. This reduction is likely most acute within the basins of PS proper. Yelloweye rockfish are probably most abundant within the San Juan Basin, but the likelihood of juvenile recruitment from this basin to the adjacent basins of PS proper is naturally low because of the generally retentive circulation patterns that occur within each of the major basins of PS proper.

Bocaccio Spatial Structure and Connectivity

Most bocaccio may have been historically spatially limited to several basins. They were historically most abundant in the Main Basin and South Sound (Drake et al. 2010) with no documented occurrences in the San Juan Basin until 2008. Positive signs for spatial structure and connectivity come from the propensity of some adults and pelagic juveniles to migrate long distances, which could re-establish aggregations of fish in formerly occupied habitat (Drake et al. 2010). The apparent reduction of populations of bocaccio in the Main Basin and South Sound represents a further impairment in the historically spatially limited distribution of bocaccio, and adds risk to the viability of the DPS.

In summary, spatial structure and connectivity for each species have been adversely impacted, mostly by fishery removals. These impacts on species viability are likely most acute for yelloweye rockfish because of their sedentary nature as adults.

Diversity

Characteristics of diversity for rockfish include fecundity, timing of the release of larvae and their condition, morphology, age at reproductive maturity, physiology, and molecular genetic characteristics. In spatially and temporally varying environments, there are three general reasons why diversity is important for species and population viability: (1) diversity allows a species to use a wider array of environments, (2) diversity 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.

Yelloweye Rockfish Diversity

Yelloweye rockfish size and age distributions have been truncated (Figure 4). Recreationally caught yelloweye rockfish in the 1970s spanned a broad range of sizes. By the 2000s, there was some evidence of fewer older fish in the population (Drake et al. 2010). No adult yelloweye rockfish have been observed within the WDFW ROV surveys and all observed fish in 2008 in the San Juan Basin were less than 8 inches long (20 cm) (Pacunski et al. 2013). Since these fish were observed several years ago, they are likely bigger. However, Pacunski et al. (2013) did not report a precise size for these fish; thus, we are unable to provide a precise estimate of their likely size now. As a result, the reproductive burden may be shifted to younger and smaller fish. This shift could alter the timing and condition of larval release, which may be mismatched with habitat conditions within the range of the DPS, potentially reducing the viability of offspring (Drake et al. 2010). Recent genetic information for yelloweye rockfish further confirmed the existence of fish genetically differentiated within the PS/GB compared to the outer coast (NMFS 2016e) and that yelloweye rockfish in Hood Canal are genetically divergent from the rest of the DPS. Yelloweye rockfish in Hood Canal are addressed as a separate population in the recovery plan (NMFS 2017a).

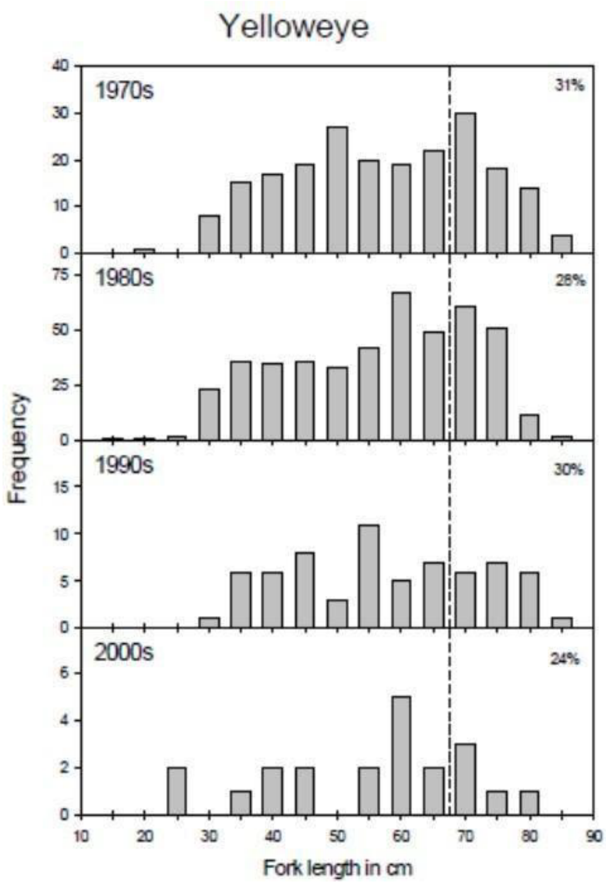

Figure 4. Yelloweye rockfish length frequency distributions (cm) binned within four decades.

Bocaccio Diversity

Size-frequency distributions for bocaccio in the 1970s indicate a wide range of sizes, with recreationally caught individuals from 9.8 to 33.5 inches (25 to 85 cm) (Figure 5). This broad size distribution suggests a spread of ages, with some successful recruitment over many years. A similar range of sizes is also evident in the 1980s' catch data. The temporal trend in size distributions for bocaccio also suggests size truncation of the population, with larger fish becoming less common over time. By the decade of the 2000s, no size distribution data for bocaccio were available. Bocaccio in the PS/GB may have physiological or behavioral adaptations because of the unique habitat conditions in the range of the DPS. The potential loss of diversity in the bocaccio DPS, in combination with their relatively low productivity, may result in a mismatch with habitat conditions and further reduce population viability (Drake et al. 2010).

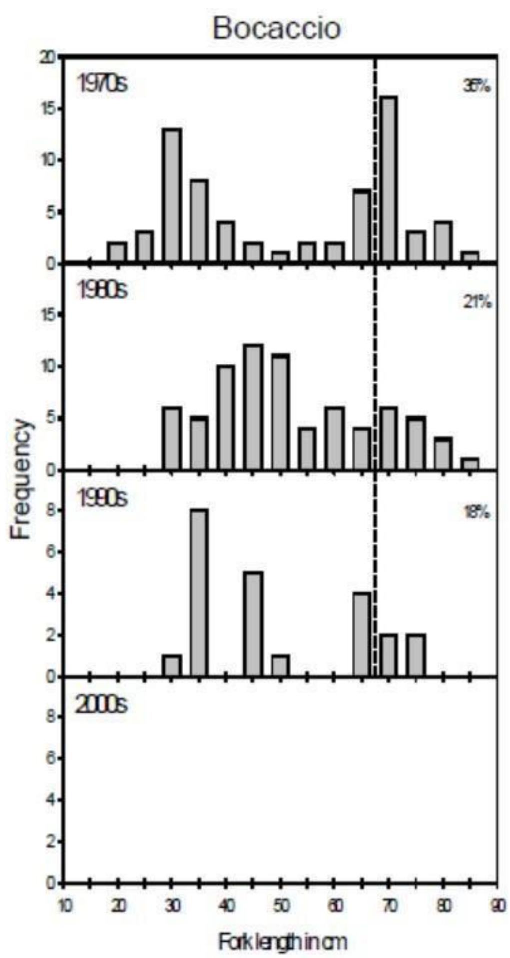

Figure 5. Bocaccio length frequency distributions (cm) within four decades. The vertical line depicts the size at which about 30 percent of the population comprised fish larger than the rest of the population in the 1970s, as a reference point for a later decade.

In summary, diversity for each species has likely been adversely impacted by fishery removals. In turn, the ability of each fish to utilize habitats within the action area may be compromised.

Limiting Factors

Climate Change and Other Ecosystem Effects

As reviewed in ISAB (2007), average annual Northwest air temperatures have increased by approximately 1.8°F (1°C) since 1900, which is nearly twice that for the previous 100 years, indicating an increasing rate of change. Summer temperatures, under the A1B emissions scenario (a “medium” warming scenario), are expected to increase 3°F (1.7°C) by the 2020s and 8.5°F (4.7°C) by 2080 relative to the 1980s in the Pacific Northwest (Mantua et al. 2010). This change in surface temperature has already modified, and is likely to continue to modify, marine habitats of listed rockfish. There is still a great deal of uncertainty associated with predicting specific changes in timing, location, and magnitude of future climate change.

As described in ISAB (2007), climate change effects that have, and will continue to, influence the habitat, include increased ocean temperature, increased stratification of the water column, and intensity and timing changes of coastal upwelling. These continuing changes will alter primary and secondary productivity, marine community structures, and in turn may alter listed rockfish growth, productivity, survival, and habitat usage. Increased concentration of carbon dioxide (CO_2) (termed Ocean Acidification, or OA) reduces carbonate availability for shell-forming invertebrates. Ocean acidification will adversely affect calcification, or the precipitation of dissolved ions into solid calcium carbonate structures, for a number or marine organisms, which could alter trophic functions and the availability of prey (Feely et al. 2010). Further research is needed to understand the possible implications of OA on trophic functions in PS to understand how they may affect rockfish. Thus far, studies conducted in other areas have shown that the effects of OA will be variable (Ries et al. 2009) and species-specific (Miller et al. 2009).

There have been very few studies to date on the direct effect OA may have on rockfish. In a laboratory setting OA has been documented to affect rockfish behavior (Hamilton et al. 2014). Fish behavior changed markedly after juvenile Californian rockfish (*Sebastes diploproa*) spent one week in seawater with the OA conditions that are projected for the next century in the California shore. Researchers characterized the behavior as “anxiety” as the fish spent more time in unlighted environments compared to the control group. Research conducted to understand adaptive responses to OA on other marine organisms has shown that although some organisms may be able to adjust to OA to some extent, these adaptations may reduce the organism’s overall fitness or survival (Wood et al. 2008). More research is needed to further understand rockfish-specific responses and possible adaptations to OA.

There are natural biological and physical functions in regions of PS, especially in Hood Canal and South Sound, that cause the water to be corrosive and hypoxic, such as restricted circulation and mixing, respiration, and strong stratification (Newton and Van Voorhis 2002; Feely et al. 2010). However, these natural conditions, typically driven by climate forcing, are exacerbated by anthropogenic sources such as OA, nutrient enrichment, and land-use changes (Feely et al. 2010). By the next century, OA will increasingly reduce pH and saturation states in PS (Feely et al. 2010). Areas in PS susceptible to naturally occurring hypoxic and corrosive conditions are also the same areas where low seawater pH occurs, compounding the conditions of these areas (Feely et al. 2010).

Commercial and Recreational Bycatch

Listed rockfish are caught in some recreational and commercial fisheries in PS. Recreational fishermen targeting bottom fish the shrimp trawl fishery in PS can incidentally catch listed rockfish. In 2012, we issued an incidental take permit (ITP) to the WDFW for listed rockfish in these fisheries (Table 7) and the WDFW is working on a new ITP application (WDFW 2017). If issued, the new permit would be in effect for up to 15 years.

Table 7. Anticipated maximum annual takes for bocaccio and yelloweye rockfish by the fisheries within the WDFW ITP (2012 – 2017) (WDFW 2012).

	Recreational bottom fish		**Shrimp trawl**		**Total Annual Takes**	
	Lethal	**Non-lethal**	**Lethal**	**Non-lethal**	**Lethal**	**Non-lethal**
Bocaccio	12	26	5	0	17	26
Yelloweye Rockfish	55	87	10	0	65	87

In addition, NMFS permits limited take of listed rockfish for scientific research purposes (Section 2.4.5). Listed rockfish can be caught in the recreational and commercial halibut fishery. In 2018 we estimated that these halibut fisheries would result in up to 270 lethal takes. In addition, NMFS permits limited take of listed rockfish for scientific research purposes (Section 2.4.4). Listed rockfish can be caught in the recreational and commercial halibut fishery. In 2017 we estimated that these halibut fisheries would result in up to 270 lethal takes of yelloweye rockfish, and 40 bocaccio (all lethal) (NMFS 2018a). A recent estimate by NMFS (2020) calculated that 0.32 percent of the PS/GB yelloweye rockfish DPS and 0.32 percent of the PS/GB bocaccio DPS is killed annually as fishery bycatch (Table 8).

Table 8. Estimated (high estimate) total annual lethal take of PS/GB bocaccio and yelloweye rockfish from fisheries and research activities.

Species	Total Lethal Take in Baseline (high estimate)	DPS Abundance Estimate	Percent of DPS Killed (total lethal takes)
Bocaccio	160[a]	4,606	3.5
Yelloweye rockfish	452[b]	143,086	0.32

Source: NMFS 2020b
[a]This includes the following estimated bocaccio mortalities: 77 from the salmon fishery, 40 from the halibut fishery, 26 during research, and 17 in other fisheries.
[b]This includes the following estimated yelloweye rockfish mortalities: 66 from the salmon fishery, 270 from the halibut fishery, 51 during research, and 65 in other fisheries.

Other Limiting Factors

The yelloweye rockfish DPS abundance is much lower than it was historically. The fish face several threats, including bycatch in some commercial and recreational fisheries, non-native species introductions, and habitat degradation. NMFS has determined that this DPS is likely to be in danger of extinction in the foreseeable future throughout all of its range.

The bocaccio DPS exists at very low abundance and observations are relatively rare. 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.

In summary, despite some limitations on our knowledge of past abundance and specific current viability parameters, characterizing the viability of yelloweye rockfish and bocaccio includes their severely reduced abundance from historical times, which in turn hinders productivity and diversity. Spatial structure for each species has also likely been compromised because of a probable reduction of mature fish of each species distributed throughout their historical range within the DPSs (Drake et al. 2010).

2.2.2 Status of the Critical Habitats

This section examines 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 areas. 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).

Salmon and Steelhead Critical Habitat

For salmon and steelhead, NMFS ranked watersheds within designated critical habitat at the scale of the fifth-field hydrologic unit code (HUC_5) in terms of the conservation value they provide to each listed species they support.[4] The conservation rankings are high, medium, or low. To determine the conservation value of each watershed to species viability, NMFS's critical habitat analytical review teams (CHARTs) 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 (NOAA Fisheries 2005). 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 if it serves another important role (e.g., obligate area for migration to upstream spawning areas).

The physical or biological features of freshwater spawning and incubation sites, include water flow, quality and temperature conditions and suitable substrate for spawning and incubation, as well as migratory access for adults and juveniles (Table 9). These features are essential to conservation because without them the species cannot successfully spawn and produce offspring. The physical or biological features of freshwater migration corridors associated with spawning and incubation sites include water flow, quality and temperature conditions supporting larval and adult mobility, abundant prey items supporting larval feeding after yolk sac depletion, and free passage (no obstructions) for adults and juveniles. These features are essential to conservation because they allow adult fish to swim upstream to reach spawning areas and they allow larval fish to proceed downstream and reach the ocean.

[4] 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).

Table 9. Primary constituent elements (PCEs) of critical habitats designated for ESA-listed salmon and steelhead species considered in this opinion and corresponding species life history events.

Primary Constituent Elements Site Type	Primary Constituent Elements Site Attribute	Species Life History Event
Freshwater spawning	Substrate Water quality Water quantity	Adult spawning Embryo incubation Alevin growth and development
Freshwater rearing	Floodplain connectivity Forage Natural cover Water quality Water quantity	Fry emergence from gravel Fry/parr/smolt growth and development
Freshwater migration	Free of artificial obstruction Natural cover Water quality Water quantity	Adult sexual maturation Adult upstream migration and holding Kelt (steelhead) seaward migration Fry/parr/smolt growth, development, and seaward migration
Estuarine areas	Forage Free of artificial obstruction Natural cover Salinity Water quality Water quantity	Adult sexual maturation and "reverse smoltification" Adult upstream migration and holding Kelt (steelhead) seaward migration Fry/parr/smolt growth, development, and seaward migration
Nearshore marine areas	Forage Free of artificial obstruction Natural cover Water quantity Water quality	Adult growth and sexual maturation Adult spawning migration Nearshore juvenile rearing

CHART Salmon and Steelhead Critical Habitat Assessments. The CHART for each recovery domain assessed biological information pertaining to occupied habitat by listed salmon and steelhead, determined whether those areas contained PCEs essential for the conservation of those species and whether unoccupied areas existed within the historical range of the listed salmon and steelhead that are also essential for conservation. The CHARTs assigned a 0 to 3 point score for the PCEs in each HUC_5 watershed for:

Factor 1. Quantity,
Factor 2. Quality—Current Condition,
Factor 3. Quality—Potential Condition,
Factor 4. Support of Rarity Importance,
Factor 5. Support of Abundant Populations, and
Factor 6. Support of Spawning/Rearing.

Thus, the quality of habitat in a given watershed was characterized by the scores for Factor 2 (quality—current condition), which considers the existing condition of the quality of PCEs in the HUC_5 watershed; and Factor 3 (quality—potential condition), which considers the likelihood of achieving PCE potential in the HUC_5 watershed, either naturally or through active conservation/restoration, given known limiting factors, likely biophysical responses, and feasibility.

Puget Sound Recovery Domain. Critical habitat has been designated in PS for PS Chinook salmon, PS steelhead, and HCSR chum salmon (HCSRC). Major tributary river basins in the PS basin include the Nooksack, Samish, Skagit, Sauk, Stillaguamish, Snohomish, Lake Washington, Cedar, Sammamish, Green, Duwamish, Puyallup, White, Carbon, Nisqually, Deschutes, Skokomish, Duckabush, Dosewallips, Big Quilcene, Elwha, and Dungeness rivers, and Soos Creek.

Critical habitat for PS Chinook salmon was designated on September 2, 2005 (70 FR 52630). Critical habitat includes 1,683 miles of streams, 41 square mile of lakes, and 2,182 miles of nearshore marine habitat in PS. The PS Chinook salmon ESU has 61 freshwater and 19 marine areas within its range. Of the freshwater watersheds, 41 are rated high conservation value, 12 low conservation value, and eight received a medium rating. Of the marine areas, all 19 are ranked with high conservation value.

Critical habitat for HCSRC was designated on September 2, 2005 (70 FR 52630). Critical habitat includes 79 miles of rivers and 377 miles of nearshore marine habitat in Hood Canal. Most freshwater rivers in HCSRC designated critical habitat are in fair to poor condition (Table 10). Many nearshore areas are degraded, but some areas, including Port Gamble Bay, Port Ludlow, and Kilisut Harbor, remain in good condition (Daubenberger et al. 2017, Garono and Robinson. 2002).

Critical habitat for PS steelhead was designated on February 24, 2016 (81 FR 9252). Critical habitat includes 2,031 stream miles. Nearshore and offshore marine waters were not designated for this species. There are 66 watersheds within the range of this DPS. Nine watersheds received a low conservation value rating, 16 received a medium rating, and 41 received a high rating to the DPS. Critical habitat for PS steelhead includes freshwater spawning sites, freshwater rearing sites, and freshwater migration corridors.

Critical habitat is designated for PS Chinook salmon and HCSRC in estuarine and nearshore areas. Designated critical habitat for PS steelhead does not include nearshore areas, as this species does not make extensive use of these areas during juvenile life stage.

The following discussion is general to salmon and steelhead critical habitat in the PS basin. More specific information for each individual species' critical habitat is presented after the general discussion.

Landslides can occur naturally in steep, forested lands, but inappropriate land use practices likely have accelerated their frequency and the amount of sediment delivered to streams. Fine sediment from unpaved roads has also contributed to stream sedimentation. Unpaved roads are widespread on forested lands in the PS basin, and to a lesser extent, in rural residential areas. Historical logging removed most of the riparian trees near stream channels. Subsequent agricultural and urban conversion permanently altered riparian vegetation in the river valleys, leaving either no trees, or a thin band of trees. The riparian zones along many agricultural areas are now dominated by alder, invasive canary grass and blackberries, and provide substantially reduced stream shade and large wood recruitment (Shared Strategy for PS 2007).

Diking, agriculture, revetments, railroads and roads in lower stream reaches have caused significant loss of secondary channels in major valley floodplains in this region. Confined main channels create high-energy peak flows that remove smaller substrate particles and large wood. The loss of side-channels, oxbow lakes, and backwater habitats has resulted in a significant loss of juvenile salmonid rearing and refuge habitat. When the water level of Lake Washington was lowered 9 feet in the 1910s, thousands of acres of wetlands along the shoreline of Lake Washington, Lake Sammamish and the Sammamish River corridor were drained and converted to agricultural and urban uses. Wetlands play an important role in hydrologic processes, as they store water that ameliorates high and low flows. The interchange of surface and groundwater in complex stream and wetland systems helps to moderate stream temperatures. Forest wetlands are estimated to have diminished by one-third in Washington state (FEMAT 1993; Spence et al. 1996; Shared Strategy for PS 2007).

Loss of riparian habitat, elevated water temperatures, elevated levels of nutrients, increased nitrogen and phosphorus, and higher levels of turbidity, presumably from urban and highway runoff, wastewater treatment, failing septic systems, and agriculture or livestock impacts, have been documented in many PS tributaries (Shared Strategy for PS 2007).

Peak stream flows have increased over time due to paving (roads and parking areas), reduced percolation through surface soils on residential and agricultural lands, simplified and extended drainage networks, loss of wetlands, and rain-on-snow events in higher elevation clear cuts (Shared Strategy for PS 2007). In urbanized PS, there is a strong association between land use and land cover attributes and rates of coho spawner mortality likely due to runoff containing contaminants emitted from motor vehicles (Feist et al. 1996).

Dams constructed for hydropower generation, irrigation, or flood control have substantially affected PS salmon and steelhead populations in a number of river systems. The construction and operation of dams have blocked access to spawning and rearing habitat (e.g., Elwha River dams block anadromous fish access to 70 miles of potential habitat) changed flow patterns, resulted in elevated temperatures and stranding of juvenile migrants, and degraded downstream spawning and rearing habitat by reducing recruitment of spawning gravel and large wood to downstream areas (Shared Strategy for PS 2007). These actions tend to promote downstream channel incision and simplification (Kondolf 1997), limiting fish habitat. Water withdrawals reduce available fish habitat and alter sediment transport. Hydropower projects often change flow rates, stranding and killing fish, and reducing aquatic invertebrate (food source) productivity (Hunter 1992).

Juvenile mortality occurs in unscreened or inadequately screened diversions. Water diversion ditches resemble side channels in which juvenile salmonids normally find refuge. When diversion headgates are shut, access back to the main channel is cut off and the channel goes dry. Mortality can also occur with inadequately screened diversions from impingement on the screen, or mutilation in pumps where gaps or oversized screen openings allow juveniles to get into the system (WDFW 2009). Blockages by dams, water diversions, and shifts in flow regime due to hydroelectric development and flood control projects are major habitat problems in many PS tributary basins (Shared Strategy for PS 2007).

The nearshore marine habitat has been extensively altered and armored by industrial and residential development near the mouths of many of PS's tributaries. A railroad runs along large portions of the eastern shoreline of PS, eliminating natural cover along the shore and natural recruitment of beach sand (Shared Strategy for PS 2007).

Degradation of the near-shore environment has occurred in the southeastern areas of Hood Canal in recent years, resulting in late summer marine oxygen depletion and significant fish kills. Circulation of marine waters is naturally limited, and partially driven by freshwater runoff, which is often low in the late summer. However, human development has increased nutrient loads from failing septic systems along the shoreline, and from use of nitrate and phosphate fertilizers on lawns and farms. Shoreline residential development is widespread and dense in many places. The combination of highways and dense residential development has degraded certain physical and chemical characteristics of the near-shore environment (HCCC 2005; Shared Strategy for PS 2007).

In summary, critical habitat for salmon and steelhead throughout the PS basin has been degraded by numerous management activities, including hydropower development, loss of mature riparian forests, increased sediment inputs, removal of large wood, intense urbanization, agriculture, alteration of floodplain and stream morphology (i.e., channel modifications and diking), riparian vegetation disturbance, wetland draining and conversion, dredging, armoring of shorelines, marina and port development, road and railroad construction and maintenance, logging, and mining. Changes in habitat quantity, availability, and diversity, and flow, temperature, sediment load and channel instability are common limiting factors in areas of critical habitat.

The PS recovery domain CHART for PS Chinook salmon and HCSR chum salmon (NOAA Fisheries 2005) determined that only a few watersheds with PCEs for Chinook salmon in the Whidbey Basin (Skagit River/Gorge Lake, Cascade River, Upper Sauk River, and the Tye and Beckler rivers) are in good-to-excellent condition with no potential for improvement. Most HUC_5 watersheds are in fair-to-poor or fair-to-good condition. However, most of these watersheds have some or a high potential for improvement (Table 10).

Table 10. Puget Sound Recovery Domain: Current and potential quality of HUC5 watersheds identified as supporting historically independent populations of ESA-listed Chinook salmon (CK) and Hood Canal summer- run chum salmon (CM) (NOAA Fisheries 2005).

Watershed Name(s) and HUC$_5$ Code(s)	Listed Species	Current Quality[a]	Restoration Potential[b]
Strait of Georgia and Whidbey Basin #1711000xxx			
Skagit River/Gorge Lake (504), Cascade (506) & Upper Sauk (601) rivers, Tye & Beckler rivers (901)	CK	3	3
Skykomish River Forks (902)	CK	3	1
Skagit River/Diobsud (505), Illabot (507), & Middle Skagit/Finney Creek (701) creeks; & Sultan River (904)	CK	2	3
Skykomish River/Wallace River (903) & Skykomish River/Woods Creek (905)	CK	2	2
Upper (602) & Lower (603) Suiattle rivers, Lower Sauk (604), & South Fork Stillaguamish (802) rivers	CK	2	1
Samish River (202), Upper North (401), Middle (402), South (403), Lower North (404), Nooksack River; Nooksack River (405), Lower Skagit/Nookachamps Creek (702) & North Fork (801) & Lower (803) Stillaguamish River	CK	1	2
Bellingham (201) & Birch (204) bays & Baker River (508)	CK	1	1
Whidbey Basin and Central/South Basin #1711001xxx			
Lower Snoqualmie River (004), Snohomish (102), Upper White (401) & Carbon (403) rivers	CK	2	2
Middle Fork Snoqualmie (003) & Cedar rivers (201), Lake Sammamish (202), Middle Green River (302) & Lowland Nisqually (503)	CK	2	1
Pilchuck (101), Upper Green (301), Lower White (402), & Upper Puyallup River (404) rivers, & Mashel/Ohop (502)	CK	1	2
Lake Washington (203), Sammamish (204) & Lower Green (303) rivers	CK	1	1
Puyallup River (405)	CK	0	2
Hood Canal #1711001xxx			
Dosewallips River (805)	CK/CM	2	1/2
Kitsap – Kennedy/Goldsborough (900)	CK	2	1
Hamma Hamma River (803)	CK/CM	1/2	1/2
Lower West Hood Canal Frontal (802)	CK/CM	0/2	0/1
Skokomish River (701)	CK/CM	1/0	2/1
Duckabush River (804)	CK/CM	1	2
Upper West Hood Canal Frontal (807)	CM	1	2
Big Quilcene River (806)	CK/CM	1	1/2
Deschutes Prairie-1 (601) & Prairie-2 (602)	CK	1	1
West Kitsap (808)	CK/CM	1	1
Kitsap – Prairie-3 (902)	CK	1	1
Port Ludlow/Chimacum Creek (908)	CM	1	1
Kitsap – Puget (901)	CK	0	1
Kitsap – Puget Sound/East Passage (904)	CK	0	0
SJDF Olympic #1711002xxx			
Dungeness River (003)	CK/CM	2/1	1/2
Discovery Bay (001) & Sequim Bay (002)	CM	1	2
Elwha River (007)	CK	1	2

Watershed Name(s) and HUC5 Code(s)	Listed Species	Current Quality[a]	Restoration Potential[b]
Port Angeles Harbor (004)	CK	1	1

[a] Current PCE Condition: 3 = good to excellent, 2 = fair to good, 1 = fair to poor, 0 = poor
[b] Potential PCE Condition: 3 = highly functioning, at historic potential, 2 = high potential for improvement, 1 = some potential for improvement, 0 = little or no potential for improvement

Critical habitat for PS steelhead was designated on February 24, 2016 (81 FR 9252). Critical habitat includes 2,031 stream miles. Nearshore and offshore marine waters were not designated for this species.

Puget Sound Rockfish Critical Habitat

NMFS designated critical habitat for PS/GB yelloweye and PS/GB bocaccio rockfish on November 13, 2014 (79 FR 68042). Critical habitat is not designated in areas outside of United States jurisdiction; therefore, although waters in Canada are part of the DPSs' ranges for both species, critical habitat was not designated in that area. The U.S. portion of the PS/GB that is occupied by PS/GB yelloweye rockfish and PS/GB bocaccio can be divided into five areas, or Basins, based on the distribution of each species, geographic conditions, and habitat features. These five interconnected Basins are: (1) The San Juan/SJDF Basin, (2) Main Basin, (3) Whidbey Basin, (4) South PS, and (5) Hood Canal.

Based on the natural history of PS/GB bocaccio and their habitat needs, NMFS identified two physical or biological features, essential for their conservation: (1) Deepwater sites (>30 m) that support growth, survival, reproduction, and feeding opportunities; and (2) Nearshore juvenile rearing sites with sand, rock and/or cobbles to support forage and refuge. Habitat threats include degradation of rocky habitat, loss of eelgrass and kelp, introduction of non-native species that modify habitat, and degradation of water quality.

We have determined that approximately 644.7 square miles (1,669.8 square kilometers) of nearshore habitat for juvenile PS/GB bocaccio and 438.5 square miles (1,135.7 square kilometers) of deepwater habitat for PS/GB yelloweye rockfish and PS/GB bocaccio meet the definition of critical habitat. Critical habitat for adult PS/GB bocaccio includes 590.4 square miles of nearshore habitat and 414.1 square miles of deep water habitat.

Nearshore critical habitat for PS/GB bocaccio at juvenile life stages is defined as areas that are contiguous with the shoreline from the line of extreme high water out to a depth no greater than 98 feet (30 m) relative to mean lower low water. The PBFs of nearshore critical habitat include settlement habitats with sand, rock, and/or cobble substrates that also support kelp. Important site attributes include: (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 (DO) to support growth, survival, reproduction, and feeding opportunities.

Deep water critical habitat includes marine waters and substrates of the U.S. in PS east of Green Point in the SJDF, and serves both adult PS/GB bocaccio, and both juvenile and adult PS/GB yelloweye rockfish. Deepwater critical habitat is defined as areas at depths greater than 98 feet (30 m) that supports feeding opportunities and predator avoidance.

The federal register notice for the designation of rockfish critical habitat in PS notes that many forms of human activities have the potential to affect the essential features of listed rockfish species, and specifically calls out, among others, (1) nearshore development and in-water construction (e.g., beach armoring, pier construction, jetty or harbor construction, pile driving construction, residential and commercial construction); (2) dredging and disposal of dredged material; (3) pollution and runoff (79 FR 68041;11/13/14). Water quality throughout PS is degraded by anthropogenic sources within the Sound (e.g., pollutants from vessels) as well as upstream sources (municipal, industrial, and nonpoint sources). Nearshore habitat degradation exists throughout the PS from fill and dredge to create both land and navigational areas for commerce, from shore hardening to protect both residential and commercial waterfront properties, and from overwater structures that enable commercial and recreational boating.

NMFS's 2016 5-year status update for PS/GB rockfish (NMFS 2016e) identifies recommended future actions including protection and restoration of nearshore habitat through removal of shoreline armoring, and protecting and increasing kelp coverage.

Table 11. Physical or Biological Features of Rockfish Critical Habitat.

PS Basin	**Nearshore sq. mi. (for juvenile bocaccio only)**	**Deepwater sq. mi. (for adult and juvenile yelloweye rockfish and adult bocaccio)**	**Physical or Biological Features**		**Activities**
San Juan/Strait of Juan de Fuca	394.4	203.6	Deepwater sites <30 meters that support growth, survival, reproduction and feeding opportunities	Nearshore juvenile rearing sites with sand, rock and/or cobbles to support forage and refuge	1,2,3,6,9,10,11
Whidbey Basin	52.2	32.2			1,2,3,4,6,9,10,11
Main Basin	147.4	129.2			1,2,3,4,6,7,9,10,11
South Puget Sound	75.3	27.1			1,2,3,6,7,9,10,11
Hood Canal	20.4	46.4			1,2,3,6,7,9,10,11

Management Considerations Codes: (1) Nearshore development and in-water construction (e.g., beach armoring, pier construction, jetty or harbor construction, pile driving construction, residential and commercial construction); (2) dredging and disposal of dredged material; (3) pollution and runoff; (4) underwater construction and operation of alternative energy hydrokinetic projects (tidal or wave energy projects) and cable laying; (5) kelp harvest; (6) fisheries; (7) non-indigenous species introduction and management; (8) artificial habitats; (9) research; (10) aquaculture; and (11) activities that lead to global climate change and ocean acidification. Commercial kelp harvest does not occur presently, but would probably be concentrated in the San Juan/Georgia Basin. Artificial habitats could be proposed to be placed in each of the Basins. Non-indigenous species introduction and management could occur in each Basin.

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). The action area is determined by the greatest extent of physical, chemical and biological effects stemming from the proposed action, including activities caused by the proposed action.

The greatest extent of physical, chemical or biological effects stemming from the action is associated with potential movement of fish (biological) that could escape from net pens into the PS. We assume that released or escaped rainbow trout/steelhead could move anywhere within (PS) and tributary rivers, whereas escaped sablefish would likely move throughout Puget Sound (see Echave et al. 2013). The reasonably likely geographic extent of escaped fish include all tributary rivers to the PS, up to the lowermost year-round upstream fish passage barrier. Retrieval of escaped fish could occur in any or all of these locations. However, given the vast amount of available habitat for salmonids and sablefish in the Pacific Ocean, and the relatively small number of escaped fish expected to reach the ocean, we do not expect any measurable or observable physical, chemical or biological effects to be caused by the escaped fish beyond the PS. For this consultation, the action area is all of PS, which is defined as all waters in the PS, including the Georgia Basin and SJDF to the mouth of the Strait (Cape Flattery) and tributary rivers (Figure 6).

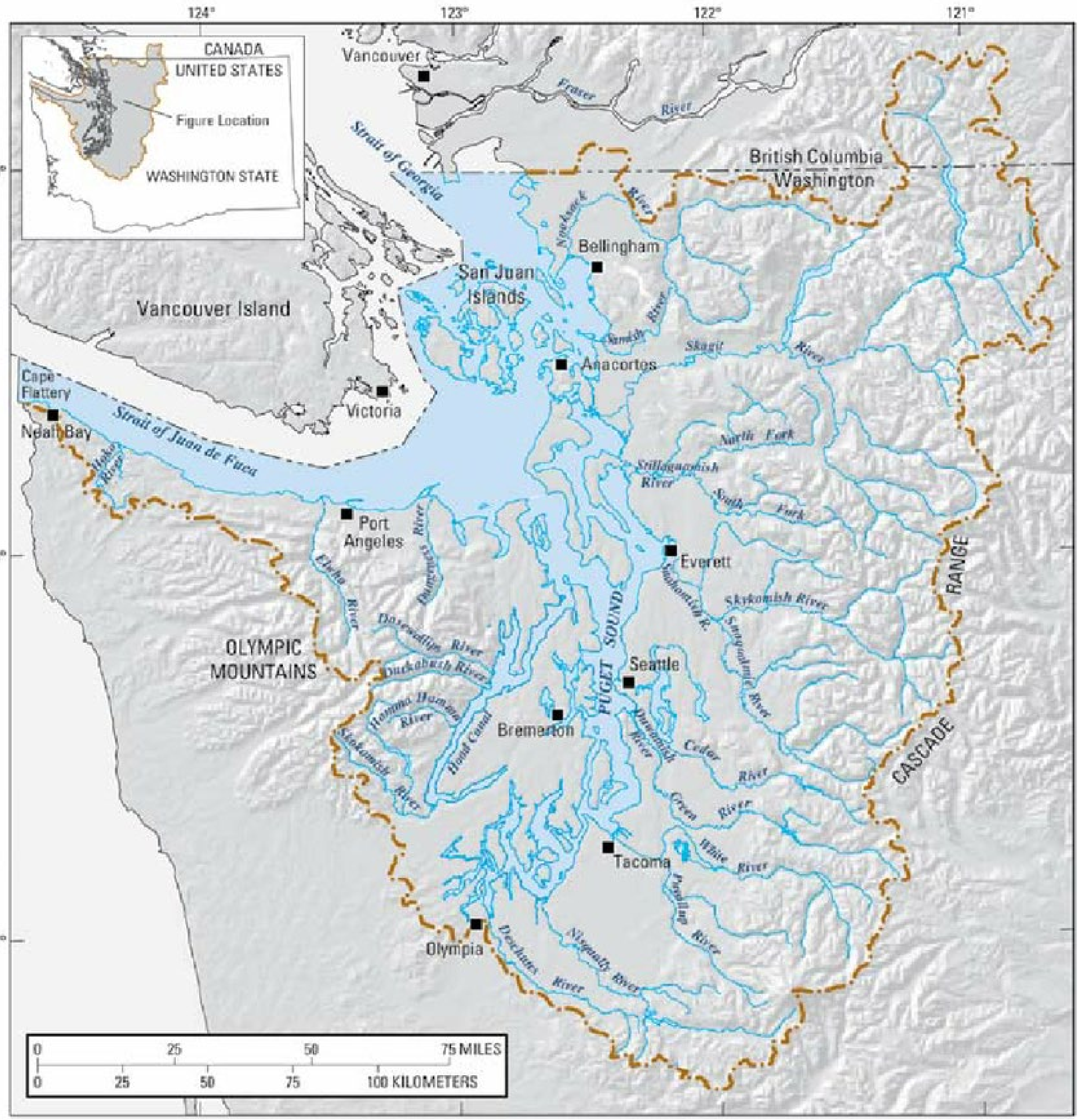

Figure 6. Action Area – Marine waters of PS (as defined to include the SJDF and Georgia Basin) and major tributary rivers, to the westernmost extent of the SJDF that defines the action area. Note that the dashed line delineates the United States - Canada jurisidictional boundary, but does not define the action area. Source: Shipman 2008.

2.4 Environmental Baseline

The "environmental baseline" refers to the condition of the listed species or its designated critical habitat in the action area, without the consequences to the listed species or designated critical habitat caused by the proposed action. 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 consultations, and the impact of state or private actions which are contemporaneous with the consultation in process. The consequences to listed species or designated critical habitat from ongoing agency activities or existing agency facilities that are not within the agency's discretion to modify are part of the environmental baseline (50 CFR 402.02).

PS is one of the largest estuaries in the United States, having over 2,400 miles of shoreline, more than two million acres of marine waters and estuarine environment, and a watershed of more than 8.3 million acres. In 1987, PS was given priority status in the National Estuary Program. This established it as an estuary of national significance under an amendment to the Clean Water Act. In 2006, the Center for Biological Diversity recognized the PS Basin as a biological hotspot with over 7,000 species of organisms that rely on the wide variety of habitats provided by PS (Center for Biological Diversity 2006). The action area includes all populations of the PS ESU of Chinook salmon, the PS DPS of steelhead and the Hood Canal summer-run DPS of chum salmon.

The State of the Sound biannual report produced by the PS Partnership (PSP) (PSP et al. 2019) summarizes how different indicators of health of the PS ecosystem are changing.[5] The assessment identifies that PS marine and freshwater habitats continue to face impacts of accelerating population growth, development, and climate change; and that few of the 2020 improvement targets (including habitat for ESA-listed salmonids and rockfish) identified by the PSP are being reached.

Over the last 150+ years, 4.5 million people have settled in the PS region. There is a suite of impacts of human development on aquatic habitat conditions in the PS, including water quality effects of stormwater runoff, industrial pollutants and boats, in-water noise from boats and construction activities, and fishing pressure, to name a few (see SSDC 2007; Hamel et al. 2015). With the level of infrastructure development associated with population growth, the PS nearshore has been altered significantly. Major physical changes documented in the PS include the simplification of river deltas, the elimination of small coastal bays, the reduction in sediment supply to the foreshore due to beach armoring, and the loss of tidally influenced wetlands and salt marsh (Fresh et al. 2011).

The PS Nearshore Ecosystem Restoration Project (PSNERP), an investigation project between the COE and the state of Washington, reviewed the historical changes to PS's shoreline environment between 1850-1880, and 2000-2006, and found the most pervasive change to PS to be the simplification of the shoreline and reduction in natural shoreline length (Simenstad et al. 2011). Recent studies have estimated the loss of nearshore habitat in PS at close to 85 percent or more (Brophy et al. 2019). Throughout PS, the nearshore areas have been modified by human activity, disrupting the physical, biological, and chemical interactions that are vital for creating and sustaining the diverse ecosystems of PS. The shoreline modifications are usually intended

[5] The Puget Sound Partnership tracks 52 vital sign indicators to measure progress toward different PS recovery goals. Of the 6 PS recovery goals, the most relevant for this Opinion include: Thriving species and food webs, Protected and Restored Habitat, Healthy Water Quality and Quantity.

for erosion control, flood protection, sediment management, or for commercial, navigational, and recreational uses. Seventy-four percent of shoreline modification in PS consists of shoreline armoring (Simenstad et al. 2011), which usually refers to bulkheads, seawalls, or groins made of rock, concrete, or wood. Other modifications include jetties and breakwaters designed to dissipate wave energy, and structures such as tide gates, dikes, and marinas, overwater structures, including bridges for railways, roads, causeways, and artificial fill. An analyses conducted in 2011 though the PS Nearshore Ecosystem Restoration Project (Fresh et al. 2011; Simenstad et al. 2011) found that since 1850, of the approximately 2,470 miles of PS shoreline:

- Shoreline armoring has been installed on 27 percent of PS shores.
- One-third of bluff-backed beaches are armored along half their length. Roads and nearshore fill have each affected about 10 percent of the length of bluff-backed beaches.
- Forty percent of PS shorelines have some type of structure that impacts habitat quality.
- Conversion of natural shorelines to artificial shoreforms occurred in 10 percent of PS.
- There has been a 93 percent loss of freshwater tidal and brackish marshes. The Duwamish and Puyallup rivers have lost nearly all of this type of habitat.
- A net decline in shoreline length of 15 percent as the naturally convoluted and complex shorelines were straightened and simplified. This represents a loss of 1,062 km or 660 miles of overall shoreline length.
- Elimination of small coastal embayments has led to a decline of 46 percent in shoreline length in these areas.
- A 27 percent decline in shoreline length in the deltas of the 16 largest rivers and a 56 percent loss of tidal wetlands in the deltas of these rivers.

Effects of shoreline armoring on nearshore and intertidal habitat function include diminished sediment supply, diminished organic material (e.g., woody debris and beach wrack) deposition, diminished over-water (riparian) and nearshore in-water vegetation (SAV), diminished prey availability, diminished aquatic habitat availability, diminished invertebrate colonization, and diminished forage fish populations (see Toft et al. 2007; Shipman et al. 2010; Sobocinski et al. 2010; Morley et al. 2012; Toft et al. 2013; Munsch et al. 2014; Dethier et al. 2016). Shoreline armoring often results in increased beach erosion waterward of the armoring, which, in turn, leads to beach lowering, coarsening of substrates, increases in sediment temperature, and reductions in invertebrate density (Fresh et al. 2011; Morley et al. 2012; Dethier et al. 2016).

The reductions to shallow water habitat, as well as reduced forage potential resulting from shoreline armoring may cause juvenile salmonids and juvenile bocaccio to temporarily utilize deeper habitat, thereby exposing them to increased piscivorous predation. Typical piscivorous juvenile salmonid and bocaccio predators, such as flatfish, sculpin, and larger juvenile salmonids, being larger than their prey, generally avoid the shallowest nearshore waters that outmigrant juvenile salmonids and juvenile bocaccio prefer. When juvenile salmonids temporarily leave the relative safety of the shallow water, their risk of being preyed upon by other fish increases. This has been shown in the marine environment where juvenile salmonid consumption by piscivorous predators increased fivefold when juvenile pink salmon were forced to leave the shallow nearshore (Willette 2001).

In addition to beach armoring, other shoreline changes including overwater structures (i.e. piers and floats), marinas, roads, and railroads reduce habitat quantity and quality, and impact nearshore salmonid migrations and juvenile bocaccio rearing. The prevalence of overwater structures (e.g., piers, ramps and floats) in the PS nearshore has also altered nearshore habitat conditions. Schlenger et al. (2011) mapped 8,972 separate overwater structures in the PS, with a total overwater coverage of 9 square kilometers. These structures, as well as turbidity from boat propeller wash typically associated with them, decrease light levels in the water column and reduce primary productivity and growth of submerged aquatic vegetation (Fresh et al. 2001; Kelty and Bliven 2003; Shafer 1999, 2002; Haas et al. 2002; Eriksson et al. 2004; Mumford 2007). This reduces forage potential and cover for juvenile fish, including ESA-listed salmonids and bocaccio. In addition to reduced cover, shading by overwater structures may also delay salmonid migration and further increase predation risk (Heiser and Finn 1970; Able et al. 1998; Simenstad 1988; Nightingale and Simenstad 2001; Willette 2001; Southard et al. 2006; Toft et al. 2013; Ono 2010). The biological opinions completed by NMFS on Regional General Permit 6 (RGP6) for structures in the PS (NMFS 2016c) and on a batch of 39 projects in the nearshore environment of PS (NMFS 2020a) provide detailed summaries of the effects of overwater structures, shoreline armoring and other nearshore structures on ESA-listed species and designated critical habitat in PS.

Benthic habitats within PS, where PS rockfish primarily occur, have been influenced by a number of factors. The degradation of some rocky habitat, loss of eelgrass and kelp, introduction of non-natural-origin species that modify habitat, and degradation of water quality are threats to marine habitat in PS (Palsson et al. 2009; Drake et al. 2010). Some benthic habitats have been impacted by derelict fishing gear that include lost fishing nets, and shrimp and crab pots (Good et al. 2010). Derelict fishing gear can continue “ghost” fishing and is known to kill rockfish, salmon, and marine mammals as well as degrade rocky habitat by altering bottom composition and killing numerous species of marine fish and invertebrates that are eaten by rockfish (Good et al. 2010). Thousands of nets have been documented within PS and most have been found in the San Juan Basin and the Main Basin. The Northwest Straits Initiative has operated a program to remove derelict gear throughout the PS region. In addition, WDFW and the Lummi, Stillaguamish, Tulalip, Nisqually and Nooksack tribes and others have supported or conducted derelict gear prevention and removal efforts. Net removal has mostly concentrated in waters less than 100 feet (33 m) deep where most lost nets are found (Good et al. 2010). The removal of over 4,600 nets and over 3,000 derelict pots have restored over 650 acres of benthic habitat, though many derelict nets and crab and shrimp pots remain in the marine environment. Several hundred derelict nets have been documented in waters deeper than 100 feet deep (NRC 2014). Over 200 rockfish have been documented within recovered derelict gear. Because habitats deeper than 100 feet (30.5 m) are most readily used by adult yelloweye rockfish and bocaccio, there is an unknown impact from deepwater derelict gear on rockfish habitats within PS.

Over the last century, human activities have introduced a variety of toxins into the Georgia Basin at levels that can affect adult and juvenile salmonid and rockfish habitat, and/or the prey that support them. Along shorelines, human development has increased nutrient loads from failing septic systems, and from use of nitrate and phosphate fertilizers on lawns and farms (Shared Strategy for PS 2007). The combination of runoff from highways and dense residential, commercial and industrial development has further degraded chemical characteristics of the PS marine environment (HCCC 2005; Shared Strategy for PS 2007; PSEMP 2017; PSEMP 2019). Toxic pollutants in PS include oil and grease, polychlorinated biphenyls (PCBs), phthalates, polybrominated diphenyl ethers (PBDEs), and heavy metals that include zinc, copper, and lead. In addition to degraded water quality, about 32 percent of the sediments in the PS region are considered to be moderately or highly contaminated (PSAT 2007), though some areas are undergoing clean-up operations that have improved benthic habitats (Sanga 2015).

Mackenzie et al. (2018) found that stormwater is the most important pathway to PS for most toxic contaminants, transporting more than half of the PS's total known toxic load (Ecology and King County 2011). During a robust PS monitoring study, toxic chemicals were detected more frequently and at higher concentrations during storm events compared with base flow for diverse land covers, pointing to stormwater pollution (Ecology 2011). The PS basin has over 4,500 unnatural surface water and stormwater outfalls, 2,121 of which discharge directly into the Sound (WDNR 2015).

In general, the pollutants in the existing stormwater discharge are diverse. The discharge itself comes from rainfall or snowmelt moving over and through the ground, also referred to here as "runoff." As the runoff travels along its path, it picks up and carries away natural and anthropogenic pollutants (U.S. EPA 2016b). Pollutants in stormwater discharge typically include the following (Buckler and Granato 1999; Colman et al., 2001; Driscoll et al., 1990; Kayhanian et al., 2003; Van Metre et al., 2006; Stokstad 2020; Tian et al., 2021):

- Excess fertilizers, herbicides, insecticides and sediment from landscaping areas.
- Chemicals and salts from de-icing agents applied on sidewalks, driveways, and parking areas.
- Oil, grease, PAHs, tire rubber-derived chemicals and other toxic chemicals from roads and parking areas used by motor vehicles.
- Bacteria and nutrients from pet wastes and faulty septic systems.
- Metals (arsenic, copper, chromium, lead, mercury, and nickel) and other pollutants from the pesticide use in landscaping, roof runoff (WDOE 2014), decay of building and other infrastructure, and particles from street and tire wear.
- Atmospheric deposition from surrounding land uses.
- Metals, PAHs, PBDEs, and phthalates from roof runoff.
- Erosion of sediment and attached pollutants due to hydromodification.

The environmental baseline would also include the projected effects of climate change for the time period commensurate with the effects of the proposed actions. Mauger et al. (2015) predict that circulation in PS is projected to be affected by declining summer precipitation, increasing sea surface temperatures, shifting streamflow timing, increasing heavy precipitation, and declining snowpack. While these changes are expected to affect mixing between surface and deep waters within PS, it is unknown how these changes will affect upwelling. Changes in precipitation and streamflow could shift salinity levels in PS by altering the balance between freshwater inflows and water entering from the North Pacific Ocean. In many areas of PS, variations in salinity are also the main control on mixing between surface and deep waters. Reduced mixing, due to increased freshwater input at the surface, can reduce phytoplankton growth, impede the supply of nutrients to surface waters, and limit the delivery of dissolved oxygen to deeper waters. Patterns of natural climate variability (e.g., El Niño/La Niña) can also influence PS circulation via changes in local surface winds, air temperatures, and precipitation.

All three ESA-listed PS salmonids were classified as highly vulnerable to climate change in a recent climate vulnerability assessment (Crozier et al., 2019). In estuarine environments, the two greatest concerns associated with climate change are rates of sea-level rise and temperature warming (Wainwright and Weitkamp 2013; Limburg et al., 2016). While the effects of climate change-induced ocean acidification on invertebrate species are well known, the direct exposure effects on salmon remains less certain (Crozier et al. 2019).

The world's oceans are becoming more acidic as increased atmospheric CO_2 is absorbed by water. The North Pacific Ocean is already acidic compared to other oceans, making it particularly susceptible to further increases in acidification (Lemmen et al., 2016). Laboratory and field studies of ocean acidification show it has the greatest effects on invertebrates with calcium-carbonate shells, and relatively little direct influence on finfish; see reviews by Haigh et al. (2015) and Mathis et al. (2015). Consequently, the largest impact of ocean acidification on salmon is likely to be its influence on marine food webs, especially its effects on lower trophic levels, which are largely composed of invertebrates such as pteropods, larval crabs, and krill, which play a significant role in some salmon diets (Haigh et al., 2015; Mathis et al., 2015; Wells et al., 2012). Marine invertebrates fill a critical gap between freshwater prey and larval and juvenile marine fishes, supporting juvenile salmon growth during the important early-ocean residence period (Daly et al., 2009, 2014).

Physiological effects of acidification may also impair olfaction, which could hinder homing ability (Munday et al., 2009), along with other developmental effects (Ou et al., 2015). Using the criteria of Morrison et al. (2015) for scoring, PS Chinook salmon, HC Chum salmon, and PS steelhead had low-to-moderate sensitivity to ocean acidification (Crozier et al., 2019).

The same document states that "sea level rise is projected to expand the area of some tidal wetlands in PS but reduce the area of others, as water depths increase and new areas become submerged. For example, the area covered by salt marsh is projected to increase, while tidal freshwater marsh area is projected to decrease. Rising seas will also accelerate the eroding effect of waves and surge, causing unprotected beaches and bluffs to recede more rapidly. The rate of sea level rise in PS depends both on how much global sea level rises and on regionally-specific factors such as ocean currents, wind patterns, and the distribution of global and regional glacier melt. These factors can result in higher or lower amounts of regional sea level rise (or even short-term periods of decline) relative to global trends, depending on the rate and direction of change in regional factors affecting sea level" (Mauger et al. 2015).

Human development in the PS region has also had significant impacts on tributary rivers. Loss of riparian habitat, decreased habitat complexity, elevated water temperatures, elevated nutrient levels, increased nitrogen and phosphorus and higher levels of turbidity have been documented in many PS tributaries (Shared Strategy for PS 2007). Increased peak stream flows as a result of increased runoff, simplified and extended drainage networks, loss of wetlands and deforestation causes substrate coarsening and decreases large wood in rivers, reducing habitat quality for spawning and rearing salmonids.

Clearing or other disturbance of riparian vegetation for roads and new developments, as well as for timber further diminishes riverine habitat quality. Often, the species that have recolonized these areas include invasive species like reed canary grass and Himalayan blackberry that provide substantially reduced stream shade and large wood recruitment (Shared Strategy for PS 2007). In the PS region, forest habitats continue to be lost (PSP et al. 2017). Decreased riparian vegetation typically destabilizes slopes leading to bank erosion, which alters stream channel morphology and can reduce the quality of spawning and rearing habitat for juvenile salmonids (Hartman et al. 1996).

Diking revetments, railroads and roads have caused significant loss of side channel habitats, channel confinement and incision, and reduced floodplain connectivity. Side channel habitats and floodplains create complex and diverse habitats that provide refugia from mainstem high flows, reduce competition for food and space, provide productive feeding areas, improve predator avoidance, and thus improve growth and survival (see Hall et al. 2007; Naiman et al. 2010; Martens and Connolly 2014). Reduced channel complexity, side channel formation and floodplain connectivity results in a significant loss of juvenile salmonid rearing and refuge habitat. Disconnecting the river channel from the floodplain also has negative impacts on nutrient cycling, system productivity, and biodiversity (Winemiller 2004). It also eliminates the recharge function that floodplains ensure by providing a source of cooler water in summer months and warmer water during winter months (Poole and Berman 2001).

Fish passage barriers, including those created by dams, culverts and weirs, have impeded the migration of native species, including access to important salmonid spawning and rearing habitat in many river systems in the PS region (Chapman 1986; Northcote 1998; LeMoine and Bodensteiner 2014). Dams constructed for hydropower generation, irrigation, or flood control have also changed flow patterns, resulted in elevated temperatures and stranding of juvenile migrants, and degraded downstream spawning and rearing habitat by reducing recruitment of spawning gravel and large wood to downstream areas (Shared Strategy for PS 2007). These actions tend to promote downstream channel incision and simplification (Kondolf 1997), limiting fish habitat. Water withdrawals reduce available fish habitat and alter sediment transport. Hydropower projects often change flow rates, stranding and killing fish, and reducing aquatic invertebrate (food source) productivity (Hunter 1992).

As described in Section 2.2 (Rangewide Status of the Species and Critical Habitats), climate change is and will continue to alter environmental conditions in the PS and tributary streams, exasperating the impacts of human development on ESA-listed species and critical habitat. Within the PS, sea level is likely to rise by 0.4 to 0.9 feet by 2050, and by 1 to 2.8 feet by 2100 (Miller et al. 2018). This is expected to result in increased coastal bluff erosion, larger storm surge, and groundwater intrusion (Miller et al. 2018). Where shoreline armoring prevents beach formation at these higher sea level elevations, the width of intertidal zones will be reduced, diminishing habitat for intertidal beach spawners, including forage species like surf smelt and sand lance (Krueger et al. 2010). It will also reduce shallow water habitat for juvenile salmonids, including PS Chinook salmon, HCSR chum salmon and PS steelhead, and juvenile PS/GB bocaccio.

Increasing average air temperatures will raise average surface water temperatures in the PS and tributary rivers. Coastal waters and the PS are expected to experience increasing but highly variable acidity, and increasing storm frequency and magnitude (Mote et al. 2014). Elevated ocean temperatures already documented for the Pacific Northwest are highly likely to continue during the next century, with sea surface temperature projected to increase by 1.0-3.7ºC by the end of the century (IPCC 2014). Habitat loss, shifts in species' ranges and abundances, and altered marine food webs could have substantial consequences to anadromous, coastal, and marine species in the Pacific Northwest (Tillmann and Siemann 2011, Reeder et al. 2013).

In the PS region, rivers will also be impacted by changes in mountain snowpack. Warming is expected to result in decreased snow pack, increased winter flows, and advanced timing of spring melt (Mote et al. 2014, Mote et al. 2016). We anticipate decreased summer precipitation, with, and more winter precipitation will be rain than snow (ISAB 2007; Mote et al. 2014). Earlier snowmelt will cause lower stream flows in late spring, summer, and fall, and water temperatures will be warmer (ISAB 2007; Mote et al. 2014). We also expect increases in the frequency of severe winter precipitation events (i.e., 20-year and 50-year events), in the western United States (Dominguez et al. 2012)

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

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

These changes will likely result in increased erosion and more frequent and severe coastal flooding, and shifts in the composition of nearshore habitats (Tillmann and Siemann 2011, Reeder et al. 2013). Estuarine-dependent salmonids such as chum and Chinook salmon are predicted to be impacted by significant reductions in rearing habitat in some Pacific Northwest coastal areas (Glick et al. 2007). Historically, warm periods in the coastal Pacific Ocean have coincided with relatively low abundances of salmon and steelhead, while cooler ocean periods have coincided with relatively high abundances, and therefore these species are predicted to fare poorly in warming ocean conditions (Scheuerell and Williams 2005; Zabel et al. 2006). This is supported by the recent observation that anomalously warm sea surface temperatures off the coast of Washington from 2013 to 2016 resulted in poor coho and Chinook salmon body condition for juveniles caught in those waters (NWFSC 2015). Changes to estuarine and coastal conditions, as well as the timing of seasonal shifts in these habitats, have the potential to impact a wide range of listed aquatic species (Tillmann and Siemann 2011, Reeder et al. 2013).

Historical harvest of salmon, steelhead and rockfish species has caused declines in PS populations. In the past, fisheries exploitation rates were generally too high for the conservation of many rockfish populations, and for naturally spawning salmon and steelhead populations. In response, over the past several decades, the co-managers have implemented strategies to manage fisheries to reduce harvest impacts and to implement harvest objectives that are more consistent with the underlying productivity of the natural populations. The effect of these overall reductions in harvest has been to improve the baseline condition and help to alleviate the effect of harvest as a limiting factor.

Since 2010, the state and Tribal fishery co-managers have managed Chinook mortality in PS salmon and Tribal steelhead fisheries to meet the conservation and allocation objectives described in the jointly-developed 2010-2014 PS Chinook Harvest RMP (PSIT and WDFW 2010), and as amended in 2014 (Grayum and Anderson 2014; Redhorse 2014), 2015, 2016, and 2017, and 2018 (Grayum and Unsworth 2015; Shaw 2015; 2016; Speaks 2017). The 2010-2014 PS Chinook Harvest RMP was adopted as the harvest component of the PS Salmon Recovery Plan for the PS Chinook ESU (NMFS 2011a). Exploitation rates for most of the PS Chinook management units have been reduced substantially since the late 1990s compared to years prior to listing (average reduction = -33%, range = -67 to +30%) (NMFS 2020b).

Fifty percent or more of the harvest of 8 of the 14 PS Chinook salmon management units occurs in salmon fisheries outside the Action Area, primarily in Canadian waters. Salmon fisheries in Canadian waters are managed under the terms of the Pacific Salmon Treaty (PST). Ocean salmon fisheries in contiguous U.S. federal waters are managed by NMFS and the PFMC, under the MSA and are managed under the terms of the PST. For salmon fisheries off of the Southeast coast of Alaska, in federal waters, the North Pacific Fisheries Management Council (NPFMC) delegates its management authority to the State of Alaska. These fisheries are also managed under the terms of the PST. The effects of these Northern fisheries (Canada and SEAK) on PS Chinook salmon were assessed in previous biological opinions (NMFS 2004; 2008e; 2019c).

NMFS observed that previous harvest management practices likely contributed to the historical decline of PS steelhead, but concluded in the Federal Register Notice for the listing determination (72 FR 26732, May 11, 2007) that the elimination of the direct harvest of wild steelhead in the mid-1990s has largely addressed this threat. The recent NWFSC biological viability assessment concluded that current harvest rates on natural-origin steelhead continue to decline and are unlikely to substantially reduce spawner abundance of most PS steelhead populations (Ford 2022).

In many PS freshwater areas, with the exception of the Skagit River, the non-treaty harvest of steelhead occurs in recreational hook-and-line fisheries targeting adipose fin-clipped hatchery summer run and winter run steelhead. Washington state prohibits the retention of natural-origin steelhead (those without a clipped adipose fin) in recreational fisheries. Treaty fisheries typically retain both natural-origin and hatchery steelhead. The treaty freshwater fisheries for winter steelhead, with the exception of the Skagit River, target primarily hatchery steelhead by fishing during the early winter months when hatchery steelhead are returning to spawn and natural-origin steelhead are at low abundance. On April 11, 2018, NMFS approved a five-year, joint tribal and state plan for a treaty harvest and recreational catch and release fishery for natural-origin steelhead in the Skagit River basin under the ESA 4(d) rule (NMFS 2018b). Average harvest rates on the same natural-origin steelhead populations have demonstrated a reduction to 1.38% in PS fisheries during the 2007/2008 to 2018/2019 time period, a 66% decline. These estimates include sources of non-landed mortality such as hooking mortality and net dropout.

To address impacts of harvest of rockfish populations, in 2010 the Washington State Fish and Wildlife Commission formally adopted regulations that ended the retention of rockfish by recreational anglers in PS and closed fishing for bottom fish in all waters deeper than 120 feet (36.6 m). On July 28, 2010, WDFW enacted a package of regulations for the closure of set net, set line, bottom and pelagic trawl, inactive pelagic trawl and inactive bottom fish pot fisheries by emergency rule for non-tribal commercial fisheries in PS in order to protect dwindling rockfish populations. As a precautionary measure, WDFW closed the above commercial fisheries westward of the listed rockfish DPSs' boundary to Cape Flattery. The WDFW extended the closure west of the rockfish DPSs' boundary to prevent commercial fishermen from concentrating gear in that area. The commercial fisheries closures were enacted on a temporary basis, but were permanently closed in February 2011. The pelagic trawl fishery was closed by permanent rule on the same date.

Hatchery programs have benefitted and harmed native-origin PS Chinook salmon, HCSR chum salmon, and PS steelhead. The central challenge of operating and managing hatchery programs is finding a balance between the risks and benefits of hatchery production for harvest or conservation. Hatchery production of Chinook salmon and steelhead can be an effective tool to increase fish abundance for conservation and harvest. However, hatcheries can also pose demographic, genetic, and ecological risks to these species. Risks and benefits of hatchery production are best evaluated in the context of the purpose of the hatchery program. Conservation of native populations is one purpose. The primary goal of Chinook salmon and steelhead conservation in Puget Sound is sustainable natural production of locally adapted fish throughout the accessible watersheds (Hard et al. 2015). Thus, to effectively achieve its goals, a conservation hatchery program must increase the abundance, productivity, spatial structure, and/or diversity of a natural-origin steelhead population. In contrast, some hatchery programs have a different goal: to provide harvest opportunities. These hatchery programs may be either integrated or segregated.

Interactions of hatchery and natural-origin Chinook salmon and steelhead pose different risks to abundance, productivity, genetic diversity, and fitness of fish spawning in the natural environment depending on how hatcheries are operated. A growing body of scientific literature, stemming from improved tools to assess parentage and other close genetic relationships on relative reproductive success of hatchery and natural-origin salmonids, suggests that strong and rapid declines in fitness of natural-produced fish due to interactions with hatchery-produced fish are possible (Araki et al. 2008; Christie et al. 2014). These studies have focused primarily on steelhead, Chinook salmon, coho salmon, and Atlantic salmon. Limited but growing evidence suggests that steelhead may be more susceptible to genetic risk (i.e., domestication) posed by hatchery propagation than other species (Ford et al. 2016). Further, because selective regimes and mortality differ dramatically between natural and cultured populations, some genetic change cannot be avoided (Waples 1999). These changes are difficult to predict quantitatively because there may be considerable variation in relative reproductive success among species, populations, and habitats, as well as temporal variability owing to environmental change.

A new role for hatcheries emerged during the 1980s and 1990s after naturally produced salmon and steelhead populations declined to unprecedented low levels. Because genetic resources that represent the ecological and genetic diversity of a species can reside in fish spawned in a hatchery, as well as in fish that spawn in the wild, hatcheries began to be used for conservation purposes (e.g., HCSR chum salmon). Such hatchery programs are designed to preserve the salmonid genetic resources until the factors limiting salmon and steelhead viability are addressed. Hatchery programs can also be used to help improve viability by increasing the number and spatial distribution of naturally spawning fish with returning hatchery adults. However, hatcheries are not a proven tool for achieving sustained increases in adult production (ISAB 2003), and the long-term benefits and risks of hatchery supplementation remain untested (Christie et al. 2014).

Because most hatchery programs are ongoing, the effects of each program are reflected in the most recent status reviews of the species (NWFSC 2015; NMFS 2017c), which was summarized in Section 2.2 of this opinion. In addition, for those hatchery programs NMFS has completed section 7 consultation on, their effects are included here in the environmental baseline. The review of HGMPs by NMFS ensures that all hatchery programs are consistent with the ESA. For those listed in Table 12, NMFS has concluded that these programs do not appreciably reduce the likelihood of survival and recovery, nor do they adversely modify critical habitat.

Table 12. Completed HGMP bundle consultations in PS and the SJDF.

HGMP Bundle	HGMP Name	Completion Date
Hood Canal Summer Chum	Quilcene NFH Supplementation	July 2002
	Hamma Hamma FH Supplementation	
	Lilliwaup Creek Supplementation	
	Union/Tahuya Supplementation/Reintroduction	
	Big Beef Creek Reintroduction	
	Chimacum Creek Reintroduction	
	Jimmycomelately Creek Reintroduction	
	Salmon Creek Supplementation	
Elwha	Lower Elwha Hatchery Native Steelhead	December 2012; Reinitiation December 2014
	Lower Elwha Hatchery Elwha Coho	
	Elwha Channel Hatchery Chinook	
	Lower Elwha Hatchery Elwha Chum	
	Lower Elwha Hatchery Pink	
Dungeness	Dungeness River Hatchery Spring Chinook	June 2016
	Dungeness River Hatchery Coho	

HGMP Bundle	HGMP Name	Completion Date
	Dungeness River Hatchery Fall Pink	
Snohomish	Tulalip Hatchery Chinook Sub-yearling	October 2017
	Wallace River Hatchery Summer Chinook	
	Wallace River Hatchery Coho	
	Tulalip Hatchery Coho	
	Tulalip Hatchery Fall Chum	
	Everett Bay Net Pen Coho	
	Wallace River Hatchery Chum Salmon Rescue Program	
Early Winter Steelhead #1	Kendall Creek Winter Steelhead	April 2016
	Dungeness River Early Winter Steelhead	
	Whitehorse Ponds Winter Steelhead	
Early Winter Steelhead #2	Snohomish/Skykomish Winter Steelhead	April 2016
	Snohomish/Tokul Creek Winter Steelhead	
Hood Canal	Hoodsport Fall Chinook	October 2016
	Hoodsport Fall Chum	
	Hoodsport Pink	
	Enetai Hatchery Fall Chum	
	Quilcene NF Hatchery Coho	
	Quilcene Bay Net Pens Coho	
	Port Gamble Bay Net Pens Coho	
	Port Gamble Hatchery Fall Chum	
	Hamma Hamma Chinook Salmon	
	Hood Canal Steelhead Supplementation	
Duwamish/Green	Soos Creek Hatchery Fall Chinook	January 2020
	Keta Creek Coho (w/Elliott Bay Net pens)	
	Soos Creek Hatchery Coho	
	Keta Creek Hatchery Chum	
	Marine Technology Center Coho	
	Fish Restoration Facility (FRF) Coho	
	FRF Fall Chinook	
	FRF Steelhead	
	Green River Native Late Winter Steelhead	
	Soos Creek Hatchery Summer Steelhead	
Stillaguamish	Stillaguamish Fall Chinook Natural Restoration	April 2020
	Stillaguamish Summer Chinook Natural Restoration	
	Stillaguamish Late Coho	
	Stillaguamish Fall Chum	

There are several enhancement net pen programs rearing native coho salmon in the PS that are operated by Tribes and WDFW, as described in Section 1.3 (Proposed Federal Action). In these operations, as part of broader hatchery programs, juvenile coho salmon are reared for a short period of time (approximately four months) in marine net pens before being released into the PS to supplement PS coho stocks. These programs provide additional coho salmon for harvest in PS commercial and recreational fisheries, as well as tribal ceremonial harvest. Separate freshwater hatcheries hatch and rear coho salmon for each of these programs before transferring them to the marine net pens. These facilities are regulated by an EPA NPDES General Permit. ESA Section 7 consultation was completed for the proposed issuance of the General Permit on the same day as this opinion.[6] Incidental take identified in the biological opinion are described below. These federal and tribal facilities and their operations, as well as any associated hatchery programs detailed above in this section, are part of the environmental baseline.

Net pens are also in operation at NOAA's Manchester Research Station in Clam Bay, near Manchester, WA to study aquaculture practices for rearing of sablefish. An ESA Section 7 and EFH consultation was completed in 2019 for proposed structural repairs and modifications being permitted by the United States Army Corps of Engineers.[7] The biological opinion identified incidental take in the form of death, injury or harassment of PS Chinook salmon, PS Steelhead, PS/GB yelloweye rockfish and PS/GB bocaccio as a result of pile driving, over-water and in-water structure presence, and entrainment by pumps. The biological opinion concluded that the proposed action is not likely to jeopardize the continued existence ESA-listed species, or destroy or adversely modify their designated critical habitat.

The federal research net pen in the PS are also regulated by the EPA NPDES General Permit, and effects of operations at the Manchester Research facility were also analyzed in the ESA Section 7 consultation for the issuance of the General Permit described above for tribal enhancement net pens. As a result of tribal enhancement and federal research net pens, the General Permit biological opinion identified incidental take of PS Chinook salmon, PS steelhead, HCSRC, PS/GB bocaccio and PS/GB yelloweye rockfish in the form of death or injury as a result of discharge effects on forage and water quality, competition and predation with escaped fish, pathogen transmission from net pen fish, and entrainment in water pumps. The biological opinion concluded that the proposed action is not likely to jeopardize the continued existence ESA-listed species, or destroy or adversely modify their designated critical habitat. The effects of these federal and tribal facilities are part of the environmental baseline and as such are considered in our jeopardy and adverse modification analysis in the Integration and Synthesis Section 2.7 below, consistent with 50 CFR 402.14(g)(4).

In addition to the sablefish net pen research operations and the coho enhancement programs, there are currently four operational commercial net pen facilities in PS, all operated by Cooke Aquaculture, Inc. The final harvest of Atlantic salmon from these PS net pens occurred during October 2020 (K. Bright, personal communication, November 23, 2020). An additional three Cooke Aquaculture, Inc. net pen farming sites are also present in the PS, but are not currently operating and Cooke Aquaculture, Inc. has removed all structures and mooring systems. Cooke Aquaculture, Inc. intends to farm all-female triploid rainbow trout/steelhead at all of their net pen facilities once they have attained the required permits and leases. There remains some uncertainly if the three sites where facilities are not present or operational would be reinstated for future net pen operations. However, for this biological opinion we assume that future rainbow trout/steelhead aquaculture would occur only at the four sites that remain operational with existing structures in place. Cooke Aquaculture, Inc. has not yet applied for permits to rear

[6] Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the NPDES General Permit for Tribal Enhancement and Federal Research Marine Net Pen Facilities Within Puget Sound, NPDES Permit No. WAG132000. WCR-2021-03087.

[7] WCRO-2019-00105, Reinitiation of Endangered Species Act Section 7(a)(2) Biological Opinion, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the Replacement of a Pump Float, Removal and Relocation of Net Pens at NOAA's Manchester Research Lab in PS (NMFS 2019b).

sablefish in PS net pens, but it has expressed an intent to begin farming sablefish as a secondary crop to rainbow trout/steelhead in the near future (e.g., see Cooke 2020e). For this reason, we include the future operation of raising both sablefish and rainbow trout/steelhead at the four existing facilities as consequences of the proposed action in the effects section of this document. The maintenance and operation of commercial net pens in the PS are considered consequences of the proposed action and their effects are assessed in the present Biological Opinion.

2.5 Effects of the Action

Under the ESA, "effects of the action" are all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action (see 50 CFR 402.02). A consequence is caused by the proposed action if it would not occur but for the proposed action and it is reasonably certain to occur. Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the action (see 50 CFR 402.17). In our analysis, which describes the effects of the proposed action, we considered the factors set forth in 50 CFR 402.17(a) and (b).

Effects of the proposed action evaluated here are those of activities caused by EPA's approval of revised water quality and sediment standards and definitions. The consequence of EPA's action is the use of net pens to 'farm raise/rear' fish in PS at four net pen sites for the foreseeable future. We have based our assumptions about net pen facility structures on the Cooke Aquaculture, Inc. facilities currently present at their four PS net pen sites (hereon referred to as 'PS commercial net pens') (see Table 1 in Section 1.3, Proposed Federal Action). We have based our assumptions about net pen operations on those most recently carried out for Atlantic salmon farming and those proposed for rainbow trout/steelhead and sablefish farming at these facilities, and included in Cooke Aquaculture, Inc.'s operations and maintenance planning documents, as well as other documentation required by state permits. We consider the rainbow trout/steelhead farming facilities and operations proposed by Cooke Aquaculture, Inc. in their permitting documents, as well as requirements imposed by permits that have been issued by state agencies to be reasonably certain to occur. We thus use these as the basis for assumptions about likely facilities and operations in our analyses of effects.

The operations and conservation measures expected with PS commercial net pens are detailed below in the analyses of effects with each effects pathway to which they pertain. The facility maintenance, operations monitoring and conservation measures include, but are not limited to the following:

- Underwater video monitoring of net pens structures and operations;
- Inspections to assess structural integrity of net pens;
- Net cleaning and maintenance procedures to prevent biofouling and fish escape;
- Implementation of site-specific response plans in the event of a fish release;
- Routine maintenance of net pens;
- Monitoring and reporting of potential fish escapes during stocking and harvesting;
- Monitoring and reporting fish feed consumption;
- Monitoring and reporting of water quality (DO) within the water column at net pen sites;
- Fallow period of a minimum of 42 days;

- Cleaning of net pens between harvest and stocking periods;
- Implementation of a Pollution Prevention Plan (Cooke 2020c);
- The use of no anti-foulants on nets;
- Disinfection of all rainbow trout/steelhead eggs, tested for regulated pathogens 30 days post-swim-up after hatching, and again before being transported to the marine net pens;
- During net pen residence, daily observations of fish behavior, feeding, and net pen water conditions;
- Assessment of moribund fish within pens for physical damage and signs of disease, and a post-mortem necropsy would be conducted to determine the cause of mortality;
- Vaccination of fish prior to stocking within net pens;
- Use of medicated feed, only as needed, to treat bacterial infections;
- Monitoring and reporting of antibiotic use. Sediment antibiotic resistance monitoring would be implemented with unusually high antibiotic usage levels;
- Stocking of only a single cohort of fish (single generation stocking) at a farm at a time to minimizes risk of pathogen transmission;
- Reporting of disease outbreaks, unexplained mortality, and regulated, reportable, or exotic pathogen findings; and
- Closure monitoring to monitor the return of sediment quality to baseline conditions if net pens are removed or relocated.

While the farming of Atlantic salmon in the PS is no longer considered reasonably likely we have used applicable information from prior Atlantic salmon farming operations in the PS and elsewhere, such as structural failure rates, observed pathogen transmission, documented water quality and sediment contaminant levels, and antibiotic and other chemical application (as the best available information) to build assumptions about the operations of these facilities and documented environmental effects for our analysis of effects of anticipated rainbow trout/steelhead and sablefish farming. Our effects determinations are based on the operation of these commercial net pens in the PS as authorized by state and federal permits or other regulatory requirements.

NMFS review established several effects pathways that could result from the federal action. To account for each effect pathway on critical habitat, including aquaculture best management practices to minimize or offset effects, NMFS assigned the likelihood that a PBF would be exposed to a stressor, the magnitude of a PBF response and the consequence of PBF exposure and response to each response action stressor a rating of low, moderate or high (Figure 7). These qualifiers are defined as follows for likelihood of exposure:

- Low—Short duration, minimal, very limited or unlikely overlap of stressors with habitat or individuals.
- Moderate—Infrequent, limited, somewhat likely overlap of stressors with habitat or individuals.
- High—Frequent, routine or highly likely overlap of stressors with habitat or individuals.

For the magnitude of response these qualifiers are defined as follows:

- Low—Minimal susceptibility to stressor; lack of response; effect levels do not rise to level of individual fitness; or anticipated effect is negligible.
- Moderate—Some susceptibility to stressor; adverse response likely occurs, but is sub-lethal in nature and highly variable; or only specific life stages are susceptible, more than negligible, but death is not expected.
- High—Very susceptible to stressor and results in overt death or ecological death (sub-lethal effect compromises ecologically significant behaviors, such as rearing, spawning and predator avoidance).

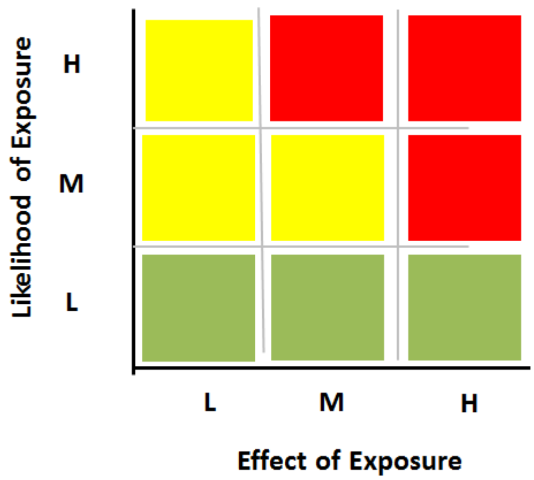

Figure 7. Likelihood of exposure and magnitude of response plot. L=low, M=moderate, H=high. Red squares indicate high consequence, yellow squares indicate moderate consequence, and green squares indicate low consequence to individual fitness

To account for each effect pathway on listed species, NMFS applied PBF stressor response magnitudes to applicable life stages to qualitatively estimate a likelihood of individual exposure, magnitude of individual response, and consequence of individual exposure and response to fitness. Finally, NMFS estimated the probability of individual exposure, magnitude of individual response, and consequence of individual exposure and response to fitness for the direct effect pathways that do not arise through a PBF. The results of this analysis are provided below in our effects matrix tables—Table 15 for effects to habitat and Table 17 for effects on species.

2.5.1 Effects on Habitat in the Action Area

Effects of the proposed action evaluated here are those of activities caused by EPA’s approval of revised water quality and sediment standards and definitions. The consequence of EPA’s action is the use of net pens to ‘farm raise/rear’ fish in PS at four net pen sites for the foreseeable future. In addition to site-specific effects at the net pen locations associated with ongoing operations, escape of famed fish into the environment as a result of large-scale structural failures and smaller leakage events is considered reasonably likely to occur, and escaped fish, as described in the action area, can travel throughout PS, as well as into rivers and streams that are tributaries to PS.

The habitat effects, therefore, would range from short-term (e.g., intermittent, temporary habitat disturbance resulting from net pen structural failures), to long term (e.g., habitat alterations resulting from regular net pen operations). We present the effects as exposure and response to long-term and short short-term habitat changes, in marine and freshwater environments, and these are summarized in Table 15.

Although forage potential may be a habitat quality, we have included our assessment of effects to forage from competition between ESA-listed species and escaped farm fish for prey resources in Section 2.5.3.2 (Exposure and Response to Direct Effects). For the purposes of flow and clarity in this Opinion we have included it in Section 2.5.3.2 since the controlling variables are dependent on the results of our analyses of encounter rates between escaped fish and wild fish. Overall, the encounter rates are more closely tied to what we consider direct effects (e.g., predation, genetic and pathogen risk) between escaped farmed fish and wild fish, rather than to habitat effects. For the same reasons, effects from competition for spawning habitat (i.e. site selection and redd superimposition) are also assessed in Section 2.5.3.2.

2.5.1.1 Effects in the Marine Environment

In the marine environment, the long-term habitat effects that are reasonably likely at all times of operation would be changes to: (1) benthic conditions and sediment quality; (2) water quality; and (3) macroalge (kelp). Short-term effects in the marine environment are to (1) benthic conditions and (2) macroalge. We detail these expected effects below.

1) Effects on Benthic Conditions and Sediment Quality

Long-Term Exposure

The sea floor would be exposed over the long-term, to the placement and presence of the anchoring system, and to physical and chemical changes in sediment quality as materials (bio-deposits and other contaminants) from the net pen drop to the bottom. Sediment degradation from net pen aquaculture bio-deposits is a well-documented risk (see Nash 2003; Price and Morris 2013; Rust et al. 2014).

Benthic Conditions—Net pen anchors, anchor chains, and mooring lines may disturb the seafloor and alter benthic conditions when they make contact with the seafloor during maintenance activities or during a structural failure. During a net pen facility failure, other structures may also become submerged and come to rest on the seafloor. This has the potential to affect prey species (invertebrates and the small fish that eat those invertebrates) that provide forage for salmonids and rockfish.

At the four Cooke Aquaculture, Inc. net pen facilities, there are a total of 16 anchor pins (drilled steel pins) and 97 anchors (steel Navy, Danforth and delta type), with an estimated surface area of 1,180 square feet (1 square foot per anchor pin, and 12 square feet per other anchor type) (Table 13). The anchors are set into the seafloor and mooring lines are tensioned back to the net pen facility. Most of the anchors are completely buried beneath the surface. There are currently a total of 113 anchor chains at the Cooke Aquaculture, Inc. facilities, with a total estimated surface area of chain on the seafloor of 2,260 square feet (approximately 40-foot length of 6 inch wide chain resting on the seafloor; K. Bright, personal communication, November 23, 2020). The overall total surface area of all mooring equipment on the seafloor at the four net pen sites is approximately 3,440 square feet, an average of 860 square feet at each site (Table 13).

Table 13. Benthic surface area of anchor/mooring systems at current Cooke Aquaculture, Inc. net pen facilities.

Net Pen Facility	# Anchor Pins	Total Anchor Pins Surface Area*	# of other Anchors	Total Anchor Surface Area*	# of Chains connected to Anchor Points	Total Chain Surface Area *	Total Surface Area of Mooring Equipment *
Hope Island	0	0	25	300	25	500	800
Fort Ward	2	2	20	240	22	440	682
Orchard Rocks	11	11	22	264	33	660	935
Clam Bay	3	3	30	360	33	660	1023
Total		**16**		**1164**		**2260**	**3440**

Source: K. Bright, personal communication, November 23, 2020
*All surface area in square feet

Net pen mooring lines are maintained in an upright position to minimize lateral movement, and anchor chains do not move laterally from side to side, so prolonged disturbance to the benthic environment around anchors is minimal. However, at some sites a small portion of the chain length would lift vertically off the seafloor during ebb and flood tidal currents, when the tension of the mooring point increases. As the tidal current slacks, the chain comes back to rest on the seafloor (K. Bright, personal communication, November 23, 2020). Generation of suspended sediment and benthic disturbance is expected to be minor and localized in the area immediately adjacent to the anchors during general presence and operation of net pen facilities. Anchors, anchor chains and mooring lines would be expected to rarely need replacement (every 10 to 15 years; K. Bright, personal communication, November 23, 2020), and benthic disturbance from removal of an anchor and installation of a new anchor would be small, localized and short-term. We anticipate colonization of exposed anchor structures by invertebrates and algae (Rensel and Forster 2007; K. Bright, personal communication, November 23, 2020). The footprint of the anchors and chains on the seafloor is the only area where benthic conditions would be affected over the long-term, and to the degree that these become covered with sediment and benthic organisms over time, we expect the presence of the anchors to have low consequence to benthic condition.

Sediment quality—Sediment under and near the net pens would be affected by the feeding operations, cleaning of structures and net pen maintenance activities. For the purpose of our analysis we rely on Cooke Aquaculture, Inc.'s Pollution Prevention Plan (Cooke 2020c) and Spill Prevention, Response and Control Plan (Cooke 2020d) and their Operations and Maintenance Manual (Cooke 2020a), which establishes procedures and methods that prevent the discharge of oil, petroleum products or other hazardous pollutants into PS that could contaminate sediments, and their feeding plan.

To reduce fish waste and avoid excess feed, Cooke Aquaculture, Inc. has developed feeding strategies to minimize the amount of food that falls through the cages and onto the sea floor. The standards provided by these strategies are part of their Pollution Prevention Plan (Cooke 2020a), and include fish size-appropriate feed size and feeding duration. Feeding rates are adjusted based on weather or water conditions that may affect fish appetite and feed consumption. Underwater cameras are used to observe the condition of feeding pellets to ensure no excessive fine material, and to observe the amount of uneaten food falling through the pens. The feeding rate is then immediately adjusted as needed to minimize excess food. With advancements in marine finfish rearing science and technology, the net pen aquaculture industry in the United States has greatly reduced waste products and impacts from nutrient discharge (Price and Morris 2013; Rust et al. 2014). Periodic cleaning of accumulated microorganisms, plants and animals on the nets (biofouling) would also result in changes in physical and chemical benthic conditions. Net cleaning causes biofouling drop-off from the nets and biodeposition on the seafloor.

Over the past several decades the use of antibiotics, antifoulants and other chemicals has been reported to have decreased by over 95% in PS finfish aquaculture (Price and Morris 2013). To reduce the accumulation of net biofouling, current NPDES permits require that Cooke Aquaculture, Inc. prevent the excessive accumulation of marine growth, and provide verification of the efficacy of in-situ net cleaning (see Ecology 2021). At all facilities, divers perform weekly visual assessment of biofouling on every containment net, and record net hygiene scores (see Cooke 2020a). Nets are washed in-situ with pressurized water and net-washing machines, as needed. After each production cycle nets are removed from the water and cleaned off-site at a specialized facility. Regular cleaning of the nets, as needed, would limit bio-fouling loads, and avoid large volumes of biodeposition from bio-fouling drop-off. Three times per week during the growing cycle, divers also inspect net pens and remove any fish mortalities, minimizing the potential for dead fish tissues to enter the water column and be deposited on the seafloor.

Despite these measures to reduce the amount of overfeeding detritus and other contaminants from reaching the sediment, we anticipate deposition of net pen waste products (feed waste and fish feces) and biofouling material from nets onto the sea floor during net pen operations. Organic carbon compounds are the main nutrient discharge from a salmon net pen operation (e.g., Wang et al. 2012). Organic enrichment from uneaten food, fecal material from farm fish and biofouling from accumulated material falling off nets may cause changes in sediment chemistry, and benthic physical properties. Accumulation of antifoulants, antibiotics and heavy metals in sediment in close proximity to net pen facilities is also well documented (Nash 2003). Of particular concern with marine net pens are levels of zinc, which is a supplement in fish feed, and copper, found in net antifoulants.

Love et al. (2020) provided a comparison of antibiotic use rates in Atlantic salmon net pens in Norway, Scotland, Atlantic Canada, Maine, British Columbia, Washington and Chile. From 2013 through 2017, antibiotic use based on kilogram of fish was highest in Washington, but this is because bacterial pathogens are more common in PS compared to the other areas (WDFW 2020a). Interestingly, Love et al. (2020) found that the net pen Atlantic salmon industry in the United States is the first United States food animal industry that reports monthly antimicrobial use at the farm-level.

Table 14. Antibiotics, anesthetics, and disinfectants used by Cooke Aquaculture in their PS net pens.

Substance Category	Name	Fish	Dose	Treatment Duration	Withdrawal Period (days)	Approval/ Standard
Antibiotic	Romet 30-sulfadimethoxine-ormetoprim	Rainbow Trout/ Steelhead	50mg/kg	5 days	42	ANAD 125-933
		Sablefish	NA			
Antibiotic	Terramycin 200-Oxytetracycline	Rainbow Trout/ Steelhead	2.5-3.75 g/100 lbs	10 days	21	INAD-9332
		Sablefish	NA			
Antibiotic	Aquaflor-Florfenical	Rainbow Trout/ Steelhead	10-15 mg/kg	10 days	15-28	INAD-10-697
		Sablefish	10-15 mg/kg	10 days	15-28	INAD-10-697
Anesthetic	Finquel (MS222)-tricaine methanesulfonate	Rainbow Trout/ Steelhead	10-1,000 mg/L	Variable	21	ANAD 200-226
Disinfectant	Iodophore	All	100 mg/L	10 min	NA	NA
Disinfectant	Chlorine Bleach	All	20 mg/L	10-60 min	NA	13 mg/L acute; 7.5 mg/L chronic, WA
Disinfectant	Hydrogen Peroxide	All	NA			
Disinfectant	Peracetic Acid	All	NA			

Note: ANAD = Approved new animal drug; INAD = Investigational New Animal Drug; WA = State of Washington; NA = Not applicable

Since antibiotics are administered to fish in net pens through medicated feed, any medicated feed that is not consumed by the farmed fish may be consumed by wild organisms, or may accumulate in sediment. Some medication may also pass through the farmed fish if not completely metabolized. Once in the sediment, antibiotics could alter bacterial communities, which could lead to an altered composition of plankton communities, and in turn, changes to the diversity and abundance of larger organisms, like salmonids, that feed on them (see Burridge et al. 2010). Friars and Armstrong (2002) identified antibiotic resistant bacteria up to 100 m away from concentrated salmon farms. In the PS, studies have shown an exponential decline in antibiotic-resistant bacteria with distance from net pens (see Hargrave 2003).

Under the National Environmental Policy Act (NEPA), the United States Food and Drug Administration (FDA) must consider environmental effects of properly administered drugs (see FDA 2021). For approval of a drug to be used in aquaculture, the FDA must first determine that it will not significantly impact the environment. Antibiotics available to aquaculture use should have little to no toxic effects on non-target organisms when applied as directed). When potential toxicity is indicated, the FDA suggests conditions that operators or regulatory bodies can follow to avoid toxic conditions, and have little harm on the environment. However, there is evidence that some antibiotics could persist in the sediment and induce localized antibiotic resistance. As required by the NPDES permits, disease control chemicals and drugs approved for use by the USFDA or the EPA for such purpose are permitted. If not used in accordance with product label instructions, then they must be administered by, or under supervision of, a licensed veterinarian, and be approved in advance by Ecology.

Through the use of improved aquaculture practices, including the use of vaccines, antibiotic use at net pen fish farms has been reduced significantly over the past 20 years (see Rust et al. 2014; Love et al. 2020). To reduce the use of antibiotics, Cooke Aquaculture, Inc. employs various practices to minimize its need to treat pathogens. These are described in Section 2.5.3 (Effects on Listed Species: Pathogens), and include, in addition to vaccination prior to transport to the pens, single generation stocking and fallow periods to break any disease or parasitic cycles; proper stocking and facility maintenance to keep stress levels low; proper biosecurity practices; and use of therapeutants only when necessary (K. Bright, personal communication, May 12, 2020).

Cooke also uses a few anesthetics and disinfectants for their commercial operation (Table 14). Finquel (MS 222) is periodically used when the fish are sampled for weight and condition factors. A small number of fish are captured by dip net from a pen and then immersed in a tote of seawater with a small amount of MS 222 mixed in. The MS 222 anesthetizes the fish so that they can be safely handled, inspected, weighed and then returned unharmed back to the fish pen. However, this chemical should not be used within 21 days of harvesting fish for food (AFS 2019). The fish quickly recover when returned to ambient seawater, and the solution in the tote is discarded into a sanitary sewer that flows into a water treatment plant (Cooke 2020e; Cooke 2020f; Cooke 2020g; Cooke 2020h).

Chlorine Bleach and/or Iodophor are surface disinfectants Cooke Aquaculture, Inc. may use at the net pen sites as a bio-security measure in footbaths year-round and occasionally to sterilize equipment used between sites. Similar to MS 222 mentioned above, these chemicals are also disposed of into a sanitary sewer. Recently, Cooke Aquaculture started using Hydrogen Peroxide and Peracetic Acid as disinfectants, and the use of chlorine bleach solutions at the sites is infrequent (Cooke 2020e; Cooke 2020f; Cooke 2020g; Cooke 2020h). Hydrogen Peroxide and Peracetic Acid are not considered toxic substances by the state of Washington (WAC 173-201A-240).

The accumulation of copper in sediment can result from the use of antifoulants on nets (Nash 2003; Price and Morris 2013). However, Cooke Aquaculture, Inc. does not use antifoulant paint on their netting material at farm sites in the PS (Cooke 2017). Therefore, we do not anticipate any deposition of copper, or other anti-foulant by-products from PS commercial net pens.

Zinc is another common contaminant in aquatic systems and may accumulate below net pens through deposition of fish feces and excess feed (e.g., Brooks and Mahnken 2003). Levels of zinc added to sediments have been reduced through the use of feeds with reduced levels of zinc or more bioavailable forms of zinc (Nash 2001). Studies have demonstrated that zinc concentrations return to background levels during fallowing, and there is no evidence of long-term buildup or cumulative effects under salmon farms (Brooks et al. 2003; Sutherland et al. 2007). The feeding practices described above that are employed by Cooke Aquaculture, Inc. to reduce excess feed is expected to minimize zinc deposition.

As outlined in the NPDES permits (see Ecology 2021a) and in Cooke Aquaculture, Inc.'s Operations and Maintenance Manual (Cooke 2020a), sediment management criteria include sediment silt-clay particles, TOC, zinc and benthic infaunal standards to protect biological resources and human health. Results are compared to baseline or reference conditions, or established protective standards. Monitoring of copper in sediment is not required since Cooke Aquaculture, Inc. does not use net anti-foulants. Monitoring these parameters is required annually between August 15th and September 30th, and within 45 days after first harvest, if not included within these dates. A total of five field replicate sediment grab samples are required at each net pen facility. These include four 100 feet from the net pen perimeter—one from the down current end, one from the seaward current end, one from the up current end and one from the shoreward end, as well as one sample 50 feet from the down current end. If the monitoring results exceed limits, additional exceedance monitoring is required at six locations—one 125 feet from the down current end, one 125 feet from the seaward end, one 125 feet from the up current end, one 125 feet from the shoreward end, one 50 feet from the down current end and one 150 feet from the down current end. If values still exceed required levels, the NPDES requires that the permittee work in consultation with Ecology to develop, refine and implement actions in order to return the SIZ to compliance.

Annual underwater video and photographic surveys, including noting *Beggiatoa* presence and quantity are also required by NPDES permits. As directed by the NPDES permits, antibiotic usage is also reported to state authorities, and sediment antibiotic resistance monitoring would be implemented with unusually high usage levels, or if new information on the environmental impacts becomes available. Closure monitoring is also required by NPDES permits, to monitor the return of sediment quality to baseline conditions if net pens are removed or relocated.

A review by Noakes (2014) found that the field of benthic and waste discharge impacts is typically contained within 100 m from the outer boundary of a net pen farm. Price et al. (2015) supports this finding, concluding that nutrient enrichment in the near-field water column is usually not detectable beyond 100 m of net pen sites when feed waste is minimized and net pen farms are properly cited in deep waters with flushing currents. In the years prior to the net pen collapse at Cypress Island Site 2 in 2017, two of the then eight operating commercial net pen facilities in PS had exceeded TOC trigger levels for enhanced monitoring (Hawkins et al. 2019). The two with TOC exceedances in the sediment followed the required NPDES permit steps to measure the expanse of sediment enrichment. Ultimately, these facilities took steps to move into deeper water with better dispersion and assimilation of wastes. Thus, with this regiment of monitoring, we do not expect effects beyond the SIZ that could rise to a level that negatively affects forage. If there was an exceedance, response measures would ensure any effect is short-term. However, based on the range of affected area presented by the different evaluations, we conservatively estimate that TOC could be slightly elevated within about 100 m from net pens.

With the measures implemented by the net pen operator to minimize effects on sediment quality and benthic conditions, and the protective requirements of the NPDES permits, we anticipate measurable changes to sediment quality to be localized to the areas directly beneath and immediately adjacent to net pens (i.e. the SIZs). Within this area, there may be changes to sediment quality that alter primary productivity, and benthic communities that result in decreased prey abundance for salmonids. Although prey species may move out of this area, any change to forage outside of this area is expected to be immeasurable by integration with prey populations in the wider action area.

Although Noakes (2014) found that the field of impacts from net pen waste discharge is typically contained within 100 m of the outer boundary of the farm, the author also noted that depending on oceanographic conditions suspended and dissolved waste materials may spread beyond this area and result in potential cumulative and far-field effects. This cumulative effect would be more likely to occur in areas with a high number of farms, for example as is found in some parts of Chile and Norway, and particularly in areas with poor flushing (see Nash et al. 2005; Price and Morris 2013). Because many nutrients and other net pen wastes are flushed away from immediate net pen areas and dispersed into the surrounding waters, it is difficult to assess far-field effects from the net pens versus other sources (see Hargrave 2003; Price and Morris 2013).

In regions like the PS where there are many anthropogenically derived nutrients entering coastal waters from numerous sources (see Ecology 2020), it is especially difficult to attribute nitrification to any one source, including net pens. However, monitoring and modeling studies of effluent dispersion has demonstrated that the vast majority of particulate organic waste and nutrients are dispersed in the near field (e.g., Costa-Pierce 2008; Costa Pierce et al. 2010; Price et al. 2015; Bannister et al. 2016). In the PS there is no available literature demonstrating the accumulation or sequestration of net pen wastes in far-field (distant) areas affecting benthic conditions. Although it is difficult to make a correlation between a particular source of nutrient loading in a highly developed region, like the PS basin, based on existing information, as well as benthic monitoring and citing requirements for net pens, we consider it unlikely that any net pen effects on benthic conditions that would have a measurable effect on forage would extend more than about 100 m. Potential near-field and far-field effects in the water column, including nutrient loading, are assessed below in our evaluation on water quality.

The use of all therapeutants for the treatment of specific pathogens are regulated by both federal (e.g., U.S. Food and Drug Administration) and Washington state rules. The Center for Veterinary Medicine (CVM) regulates the manufacture, distribution and use of animal drugs. Approved drugs are those that are considered safe for the target fish when applied at labeled doses. The use of unapproved drugs or approved drugs in a manner that differs from that specified on the label are prohibited unless the user has an Investigational new animal drug exemption (INAD) or an extra-label prescription from a veterinarian (AFS 2019).

Antibiotics are administered to net pen fish usually through medicated feed, referred to as Veterinary Feed Directives (VFDs) to treat bacterial pathogens (e.g., *A. salmonicida*, *Vibrio spp.*). These are prescriptions written by a licensed veterinarian of record (VOR) for a facility. Cooke proposes to use Romet 30, as well as Terramycin 200 (TM 200) and Aquaflor, which can be used under INADs obtained by the U.S. Fish and Wildlife Service, numbers 9332 and 10-697, respectively. The doses and treatment durations that Cooke proposes are within the parameters identified in the drug approvals and INAD guidelines (Table 14).

The chemical and benthic physical properties described above are likely to change the benthic community abundance and composition. Both may cause changes in benthic community composition as less tolerant species are excluded, and may ultimately reduce faunal abundance as high concentrations of contaminants become toxic. A review by Hargrave (2003) found that most studies find that the local extent of altered benthic community structure and biomass extends no further than 50 m, but in some cases diversity of infauna may be reduced up to 500 m away, depending on site depth and water currents.

Nutrient enrichment of sediment beneath net pens can result from carbon, nitrogen and phosphorus deposition as a component fish feces and excess feed. Nitrogen and phosphorus deposited from net pens may be reduced to their inorganic form through microbial decomposition and be utilized by organisms within the sediment, increasing total organic carbon. Benthic macrofauna also feed on particulate matter that descends to the seafloor, and thus abundance and diversity may increase as a result of increased food availability. This may lead to an increase in the productivity of macro-algae, invertebrates and fish (see Rust et al. 2014; Keeley et al. 2019). As a result, benthic community composition, including invertebrate and small fish species that may become prey of salmonids, may be altered. Forage is a PBF of estuarine and nearshore marine critical habitat for PS Chinook salmon and HCSRC. Benthic community composition may also be altered by nutrient enrichment by attracting predators and scavengers, and also by providing substrate (i.e. shell material) for sessile organisms (Keeley 2013). The attraction of organisms to the area under the net pens and the biomass accumulation from biofouling drop-off may exacerbate enrichment effects. For all PS commercial net pens, 30 to 42-day fallow periods are required between the time fish are harvested and new fish are stocked. This acts as a recovery period for benthic conditions.

In some cases, organic enrichment may result in an increase in the total invertebrate abundance in the sediment beneath a net pen, but also typically reduces species diversity (Obee 2009), which may reduce the abundance of appropriate salmonid prey species (forage). Elevated levels of total organic carbon is often only detectable directly beneath net pens, or in close proximity (e.g., within 100 m), and at highly dispersive sites (greater water movement/exchange) organic accumulation is reduced and may be undetectable (Keeley 2013; Price et al. 2015). Studies and data reviewed by Nash (2001; 2003) indicated that levels of carbon in sediment was elevated to about 30 m beyond Atlantic salmon net pens in the Pacific Northwest. As we mentioned above, the range of the affected area is 30 m to 500 m, and so we have made a conservative estimate within that range, at 100 m.

During decomposition of organic matter, oxygen is depleted by microbial respiration. If the amount of organic deposition beneath a net pen exceeds the assimilative capacity of the benthic community, layers may accumulate, essentially smothering the substrate. This may cause hypoxic (low oxygen levels) or anoxic (extreme hypoxia) conditions. Therefore, with excessive organic enrichment, hypoxic conditions may arise, leading to an increase in nutrient tolerant organisms and a decrease in species diversity. In anoxic conditions, sulfate reduction takes place, resulting in sulfide compounds that are toxic to benthic organisms, but may create conditions ideal for the mat-forming bacteria, *Beggiatoa* (Hargrave et al. 2008). In such an environment only species tolerant of suboxic conditions can survive, resulting in altered community structure (Rosenberg 2001; Hargrave 2010; Keeley 2013).

Nutrient enrichment also has the potential to lead to eutrophication when a body of water becomes overly enriched with nutrients results in excessive plant and algae growth. Nitrogen (dissolved inorganic nitrogen) in particular is considered a limiting nutrient in the PS, typical of marine systems (Newton and Van Voorhis 2002; Hawkins et al. 2019), and thus deposition of phosphorus and nitrogen may increase primary productivity and has the potential to lead to eutrophication. However, causal linkages between fish farming and eutrophication or phytoplankton blooms have not been identified (see Rust et al. 2014).

Short-Term Exposure

It is reasonably likely that a low number of net pen structural failures would occur and may disturb benthic conditions. Cooke performs weekly surface inspection of mooring points, and annual below surface mooring system inspection which would identify lines and attachment points in need of repair or replacement (Cooke 2020a; Cooke 2020b). Anchors, anchor chains and mooring lines are replaced as needed for maintenance, approximately every 10 to 15 years. During typical operations, any individual line failures that occur would be caught at a minimum during weekly inspection and we expect repairs to be completed in a matter of days. With this routine maintenance, we expect large-scale net pen facility failures to occur on a very infrequent basis.

Since 1985, when commercial Atlantic salmon net pens began operating in the PS (WDFW 2020a), we are aware of only four large-scale structural failure and escape events. These occurred in 1996 (107,000 salmon escaped after failure of a pen system anchor line), 1997 (369,000 salmon escaped during towing of a pen to avoid a toxic algae bloom), 1999 (115,000 salmon escaped following a pen system failure during an extreme tidal exchange). The last known escapement event occurred 18 years later with the collapse of Cooke's Cypress #2 net pen in 2017 (250,000 fish escaped after a mooring system failure and net pen collapse) (Amos and Appleby 1999; WDFW 2020a). Although there are few details available describing these four escapes, we assume that each of these escapes was a large-scale structural failure of the net pen facilities. Smaller-scale structural failure events, such as a small number of anchor lines breaking or the loss of a single cage structure, are expected to occur on a more frequent basis. We are not aware of historic information that documents the frequency of smaller scale events, but we anticipate them to also be infrequent with the expected regular monitoring and maintenance activities implemented by Cooke Aquaculture, Inc.

Current state permits, improvements in net pen technology and the commitment of the net pen aquaculture operators would reduce the likelihood of a future net pen collapse or other large-scale structural failure. For our analysis in deference to the species, NMFS considers it reasonably likely that one large-scale structural failure event would occur at each of the four net pen sites over any 50-year period of time. We have based our assumptions of future escape events on the most recent Cypress #2 failure where, based on the total production of the site, an estimated 29% of the total production of fish at the site (262,659 / 915,000) escaped (and were not recaptured). Thus, for this analysis we have defined a large-scale event and the escape and loss of fish (i.e. not recaptured/recovered) as one in which more than 29% of the maximum production number of fish at that site escape. In Section 2.5.3, Effects on Listed Species, the OMEGA model, describes how this rate of large-scale structural failures was determined. We also describe the basis for our assumptions next. Despite the rare occurrence, the effects are not discountable, and we present the likely effects that would occur with a net pen failure and fish escape.

To determine likely effects of a large-scale failure, we base our assumptions of the magnitude of potential large-scale structural failures and resulting impacts on the failure of Cypress Island #2 net pen facility that occurred in 2017. This event resulted in net pen structures and mooring lines loose in the water column and on the seafloor. Although most of the structural components were removed within two months, complete removal of debris was not completed for approximately 6 months (see Clark et al. 2017). The Cypress #2 net pen failure also resulted in the dragging of anchors along the seafloor for up to several hundred feet (Clarke et al. 2017). This, as well as removal of the anchors and other debris during salvage operations would have caused disturbance of benthic substrate. The benthic disturbance of the seafloor during this, and other potential future events, would likely displace a small number of invertebrates from the substrate, localized to the disturbance areas. We consider large-scale net pen failure events to be rare, with only four known large-scale escape events in the past 35 years. Since the Cypress #2 failure, updated NPDES permits (issued July 2019) require increased protective measures to prevent future net pen failures and escapes in PS (see Ecology 2021), including:

- Increasing underwater video monitoring of net pens;
- Conducting inspections to assess structural integrity of the net pens and submit inspection reports certified by a qualified marine engineer to Ecology;
- Improving net cleaning and maintenance procedures to prevent biofouling and fish escape;
- Requiring the permittee to develop site specific response plans in the event of a fish release, and to conduct and participate in preparedness trainings;
- Requiring improved maintenance of the net pens; and
- Maintaining contact information to notify area tribes in the event of a fish release.

Changes to the NPDES permits for modification to raise rainbow trout/steelhead also specifically include the following (see Ecology 2021):

- Clarifying that any fish reared in Cooke’s net pens are prohibited from release;
- Adding requirements and details on how to notify state agencies of events that could potentially lead to fish escape;
- Increasing monitoring and reporting of potential fish escape during stocking and harvesting;

- Adding reporting for fish feed consumption;
- Adding details on how nets must be maintained; and
- Adding a requirement to study new technologies and propose alternatives that reduce or prevent discharge of uneaten feed or metabolic waste

These and additional maintenance measures are also detailed in Cooke Aquaculture, Inc.'s Operations and Maintenance Manual (Cooke 2020a) and Fish Escape Prevention Plan (Cooke 2020b). As a result of these preventative measures, we anticipate any future mooring system failures to be more infrequent than they have been historically. Taking a conservative approach by analyzing likely effects based on the Cypress # 2 failure example, prior to more stringent inspection and maintenance measures, we anticipate localized benthic disturbance in the approximate net pen footprint following a failure event for a duration of less than 6 months.

When sediments are disturbed benthic prey communities are also disrupted. We expect within the footprint of disturbed areas an immediate reduction in prey abundance and prey community composition, however the response would be an intermediate reduction of prey availability, as the disrupted prey communities can quickly begin to recolonize. Similarly, net pen debris recovery following a failure would be expected to result in a small reduction to prey availability in a very small area. Any change in benthic conditions is expected to begin ameliorating its return to background shortly after disturbance, with recolonization of the sediment by invertebrates from adjacent areas. We expect no measurable effect on benthic invertebrate species abundance, diversity or productivity beyond the first few weeks' post-disruption. A review by Bolam and Rees (2003) on benthic recovery from maintenance dredge disposal in marine environments found that invertebrates typically recover within nine months to four years, depending on site conditions and the depth of the disturbance. Because impacts from net pen structures would be in a limited in spatial scale (e.g., width of mooring line movement, or footprint of debris on seafloor) compared to dredge disposal, we anticipate quicker re-colonization of disturbed areas by invertebrates in adjacent substrate (see Wilber and Clarke 2007).

During normal operations (i.e. not during or after a large-scale structural failure events) some disturbance of the benthos would likely be associated with the installation, presence and replacement of mooring systems. Habitat response to both the placement and the presence of the anchors and anchor chains is expected to be brief, even though presence of the anchors is contemporaneous with the structure over the long-term. The physical area displaced by the anchors themselves and portion of anchor chains resting on the seafloor is approximately 860 square feet per net pen facility at the four existing sites (Table 13; K. Bright, personal communication, November 23, 2020). Approximately 291 square feet, of this is associated with the anchors, which are placed below the surface of the seafloor. Benthic disturbance associated with anchor, anchor chain, and mooring lines during normal conditions and during maintenance and replacement would be in a small footprint and likely recover to prior abundance and complexity within weeks or months.

However, response to modified sediment quality associated with deposition of net pen wastes and chemicals during normal operations is more acute, more persistent, and covers a much larger area, extending beyond the square footage of the net pens (surface area of aggregate net pen area for the four PS commercial net pens is approximately 407,300 square feet; Table 1) by up to 100 m (328 feet). Within this area we expect prey communities to diminish both in total abundance, and in prey complexity, for the duration that the net pens are present, and up to four years for recolonization of benthic communities after net pens are removed or cease operation.

Because we expect that benthic communities would be notably diminished in both abundance and composition in each location of the net pen and up to 100 m adjacent to each net pen, we characterize the response to modified substrate as medium for the prey communities, as a habitat feature.

2) Effects on Water Quality

Long-Term Exposure

Water quality impacts of marine finfish net pens are well documented (see Price and Morris 2013; Rust et al. 2014; Price et al. 2015), and water quality would be affected by a variety of contaminants over the long-term. Effects on water quality below and surrounding net pens are likely to vary over time, with fluctuations associated with environmental changes (e.g., temperature, land-based contaminants, etc.), changes in net pen fish biomass (i.e., smolt to adult ratio), and during fallow periods. Although water quality conditions are expected to fluctuate, we assume that effects on water quality would occur indefinitely, for the length of time the net pens are operating.

Similar to sediment impacts described above in Section 2.5.1 (Effects to Forage, Stressor: Sediment quality degradation by bio-deposits and contaminants)**,** effects to water quality may stem from nutrient loading by fish waste products (feces and urea) and excess (uneaten) feed, and contaminants from feed additives (e.g., medicated feed) or other disease control (e.g., bath or dip treatment). Nitrogen and phosphorus at fish farms may be released into the water column in fish feces, or bound in uneaten food (see Price et al. 2015). The primary concern from a water quality perspective regarding elevated nitrogen and phosphorus levels arise from their nutrient enrichment effects. These may result in increases in phytoplankton and macroalgae production. Nitrogen in particular can have a nutrient enrichment effect that cause eutrophication and harmful algal blooms, potentially resulting in oxygen depletion (see Price et al. 2015). In the PS, and most marine waters, nitrogen is limited, so supplemental nitrogen can increase primary productivity and cause algal blooms (Price et al. 2015).

A synthesis by Price and Morris (2013) of global aquaculture scientific literature reported nitrogen ranges from none to significant differences from background concentrations, but found that measurable differences were rarely seen beyond 100 m from net pens. Studies of PS net pen salmon farms have documented slightly increased nitrogen levels in the center of net pens, but no measurable difference 30 m away (Brooks et al. 2003). Rensel and Forster (2007) determined that nitrogen released from properly sited net pen facilities in the PS are unlikely to have an adverse effect on water quality or cause algal blooms.

Studies in the PS have not identified dissolved phosphorus production at salmon farms as a concern (see Price et al. 2015). The amount of phosphorus in net pen farm effluent has decreased over time through decreases in levels of phosphorus in feed (Hardy and Gatlin III 2002). Improvements in feed formulation and management have led to significant reductions in nitrogen and phosphorus loading (Price et al. 2015).

DO levels can be reduced by increased microbial respiration or algal blooms associated with organic/nutrient enrichment from net pens. Nitrogen (dissolved inorganic nitrogen) in particular is considered a limiting nutrient in the PS, typical of marine systems (Newton and Van Voorhis 2002; Hawkins et al. 2019), and thus deposition material from net pens, including nitrogen, but also phosphorus, may increase primary productivity and has the potential to lead to eutrophication. Sufficient DO levels are essential to the health of organisms in the water column, including fish within net pens (see Solstorm et al. 2018). Salmonids are particularly sensitive to reduced DO levels at all life stages (Carter 2005). Low DO levels have been shown to also cause shifts in community structure in the water column, and reduced density and species richness of benthic infauna (Long 2007).

Historically, widespread low DO levels occur seasonally in certain geographical portions of the action area (see Encyclopedia of the PS 2020b). This has been most pronounced in southern portions of Hood Canal, but also in parts of the PS south of the Tacoma Narrows. Hypoxic conditions have resulted that are harmful to fish. Several hypoxic events have been documented in southern Hood Canal that have resulted in fish kills (see Encyclopedia of the PS 2020b; Palsson et al. 2008; Cope and Roberts 2013).

A meta-analysis by Sarà (2007) found that aquaculture operations do not generally affect DO. Seasonal and diurnal fluxes in the environment have been shown to often cause greater changes in DO than fish farms (see Price and Morris 2013). Monitoring in the PS have shown dissolved oxygen depression to be minimal in distance, usually no more than 0.1 to 0.2 mg/L depressed just 5 m downstream of net pens, and generally never measurable more than 30 m downstream (Nash 2001). Furthermore, no PS commercial net pens are located within Hood Canal or south of the Tacoma Narrows.

A potential accumulation of nutrients from net pens could have far-field (beyond the immediate vicinity of net pens) effects on water quality. A review by Noakes (2014) found that the field of impacts from net pen waste discharge is typically contained within 100 m of the outer boundary of the farm, consistent with other studies, but noted that depending on oceanographic conditions, suspended and dissolved waste materials may spread beyond this area, and result in potential cumulative and far-field effects. In the PS, where nitrogen is limited for algal and microbial productivity, nitrogen loading of the water column by net pens provides a potential pathway to eutrophication and decreased DO.

Ecology regulates discharge into the water column through NPDES permits. These include water quality standards and additional criteria to minimize impacts to water quality, as required by Surface Water Quality Standards specified in WAC-173-210A. As described above in our review of sediment quality degradation by bio-deposits and contaminants, Cooke Aquaculture, Inc. implements several measures to reduce excess feed and the use of medicated feed. The NPDES permits (available at Ecology 2021) also require monitoring and reporting of water quality (DO) within the water column at the corners of the net pen daily, from August 15th to September 30th each year. Annual sampling of DO is also required at the SIZ perimeter, as well as at reference stations during this same period for comparison with reference conditions. Because decreased DO levels can result from nutrient loading, monitoring of DO provides information about nutrient discharge effects immediately adjacent to the facility and around the SIZ. Water column sampling consists of samples at one meter of the water surface, at approximately half the depth of the pen, and within one meter of the bottom. If DO levels decrease to create hypoxic stress to fish, Cooke Aquaculture, Inc. provides supplemental aeration to net pens (Hawkins et al. 2019).

Prior to the net pen collapse at Cypress Island in 2017, all Cooke Aquaculture, Inc. net pen facilities in the PS have met state water quality standards (Hawkins et al. 2019), and we are unaware of any exceedances since that time. Hawkins et al. (2019) reported TOC exceedances during sediment sampling at two sites prior to the 2017 collapse, likely a result of nutrient enrichment that would have been in the water column before being deposited on the seafloor. These sites were moved into deeper waters more favorable to dispersion and assimilation of net pen wastes (Hawkins et al. 2019).

Fallow periods, the time in which no fish are present in the net pens between harvest and stocking, also help to reduce water quality effects. These periods were a minimum 30 days for recent Atlantic salmon farming and would be a minimum of 42 days for rainbow trout/steelhead and sablefish farming (Cooke 2019a; WDFW 2020a). Flushing (water exchange) by currents during this time is expected to return water quality to background.

Through careful management, modern marine aquaculture operating conditions have minimized impacts of farms on water quality, including mostly eliminating effects on dissolved oxygen and turbidity, and localizing any detectable nutrient-enrichment (Price et al. 2015). Modern improvements at PS net pens by Cooke Aquaculture, Inc. have reduced excess feed and fish waste, as described above. Given the small number and size of net pen farms in the PS, relative to the action area, we do not expect additive or compounding effects of net pens on nutrient loading.

Cooke Aquaculture, Inc.'s Pollution Prevention Plan (Cooke 2020c), is required by its NPDES permits, and establishes procedures to prevent the discharge of oil, petroleum products or other hazardous pollutants into the PS. It also specifies protocols for storage and disposal of waste products and chemicals used for disease treatment, and storage of feed at net pen facilities. With implementation of these protocols we do not anticipate these materials from entering the water column and affecting water quality. Additionally, no anti-foulants are used on nets so this avoids potential associated contaminants in the water column, such as copper.

Short-Term Exposure

Water quality effects could also temporarily arise intermittently during net pen operations from the routine dislodging of biofouling from nets, fines from broken fish food and fish waste, from turbidity from benthic disturbance during replacement or maintenance of anchors and mooring lines, and during any future net pen failure, and disturbance/prop wash of response vessels working in shallow water. Potential water quality effects include increases in nitrogen and phosphorus, decreases in dissolved oxygen (DO), the presence of disease control chemicals, turbidity and algal blooms.

We also expect net pen structural failures that disturb seafloor sediment to be very rare. Such short-term elevated suspended sediment levels that may result from a failure can result in gill abrasion in salmonids (Bash et al. 2001), and harmfully low DO levels (Carter 2005). For example, following the Cypress Island Site 2 failure in August 2017, a turbidity plume was observed surrounding one of the response vessels at the net pen site and DO levels below four parts per million (ppm) were recorded. According to state criteria, DO levels must be above 4.0 milligrams/liter (lowest one-day minimum) to be at least fair quality (WAC-173-210A). In response, Ecology established monitoring protocols to ensure that if DO dropped below four parts per million, operations may be paused and/or aeration done until DO levels recovered to about six parts per million (Clarke et al. 2017). Extra screens and booms were also deployed. We anticipate that during a future net pen failure event, response measures would similarly ensure disturbance of sediment is minimized and poor water quality conditions are localized and short-term.

The combined effect of long-term and short-term effects on water quality is chronic and acute within the marine areas close to the net pens, but dissipates to low levels a short distance (100 feet) away as flushing distributes and dilutes the contaminants. We characterize the water quality exposure and response close to the net pens as moderate.

3) Effects on Macroalgae

Long-Term

In PS pelagic areas, the euphotic zone (the lighted area) extends to about 20 m in the clearer waters of the northern PS and to about 10 m in the more turbid waters of the southern PS (Encyclopedia of the PS 2020a). However, net pens are located in areas of about 65 feet or deeper, meaning that they are at the outer edge of conditions that favor macroalge (e.g., kelp). Within the action area, bull kelp occurs throughout the PS, including the SJDF, and giant kelp is restricted to the SJDF (Berry et al. 2005; Mumford 2007). These two species are the most likely to provide cover in the deeper subtidal portions of the PS. Both species may occur in water depths where PS commercial net pens are located, but typically do not occur at depths greater than approximately 65 feet (Mumford 2007). Other species of aquatic vegetation (e.g., seagrasses) are typically found in much shallower areas, less than about 30 feet deep (see Christiansen et al. 2019; Encyclopedia of PS 2020d).

The vast majority of the net pen facilities' surface areas are nets that allow light penetration, and much of the other structure is grated (walkways) to allow partial light penetration, so the presence of the net pens themselves are unlikely to inhibit macroalgal growth. Furthermore, a study by Rensel and Forster (2007) found that the increased surface area provided by anchor chains, floats and other net pen structures supports a high abundance and diverse assemblage of organisms, including kelp and invertebrates, which may provide increased cover and forage opportunities for salmonids and rockfish species. However, with Cooke Aquaculture, Inc.'s regular cleaning protocols (see Cooke 2020a), any increased cover and forage provided by organisms on net pen structures would be temporary and intermittent.

Short-Term Exposure

Based on only four known large-scale escape events (i.e. failures) since 1985, we expect kelp and other macroalgae exposure to disturbance from net pens to be infrequent to be largely related to net pen failure. However, although rare, we consider it reasonably likely that any future structural failures would uproot kelp. Any such occurrence would result in temporary disturbance and short-term effects.

We assume that any disturbance to habitat by net pen structures from future large-scale structural failures would be of similar magnitude to the failure of Cypress Island #2 net pen facility that occurred in 2017. As described above, this event resulted in net pen structures and mooring lines collapsed in the water column and on the seafloor that would have disturbed surface substrate. The disturbance on the seafloor during this and other potential future events, would likely damage or detach from the substrate the kelp present in the disturbed area. Kelp provides areas of refuge (cover) from predation to outmigrating juvenile salmonids in PS Chinook salmon critical habitat (Shaffer 2004; Shaffer et al. 2020) and refuge for juvenile PS/GB bocaccio in their designated critical habitat (Love et al. 1991; Love et al. 2002). Any reductions to cover would be localized to the area of disturbance in the footprint and immediate vicinity of net pens.

The occurrence of kelp may change over time at a given location, and kelp has been documented to grow on net pen nets, floats and anchor lines (Rensel and Forster 2007), and thus these areas may be selected for rearing by juvenile bocaccio. However, with the regular monitoring and cleaning of nets, we expect minimal kelp growth on the nets, we anticipate minimal presence of kelp on the net pens themselves. Kelp grows in the photic zone, the area of the nearshore where light penetrates to the seafloor at a rate where net photosynthesis exceeds respiration (Dayton 1985; Hurd 2014). All of the PS commercial net pen facilities are in waters with depths where kelp may grow (up to about 65 feet; Mumford 2007). However, as the net pens are in water depths close to the maximum extent of depths at which kelp typically occurs, kelp presence near net pens may in fact be limited by virtue of the net pen site selection (see Mumford 2007).

If kelp is present in the disturbed area, any kelp damaged/broken, but not detached from the substrate, by mooring lines or other materials would be expected to regrow. With effects on macroalgae highly localized, we anticipate relatively fast recovery of any disturbed areas where kelp is detached by the recolonization by kelp gametophytes or sporophytes carried by currents from adjacent areas. Although we expect the effects on cover to thus be short-term, there is some uncertainty in recovery rate given recent observations of bull kelp declines in the PS (Berry et al. 2019; 2020), which could indicate reduced habitat suitability that would inhibit re-establishment and growth. Similar effects of loose anchor chains and mooring lines resting on the seafloor have been documented with mooring buoys in the PS (see Nightingale and Simenstad 2001). The disturbance of rooted macroalgae could also displace invertebrates and cause a localized, minor reduction in primary productivity (see analysis on forage, above). We expect the footprint of debris to be small and thus disturbed areas to also be small. Macroalgae would be expected to regrow or fill back into the disturbed areas, and any up-rooted or damaged kelp would be incorporated into the food web.

Overall, both long-term and short-term disturbance to macroalgae are expected to be minor due to the infrequent occurrence of failure and the relatively limited duration (up to 6 months per failure) and footprint of the equipment on the seafloor subsequent to a failure (several hundred feet). Replacement and maintenance of net pen mooring systems would also be expected to have a very small, localized, short-term effect on macroalgaes. We characterize the effects on macroalgae as low.

2.5.1.2 Effects in the freshwater environment of the action area

In response to net pen failures or collapses that release farmed fish into the PS, measures may be implemented to recapture fish in the PS and tributary rivers. The Cypress Island Site 2 failure and response provides a recent example of efforts to recover fish escaped from PS commercial net pens. Clarke et al. (2017) provides an overview of the escape and response. At the time of the collapse, an estimated 305,000 Atlantic salmon were in the Cypress Island Site 2 net pens. Approximately 42,341 to 62,041 fish were initially harvested from the failed net pens using vacuum harvest pumps, and approximately 242,959 to 262,659 were released into the PS. Some of these escaped fish survived and migrated to freshwater environments (see Lee and Murphy 2018; WDFW 2018).

Fish can also escape from the net pens in low numbers in circumstances other than a structural failure. Whether escape is in large or small numbers, not all escaped fish would die in the marine environment, and some would enter tributaries, where freshwater interactions would occur. Both escaped fish and the efforts to recapture them predominantly affect listed species directly, rather than causing habitat effects.

In Section 2.5.3.2 we provide a detailed description of exposure and response of listed fish to: (1) the marine habitat effects that were described here; (2) direct effects of recapture efforts within the marine portion of the action area; and (3) direct effects on salmonids of escaped fish and to recapture efforts in freshwater environments.

The detailed presentation of effects on physical, chemical, and biological components of the environment described above are those that set the action area for this consultation. Below, we analyze the influence of these changes, both long and short-term, for the influence they have on ESA listed resources—these are: (1) the features of critical habitat and the conservation purpose for which they were included in the designation (Section 2.5.2) and (2) the listed species that would be exposed to these habitat changes, whether or not any of the area of the habitat is designated as critical (Section 2.5.3).

Table 15. Effects Matrix—summary of habitat effects

PBF/ habitat effect	Stressor	Species	Habitat Analysis by PBFs*			Species Analysis by Lifestage*							
			Likelihood of exposure	Magnitude of response	Consequence of exposure and response	Life stage	Likelihood of exposure	Magnitude of response	Consequence of exposure and response	Life stage	Likelihood of exposure	Magnitude of response	Consequence of exposure and response
Forage	Benthic disturbance by structures	PS Chinook salmon	Low	Low	Low	Juvenile	Low	Low	Low	Adult	Low	Low	Low
		PS steelhead		NA		Juvenile	Low	Low	Low	Adult	Low	Low	Low
		HCSR chum		NA		Juvenile	Low	Low	Low	Adult	Low	Low	Low
		PS/GB yelloweye	Low	Low	Low	Larval, juvenile	Low	Low	Low	Adult	Low	Low	Low
		PS/GB bocaccio	Low	Low	Low	Larval, juvenile	Low	Low	Low	Adult	Low	Low	Low
	Sediment quality degradation by bio-deposits and contaminants	PS Chinook salmon	Moderate	Low	Low	Juvenile	Moderate	Low	Low	Adult	Moderate	Low	Low
		PS steelhead		NA		Juvenile	Moderate	Low	Low	Adult	Moderate	Low	Low
		HCSR chum		NA		Juvenile	Low	Low	Low	Adult	Low	Low	Low
		PS/GB yelloweye	Moderate	Low	Low	Larval, juvenile	Low	Low	Low	Adult	Low	Low	Low
		PS/GB bocaccio	Moderate	Low	Low	Larval, juvenile	Low	Low	Low	Adult	Low	Low	Low
	Competition with escaped fish	PS Chinook salmon	Moderate	Low	Low	Juvenile	Low	Low	Low	Adult	Low	Low	Low
		PS steelhead	Moderate	Low	Low	Juvenile	Low	Low	Low	Adult	Low	Low	Low
		HCSR chum	Moderate	Low	Low	Juvenile	Low	Low	Low	Adult	Low	Low	Low
		PS/GB yelloweye	Low	Low	Low	Larval, juvenile	Low	Low	Low	Adult	Low	Low	Low
		PS/GB bocaccio	Low	Low	Low	Larval, juvenile	Low	Low	Low	Adult	Low	Low	Low
Cover	Benthic disturbance by structures	PS Chinook salmon	Low	Low	Low	Juvenile	Low	Low	Low	Adult	Low	Low	Low
		PS steelhead		NA		Juvenile	Low	Low	Low	Adult	Low	Low	Low
		HCSR chum		NA		Juvenile	Low	Low	Low	Adult	Low	Low	Low
		PS/GB yelloweye	Low	Low	Low	Larval, juvenile	Low	Low	Low	Adult	Low	Low	Low
		PS/GB bocaccio	Low	Low	Low	Larval, juvenile	Low	Low	Low	Adult	Low	Low	Low
Water quality	Bio-deposits, contaminants and turbidity	PS Chinook salmon	Moderate	Low	Low	Juvenile	Low	Low	Low	Adult	Low	Low	Low
		PS steelhead		NA		Juvenile	Low	Low	Low	Adult	Low	Low	Low
		HCSR chum		NA		Juvenile	Low	Low	Low	Adult	Low	Low	Low
		PS/GB yelloweye	Moderate	Low	Low	Larval, juvenile	Moderate	Low	Low	Adult	Low	Low	Low

PBF/ habitat effect	Stressor	Species	Habitat Analysis by PBFs*			Species Analysis by Lifestage*							
			Likelihood of exposure	Magnitude of response	Consequence of exposure and response	Life stage	Likelihood of exposure	Magnitude of response	Consequence of exposure and response	Life stage	Likelihood of exposure	Magnitude of response	Consequence of exposure and response
		PS/GB bocaccio	Moderate	Low	Low	Larval, juvenile	Moderate	Low	Low	Adult	Low	Low	Low

*Color coding: low, moderate

2.5.2 Effects on Physical and Biological Features of Critical Habitat

The effects to habitat features in the action area must also be evaluated for their influence on PBFs of critical habitat. For example, changes in benthic conditions, whether physical or chemical, result in changes to the invertebrate communities that reside in the benthic layer, and as these species serve as prey, the effects translate to a change in forage, a PBF of designated critical habitat. Water quality and cover are also PBFs, and therefore must be evaluated for the effect changes have on the conservation role that they serve in the designated area.

1) Effects on Forage

In the marine environment, forage, a PBF of Chinook salmon and both rockfish species, would be diminished in the small footprint of the four net pen facilities, in the short-term with the placement of anchors, and in the event of a net pen failure. Because there is no sediment monitoring or mitigation requirement within the SIZ, other than at closure, we consider there to be a moderate likelihood of exposure to benthic bio-deposits and contaminants to affect forage quality and availability under and within approximately a 100-meter perimeter of net pens (i.e. the SIZ). We considered the overall effect on the habitat in this immediate net pen vicinity to be moderate. We now evaluate that reduction in benthic communities described above in relation to the PBF of forage for the listed species.

HCSRC critical habitat in the marine environment is only designated within Hood Canal and west within the SJDF to approximately Dungeness Spit, over 20 miles from any of the net pen sites. As described above, we do not anticipate effects on prey communities to extend beyond the immediate vicinity of net pens, and thus not to areas where critical habitat is designated for HCSRC. Because HCSRC critical habitat does not include and is not near any of the located net pens, this PBF for marine portions of designated critical habitat would not be affected for this species. PS steelhead do not have marine areas designated as critical habitat. Therefore, we only expect effects on PBFs of PS Chinook salmon, PS/GB yelloweye rockfish and PS/GB bocaccio marine critical habitat.

The forage PBF for nearshore PS Chinook salmon includes “aquatic invertebrates and fishes, supporting growth and maturation.” The forage PBF for both deepwater and shallow critical habitat of PS/GB yelloweye rockfish and bocaccio includes “quantity, quality and availability of prey species to support individual growth, survival, reproduction and feeding opportunities.”

Effects on forage below net pens are likely to vary over time, with fluctuations associated with environmental changes (e.g., water temperature), changes in net pen fish biomass (i.e. smolt to adult ratio), and during fallow periods. However, taking a conservative approach, we assume that effects on forage would occur indefinitely, for the length of time the net pens are operating.
All of the commercial net pens in PS are within nearshore critical habitat for juvenile PS/GB bocaccio, and overlap with or are in close proximity to deepwater juvenile and adult PS/GB yelloweye rockfish critical habitat and adult bocaccio critical habitat.

Therefore, we consider it reasonably likely that effects of benthic disturbance from both the presence and the operation of net pen structures would occur in designated nearshore and deepwater rockfish critical habitat at all facilities. The forage PBF for both deepwater and shallow critical habitat of PS/GB yelloweye rockfish and bocaccio includes "quantity, quality and availability of prey species to support individual growth, survival, reproduction and feeding opportunities." The effects on forage as a PBF of PS Chinook salmon are also a long-term diminishment of available prey in the affected footprint.

However, when evaluating the influence of this diminishment on the conservation role for which this PBF was identified, we must note that forage is not a limiting factor for any of these species in the marine environment, therefore the PBF for these three species, while diminished, is so constrained spatially that this diminishment would likely not impair the conservation role of providing adequate prey for the three listed species. The response to the forage/prey PBF for all three species is low.

We also anticipate effects to forage from competition for resources with escaped farmed fish. The effects to the forage PBF of both marine and freshwater critical habitat for PS Chinook salmon, PS steelhead, HCSRC, and marine critical habitat for PS/GB bocaccio and PS/GB yelloweye rockfish resulting form completion for prey items with escaped farmed fish are assessed in the 'Competition and Predation' portion of Section 2.5.3.2. As described there, we expect some minor reductions to prey abundance. With likely overlap in habitat and resources, particularly between farmed rainbow trout/steelhead and wild salmonids, we consider there to be a moderate likelihood of exposure for the forage PBF of PS Chinook salmon, PS steelhead and HCSRC critical habitat. With less likely overlap of habitat use and prey resources between PS/GB bocaccio and PS/GB yelloweye rockfish, and famed sablefish and rainbow trout/steelhead, we consider there to be a low likelihood of exposure for the forage PBF of these two species.

Based on relatively low levels of competition for resources, as described in detail in Section 2.5.3.2, we consider the magnitude of consequence to be low and the response to exposure and magnitude of consequence of forage as PBF of critical habitat to be low for all five ESA-listed species.

2) *Effects on Water Quality*

Section 2.5.1.1 includes a detailed description of long and short-term water quality effects in the environment, which we characterized as moderate in the areas around net pens. Because water quality is a PBF for PS Chinook, HCSRC, and two rockfish species, we evaluate whether the water quality changes described above would impair the conservation role that water quality serves for these species.

Relative to salmonids, the net pens are only located in critical habitat for PS Chinook salmon, and thus we expect effects to be limited to the water quality PBF of nearshore PS Chinook salmon critical habitat—water quality is identified as a PBF because it supports growth and maturation. The water quality PBF would not be diminished for HCSRC because the net pens are not located near HCSRC migration routes and the most intense water quality degradation would be localized to areas below and in close proximity to net pens. PS steelhead do not have critical habitat in the marine environment. For rockfish, the conservation role of the water quality PBF of juvenile and adult PS/GB yelloweye rockfish and bocaccio critical habitat is to support growth, survival, reproduction, and feeding opportunities.

The aggregate effects of nutrient loading from all land and water-based sources in the PS basin (e.g., nitrogen inputs from human activities), contribute to seasonal low DO (see Encyclopedia of the PS 2020c). As described in Section 2.5.1.1 it is difficult to assess far-field effects from the net pens versus other anthropogenic sources. However, none of the commercial net pens are located in Hood Canal or the southern PS where this is most pronounced, so any additive effect of the net pens in these events is unlikely. Additionally, in the main basins of PS where the net pens are located, background levels of ocean-upwelling sourced nitrogen are high, and are not limiting for plankton grown, and thus dissolved nutrients discharged to these basins have little to no effect on the rate of phytoplankton production (see WDFW 1990; Rensel Associates and PTI Environmental Services 1991). Because of the combination of high background levels of nitrogen, and natural and anthropogenic nitrogen inputs (see Ecology 2020), we do not expect any dissolved nitrogen inputs from existing net pens to have a measurable effect on algal blooms.

The generation of suspended sediment, and resulting turbid conditions, may also arise from the movement of net pen structures on the seafloor stirring up sediment. This may occur during repair and replacement of anchors, or during a net pen failure that results in loose mooring lines or other debris on the seafloor. As described in Section 2.5.1.1, with the monitoring and maintenance measures implemented at PS commercial net pens, we expect any disturbance of sediment from regular maintenance and repair to be infrequent and result in very minor, localized, short-term elevated turbidity. Therefore, we expect that this effect on the condition of water quality as a PBF of PS Chinook salmon critical habitat would not diminish the action area's conservation value for the species, because acute water quality changes would occur in a limited footprint and the dispersal of the contaminants would be at low enough concentrations, that exposure of individuals at any lifestage would not impair survival, growth, maturation, reproduction or feeding opportunities of these species within their critical habitat.

Rockfish display site fidelity, so are likely to have more prolonged exposure to areas with higher water quality diminishment. This is particularly true for yelloweye rockfish, with bocaccio tending to move around more. With the measures implemented to minimize impacts to water quality, and ongoing monitoring of DO, we anticipate that any input of bio-deposits and contaminants from the net pens to the water column would have a minor, localized effect on water quality, and only infrequently (periodic, but short-term on each occasion) at a level that diminishes the suitability of habitat to support yelloweye rockfish and bocaccio growth, or that would be harmful to fish health (i.e. reduced DO levels, or presence of mercury). Therefore, the exposure of water quality to degrading conditions is considered to be moderate in areas around net pens, but the response of the PBF is low for salmonids and moderate for rockfish.

3) Effects on Cover

Effects on macroalgae, primarily kelp, in the marine environment are characterized as *low* because those effects are expected to be infrequent, and affect only very small areas of this biological feature. Macroalgae provides cover, which is a PBF of PS Chinook salmon, HCSRC, and PS/GB bocaccio critical habitat. In this subsection we evaluate how changes in macroalgae may have meaningful influence on the conservation role that cover provides.

Of the salmonid species, PS commercial net pens are located only in critical habitat for PS Chinook salmon, and thus we only anticipate effects on cover as a PBF of critical habitat for this species. Cover, defined as areas providing habitat avoidance, is also a PBF of critical habitat for the deepwater lifestages of juvenile and adult PS/GB yelloweye rockfish and adult PS/GB bocaccio. For juvenile PS/GB bocaccio critical habitat, cover includes "areas in the nearshore with 'substrates such as sand, rock and/or cobble compositions that also support kelp.' Cover confers two values—forage opportunities, and predator avoidance.

Cover is likely to be impaired if/when a large-scale net pen failure occurs. We expect that once all salvage operations are complete following any net pen facility failure, including removal of all debris from the sea floor, benthic conditions would return to background, allowing cover to re-establish. All depths at the net pen sites are close to the maximum extent of depths at which kelp typically occurs, so we also expect limited kelp presence as a starting condition and this suggests the amount of expected disturbance to cover would be low. Therefore, we anticipate low exposure of cover to short-term, localized, minor effects.

In the marine environment kelp functions as cover for small fish, and increases the overall primary productivity of the habitat (see Pfister et al. 2019), thereby increasing forage potential for salmonids and for rockfish. Kelp bed habitats have diverse marine invertebrate communities (Christie et al. 2009; Greene 2015; Siddon et al. 2008) that provide forage for juvenile and adult salmonids and rockfish. They also provide spawning habitat for Pacific herring, and feeding and rearing habitat for Pacific herring, sand lance and surf smelt, important prey of salmonids in the PS (Shaffer 2000; Shaffer 2004; O'Brien et al. 2018). If kelp is present in the disturbed areas, and is damaged or removed by benthic disturbance, the response of this PBF would be reduced cover and forage (see forage effects in more detail, above).

Macroalge, as a source of cover and forage, is also a feature of CH for larval and juvenile PS/GB bocaccio, again providing cover and nutrition for invertebrates and microbes. As described above, macroalgae can grow on the equipment of the net pen, and larval rockfish that arrive in these locations during their pelagic lifestage may rely on this growth for cover as they grow and mature for both forage and predator avoidance. Regular cleaning of the equipment is expected, and would either disrupt this cover if established, or prevent its establishment. Loss of cover would have a contemporaneous highly localized displacement of invertebrates and rooted macroalgae, and a minor, short-term, localized decrease in forage potential—see the description on forage, above. Localized benthic disturbance in the approximate net pen footprint following a failure would have an expected duration of less than 6 months, and any disrupted cover would begin to re-establish within weeks to months after that.

Based on the frequency and nature of disturbance to cover and the likelihood that cover is not present in high quantities in net pen locations we consider the consequence of the proposed action on cover as a PBF for PS Chinook salmon and rockfish is low. Because the net pens are not connected to shorelines, shading or other overwater impacts that interfere with the migration of nearshore-oriented PS Chinook salmon and HCSRC, well documented with piers, docks and floats as artificial cover that extend out from the shoreline (e.g., Nightingale and Simenstad 2001) are not likely.

2.5.3 Effects on Listed Species

Effects on listed species may occur when individuals are exposed to changes in environmental conditions in the action area, and also from activities that directly affect individuals. We present the exposure and response of species to habitat changes first, and then present the consequences of the proposed action that directly affect listed fish.

2.5.3.1 Exposure and Response to Habitat Changes

1) Modified Benthic Conditions/Reduced Forage

Effects on forage below net pens are likely to vary over time, with fluctuations associated with environmental changes (e.g., water temperature), changes in net pen fish biomass (i.e. smolt to adult ratio), and during fallow periods. However, taking a conservative approach, we assume that effects on forage would occur indefinitely, for the length of time the net pens are operating.

As these net pens are expected to be present indefinitely into the future, it is also likely that some individual PS Chinook Salmon and PS steelhead would experience the slight diminishment of prey availability caused by net pen operations. This exposure is expected to be small and very brief because the mobility of these species is high and the likelihood that they would linger to forage in depleted areas is low. HCSRC are not expected to occur near net pens, where modified benthic conditions and forage are anticipated.

As described above, the effects on benthic conditions and forage in the marine environment, are "low" due to limited footprint of diminished prey, and widely available prey throughout the remainder of the action area. We expect juvenile and adult PS/GB yelloweye rockfish and bocaccio to occasionally occur in and forage in the benthic environments with sediment quality potentially impacted by bio-deposits. Invertebrate displacement and potentially reduced primary productivity would temporarily reduce the forage potential of the habitat for rockfish.

However, we expect exposure to reduced forage to remain low at any given time. The habitat area with reduced forage would be very small relative to forage available in the immediately adjacent areas, and wider action area, and only rockfish are likely to have a longer duration of exposure based on their habitat preferences. Salmonids are generally more mobile and any exposure to areas of reduced forage abundance would be extremely brief as they move through the small areas affected.

The number of rockfish feeding in the in the area with potentially degraded forage would be few, but we expect juvenile bocaccio rearing in nearshore waters close to where PS commercial net pens are located the most likely to be exposed to any forage effects. The number of adult PS/GB yelloweye rockfish and bocaccio even over multiple years would be low, due to depth preferences of adults. Although deepwater critical habitat is designated in waters over 98 feet, adults of both species are most commonly found between 131 to 820 feet (Orr et al. 2000; Love et al. 2002), deeper than where PS commercial net pens are located and thus where forage effects are expected. Given the infrequency of net pen facility failure events, the limited amount of adult habitat in the immediate area of net pens, the small footprint of affected habitat and the short-term nature of benthic disturbance, we consider there to be a low likelihood of adult rockfish exposure to a reduction in forage in any given year.

Larval and juvenile rockfish feed on small organisms, such as zooplankton, copepods, phytoplankton, small crustaceans, invertebrate eggs, krill and other invertebrates (see NMFS 2017a). Rockfish larvae, including PS/GB yelloweye rockfish and bocaccio, are typically found in the pelagic zone, often occupying the upper layers of open waters, where they may encounter net pens. Rockfish larvae are thought to be initially distributed passively by currents (Love et al. 2002), until they are big enough to progress toward preferred habitats. Encounters with net pens would be a result of passive dispersal of larvae by prevailing currents through areas with net pens. Because larvae are carried by currents, any exposure would be very brief. The magnitude of effects on forage for larvae stemming from change in benthic conditions, would be diluted by availability of prey items drifting into the pelagic area, where larvae occur, from other undisturbed sites. Additionally, the diverse diet of larval rockfish limits any effect on overall forage from reduced prey abundance.

When bocaccio reach sizes of 1 to 3.5 inches (3 to 9 cm) (approximately 3 to 6 months old), they settle in shallow nearshore waters in rocky or cobble substrates with or without kelp (Love et al. 1991; Love et al. 2002). Juvenile yelloweye rockfish typically settle in water 98 to 131 feet, typically in habitats with moderate to extreme steepness, complex bathymetry, and rock and boulder-cobble substrate (Yamanaka and Lacko 2001; Love et al. 2002). None of the PS commercial net pen facilities are in close proximity to deeper areas where juvenile yelloweye rockfish are typically found (over 98 feet depth). However, some juvenile yelloweye rockfish may also forage in areas where the effects of benthic disturbance after a net pen failure extend. We expect some juvenile PS/GB bocaccio to occur in and forage in the benthic environments potentially disturbed by net pen failures. Invertebrate displacement and potentially reduced primary productivity resulting from the footprint, movement and recovery of failed net pen debris would temporarily reduce the forage potential of the habitat for both juvenile PS/GB yelloweye rockfish and bocaccio. Given the infrequency of such events, and the small footprint of affected habitat, we consider there to be low likelihood of juvenile exposure to a reduction in forage.

Because exposure to low forage habitat is expected to be infrequent for most individuals of the listed species, and brief when it does occur, even over the long timeframe considered here, we characterize exposure of listed species to reduced forage as low.

Although it is likely that some juvenile and adult salmon and steelhead migrating through the action area would encounter net pens and the areas of diminished prey associated with them, the small area of benthic impacts and the infrequent nature of net pen failures that could expand the footprint of areas with diminished prey we expect very few fish to be exposed to reduced forage, and such exposure brief. Similarly, juvenile and adult rockfish (both bocaccio and yelloweye) are able to swim to areas of higher prey abundance. Of the few individuals of the listed species that are exposed to areas of reduced forage, we expect only the behavioral response of moving to areas where prey is more abundant.

Larval juvenile rockfish may have longer exposure because they are weaker swimmers, but even in this circumstance we expect response to reduced forage (invertebrate displacement in the footprint of net pen, via debris, or via reduction in macroalgae), would be very low due to availability of prey items drifting into the area from other undisturbed sites. Additionally, the diverse diet of larval rockfish limits any effect on overall forage from reduced invertebrate abundance from the net pens long-term presence or short-term effects on forage associated with structure failure. We anticipate no response that would reduce growth, maturation, fitness, or survival of exposed individuals of any of these listed salmonid or rockfish species despite their exposure to areas of low forage, because of the sufficiently abundant prey in adjacent areas. We characterize response of all species exposed to reduced forage as low.

2) Reduced Water Quality

Listed species are likely to be exposed to reduced water quality in the marine environment. We expect measurable effects on water quality to be limited to the area directly beneath and in close proximity to net pens (e.g., within 100 m down current), diminishing with distance from the net pens. Overall, we anticipate that during operations of net pens, water quality, particularly DO, may be diminished to sub-optimal levels for salmonid health. With proposed monitoring and waste product minimization measures, we anticipate such conditions to occur infrequently and only persist for the short-term. Therefore, we consider there to be a moderate likelihood of exposure to diminished water quality among PS Chinook and PS steelhead. The location of net pens makes exposure of HCSRC extremely unlikely.

Because the more acute water quality diminishments are expected to be localized, and minor, and infrequently at a level harmful to fish, and because PS Chinook salmon and PS steelhead can detect and avoid areas of low DO, we anticipate a low overall response to poor water quality, and the primary response would be avoidance behavior.

Elevated levels of turbidity can also occur at net pen sites from fines being released to the water column as dust from broken feed pellets, and from fish waste, as well as from the scraping of biofouling (see Price et al. 2015; Floerl et al. 2016). High levels of turbidity can create conditions harmful to fish (Cooke-Tabor 1995; Bash et al. 2001), as well as reduce primary productivity in the water column and on the seafloor by limiting light penetration (see Price et al. 2015). Price et al. (2015) summarized that increased turbidity may be detected in both the near-field (immediate net pen area) and far-field (distant from net pen) area around net pens, but no detection of cumulative impacts of multiple farms. As with DO, salmonids can easily detect and if space is available, avoid areas where water quality is impaired by turbid conditions/suspended sediment. Exposure is likely among a few individuals of both salmonid species, but response is expected to be avoidance, and not sufficient to create any injury among the exposed individuals or diminish growth, feeding or fitness.

We expect minor reductions to water quality in the immediate vicinity of net pens. This may result in short-term exposure to reduced water quality as PS Chinook and PS steelhead migrate through the affected area. Furthermore, because salmonids are highly mobile, exposure to potentially harmful conditions (e.g., low DO) would be for a very short duration of time. Therefore, we do not expect exposure to result in adverse effects on individual health. Exposure to water quality reductions could have a greater consequence for PS/GB yelloweye rockfish and PS/GB bocaccio. In addition to the water quality effects described above and in this section, elevated levels of mercury in rockfish have also been linked to proximity to net pens in some parts of the world. Because of their site fidelity and benthic habitat use, as well as their long life-span, they may be particularly susceptible to accumulation of mercury. Elevated levels of mercury could lead to reduced growth rates and impaired reproduction in rockfish (Drake et al. 2010).

A study by deBruyn et al. (2006) identified elevated levels of mercury in rockfish near net pens in BC. This was attributed to fish feed and feces incorporated through the food web (invertebrate and small fish) to rockfish, and the mobilization of naturally occurring mercury in the sediment under and near the pens because of farm-induced anoxia. Although a potential contributor of mercury, it is difficult to determine the role net pens play in mercury levels in rockfish in the PS. Elevated mercury levels in rockfish are well documented in fish in urban areas (see NMFS 2017a). We expect that current practices at PS commercial net pens to reduce contaminants, including no use of antifoulants, reduced feed waste, cleaner feed products, and monitoring of sediment and water quality, have greatly reduced the risk of mercury contamination. However, taking a conservative approach, we assume that effects on water quality would occur indefinitely, for the length of time the net pens are operating, and, because rockfish are particularly long lived, and exhibiting site fidelity, that some individuals would be exposed for long periods.

Larval rockfish exposure is expected to be less acute. They are pelagic so may be exposed to portions of the water column near net pens with diminished water quality. As a result of passive dispersal of larvae through areas with net pens. Because larval rockfish generally move passively, they would not be able to swim away from and avoid areas of degraded water quality, currents are likely to convey most larvae out of the area of acute exposure within a short (days to weeks) timeframe. While exposure of salmonids to degraded water quality is low, exposure of PS/GB yelloweye rockfish and bocaccio at all life stages is moderate.

Response to reductions to water quality near net pens for salmonids is expected to be behavioral only, as avoidance of areas of high turbidity or low DO is a common and instinctive response. Salmonids are highly mobile and their likelihood of encountering these areas of diminished water quality is low when they are migrating either out to the ocean or back to spawning areas, so short-term exposure would be so brief that no negative health effects are likely. A significant portion of Chinook salmon, known as ‘resident’ fish, spend a significant portion, or potentially all of their marine rearing phase within the Salish Sea (PS, the Strait of Georgia and associated water bodies), instead of beyond the mouth of the SJDF in the northern Pacific Ocean (see Chamberlin and Quinn 2014; Kagley et al. 2017). These ‘resident’ fish thus spend most, if not all, of their life within the action area. Despite this inherent increased potential for exposure to habitat effects of net pens, we expect exposure to areas of diminished water quality to be low given the ability of juvenile and adult PS Chinook salmon to avoid these areas. We expect any exposure to be very brief, and unlikely to have negative effects on health.

Because exposure to reduced water quality may be longer among rockfish at all lifestages, response could be more significant. Larval PS/GB yelloweye rockfish and bocaccio are carried by currents through the affected area and cannot engage in avoidance behavior. Exposure to potentially harmful conditions (e.g., low DO) may persist for a relatively short duration of time as larvae drift through the area, but currents are expected to carry them out of the area with the most acute water quality diminishment within hours to days.

For juvenile (non-larval) and adult rockfish, the habitat area with reduced water quality would be very small relative to suitable habitat available in the immediately adjacent and broader nearshore habitat of the action area where PS/GB yelloweye rockfish and bocaccio occur. We anticipate response to impaired water quality would only infrequently be at a level severe enough to affect fish health (exposure to potentially harmful conditions would be limited). Because adult PS/GB yelloweye rockfish and bocaccio prefer habitat deeper than where net pens are located, most individuals would not be exposed at acute levels, making chronic response to low level impairment indistinguishable from background health and fitness. Juvenile bocaccio could have slightly higher exposure because of their life history behaviors that include settling in shallower water and migrating over time to deeper areas. This could expose them to more load and more bioaccumulation. However, since contaminants, such as mercury are present in mature adult fish, this may not be a detriment to their long-term individual fitness or survival. Response to reduced water quality is thus expected to be low.

3) Reduced Macroalgae/Cover

Cover considered in this analysis refers to macroalgae, such as kelp. As described above, kelp and other cover are not expected to be abundant in areas where net pens are located, however the occurrence of kelp may change over time at a given location. Because reductions in available cover are most likely caused by net pen failure, which is infrequent and affects a limited footprint, or by the maintenance of the structures that inhibits the establishment of macroalgae on the net pen itself, the potential exposure of listed fish to this reduction is very low. Steelhead juveniles are larger, older fish when they reach marine waters, because of their longer freshwater residence during rearing. Therefore, PS steelhead do not rely heavily on cover to avoid being preyed upon. We expect low exposure to the loss of this sub-aquatic vegetation for all three species, and the least exposure for steelhead. Furthermore, with any reductions in cover highly localized, we expect suitable cover to be available immediately adjacent to any disturbed areas.

If individuals are exposed, we expect such an event to be among very few individuals of any of the listed species, even when considered over multiple years of net pen operations. Salmonids are highly mobile and individual fish would be expected to naturally avoid areas with reduced cover. Furthermore, because of the migratory nature of salmonids through the action area, we expect any encounter to be brief. This is particularly true for juvenile PS Chinook salmon and HCSRC that migrate through the nearshore area, typically in areas shallower than where net pens are located, as well as for PS steelhead that migrate quickly through the action area to the Pacific Ocean.

For these reasons, while we expect a minor reduction to cover availability for salmon and steelhead in the area, the nature of the exposure is so brief, that response would be negligible for any exposed individuals. The consequence of exposure and response among these species is low.

Considering exposure of PS/GB yelloweye rockfish and bocaccio, juvenile rockfish recruit to floating kelp canopies that provide forage and areas of refuge (cover) from predation (Love 1991; Singer 1985). As they grow they move to deeper water and prefer larger substrate in kelp understories that provide cover and larger prey (Love 1991). In the PS, young-of-year rockfish show a strong association with kelp habitats (Doty et al. 1995). Areas with floating and submerged kelp species support the highest densities of most juvenile rockfish (Carr 1983; Halderson and Richards 1987; Matthews 1990; Hayden-Spear 2006). Kelp has been documented to grow on net pen nets, floats and anchor lines (Rensel and Forster 2007), and thus these areas may be selected for rearing by juvenile bocaccio. However, with the regular monitoring and cleaning of nets, we expect minimal kelp growth on the nets.

Movement of anchors, anchor chains, and mooring lines on the seafloor during regular operations, including breaking of an individual line, and repair and replacement activities could result in a very small, brief and highly localized displacement of macroalgae, like kelp. Large-scale net pen failures can damage or detach macroalgae from the substrate. However, kelp is not likely to be present in high amounts near net pens, due to the depth at which they are placed, and because large-scale failure events are expected to be very infrequent over the life of the proposed action, we consider there to be a low likelihood reducing cover in PS/GB yelloweye rockfish or bocaccio critical habitat. While there could be a very small increase in predation risk (mortality) for individual fish in the area following a large-scale failure event that results in reduced cover, this is likely to affect very few individuals over the life of the project. Accordingly, both exposure and response of rockfish at all lifestages is expected to be low.

2.5.3.2 Exposure and Response to Direct Effects

In this section the effects of non-habitat related impacts (i.e., direct effects) on ESA-listed species are analyzed. These include: increased predation within net pens, entrainment by harvest, entrainment by recapture efforts for escaped fish, pathogens, competition for resources with escaped fish, and predation by escaped fish. The exposure and response are presented in detail, and also in summary form in Table 17.

1) <u>Predation by Fish in Net Pens</u>

Juvenile PS Chinook salmon and PS steelhead could be preyed upon if they enter net pens. Adults are too large to enter net pens and therefore we consider there to be no risk of predation by farmed fish within net pens. HCSRC are highly unlikely to occur near the net pen sites and would thus would not be at risk of predation within the pens.

If juveniles enter net pens they are likely to be consumed by larger rainbow trout/steelhead or sablefish in the pens. Net pens used most recently for Atlantic salmon have an approximately 1.5 inch stretch measurement from knot to knot (0.75-inch length each side), but mesh size may increase with triploid rainbow trout/steelhead or sablefish if entry/stocking size of fish is larger

(K. Bright, personal communication, May 7, 2020). Thus any smaller wild fish could enter the net pens. The risk of predation of wild fish by escaped net pen fish is assessed separately in our assessment of direct effects from competition and predation, below.

It is reasonably likely that juvenile salmonids encounter net pens during their out-migrations to the ocean. This is particularly true for juvenile steelhead, since their migration path is in the deeper water where net pens are located, further from shore, than that of the more nearshore-oriented Chinook salmon. However, we anticipate that individuals of both species would occasionally encounter and potentially enter net pens.

The risk of predation increases with the size of the farmed fish. Chinook salmon and chum are typically less than 50 millimeters when they enter the PS (Fresh 2006), and steelhead closer to 160 millimeters after a longer freshwater residence (Blanton et al. 2011). The farmed fish would be stocked in the net pens when they are between approximately 140 to 160 millimeters (rainbow trout/steelhead smolts), similar size to the wild juvenile salmonids, and harvested when they are over 3.5 kilograms, much larger than the wild fish. Thus, the risk of predation is expected to be significantly lower during the first several months after stocking, and increase until harvest.

Some juvenile wild salmonids may be attracted to net pen feed in the water, but we also expect that upon encountering or sensing larger fish in the nets, juvenile salmonids would avoid the area (e.g., see Berejikian 1995). Observations of the contents of gastrointestinal tracts of fish both within and escaped from net pens shows a very low rate of predation on wild fish. An early study in the Pacific Northwest on the stomach contents of maturing escaped Atlantic salmon by McKinnell et al. (1997) found that of the 813 stomachs examined (63 from freshwater catches and 750 from ocean catches), 61.9% of the freshwater samples and 78.7 of the ocean samples were empty. A review paper by Amos and Appleby (1999) documented that all analyzed stomachs of recaptured Atlantic salmon in Washington were empty and in BC and Alaska, approximately 2-4% had herring in their stomachs, 2-4% had commercial fish food pellets and 1-5% had wood chips, kelp or other material not recognized as food. Similarly, analysis of 138 recaptured Atlantic salmon from the Cypress Island net pen failure showed no evidence of eating (Clark et al. 2017). Only one fish caught in the Skagit River had wood chips about the size of pelleted fish food.

Researchers in Tasmania investigating the ability of escaped farmed rainbow trout and Atlantic salmon ranging in size from 0.5 to 3 kg to feed on native marine fauna demonstrated differences between these two non-native species (Abrantes et al. 2011). About 63% of rainbow trout stomachs were empty, 21% contained commercial feed pellets, and about 24% contained native animals. For Atlantic salmon, none of the fish collected fed on nutritious material; 79% had empty stomachs, and the stomachs of the remainder contained leaves. Both Atlantic salmon and rainbow trout escapees had lower condition factors compared to fish of each species caged at the farm sites. Thus, although escaped rainbow trout appeared to adapt better to feeding on natural prey than Atlantic salmon, this only occurred for a quarter of those that escaped.

Studies on fish within net pens has also shown low rates of predation on wild food items. Hay et al. (2004) examined the stomachs of 734 farmed salmon (Atlantic, coho and Chinook salmon) in BC net pens, and found very few contained wild prey items. Most common were small crustaceans called caprellids that likely were a component of net fouling organism community. Only one fish was found, a sand lance. No fish larvae were found, but very small, fragile items, like larval fish tissue, may have gone undetected if they were unrecognizable. However, the authors conclude that if large numbers of larvae had been consumed, some would have been detected. A more recent, yet unpublished, 2-year study by the Canadian Department of Fisheries and Oceans (DFO) analyzed stomach contents of 14,100 adult Atlantic salmon from 47 farms (K. Shaw, personal communication, April 14, 2020). They found only 11 wild fish, 10 confirmed or likely to be herring, and one possibly a sand lance.

Within net pens, farmed fish are habituated on pellet food, which is readily available. They therefore may have poor hunting ability, being cued in to food coming from the water surface as small pellets. Because they are well fed to maximize growth rate, they are also less likely to seek out other sources of nutrition. Therefore, although we cannot completely eliminate the possibility of opportunistic feeding on a juvenile salmonid that swims into a net pen with larger fish, we consider the occurrence of predation to be very low. However, all predation is considered fatal, whether injured by attempted predation or completely consumed. Exposure of juvenile salmonids to predation in net pens is low, but if it occurs, the consequence to those individuals is high.

Predation on PS/GB yelloweye rockfish and bocaccio could also occur during net pen operations. Again, exposure to this is limited to juvenile lifestages, particularly larvae, as adults and most non-larval juveniles have settled to the sea floor. Exposure at these lifestages is much more likely for rockfish than for salmonids. Larval rockfish of both species may be passively carried by currents through net pens. Juvenile yelloweye rockfish and bocaccio may potentially swim through net pens, but because juveniles of both species are benthic, they would typically swim under net pens rather than through them. As described above for salmonid species, farmed fish are well fed and habituated on pellet food, and based on available studies of stomach contents of farmed fish, we expect very few rockfish to be preyed upon by farmed fish. However, all episodes would be fatal. Exposure of rockfish to predation in pens is low for rockfish larvae, and response is high for those exposed.

2) <u>By-catch (Entrainment During Harvest)</u>

Harvest of farmed fish from net pens involves the use of a vacuum hose and pump that could entrain and kill juvenile PS steelhead and PS Chinook salmon, juvenile and larval PS/GB bocaccio, and larval PS/GB yelloweye rockfish. Any small fish that occur at the locations of the net pens could enter (the mesh size of the net pens is approximately 1.5 inches, so only fish smaller than this size could enter) and be exposed to vacuum intake. The net pens are located in areas of the PS away from the shoreline, deeper than 45 feet (MLLW) (see Table 1). The nearest net pen to the shoreline is 750 feet from the shore (at MLLW). HCSRC are not expected to occur near net pens or be at risk of entrainment by net pen harvest.

To harvest fish from the net pens, a transport vessel and a hose are first attached immediately adjacent to the net pen that is going to be harvested (see Cooke 2019). The hose is attached to a fish pump and is supported by a crane on the vessel. The intake end of the hose is placed into the fish pen designated for harvest and secured with mooring lines. Prior to vacuum removal of fish, size-graded seines are used to isolate larger fish for harvest (i.e. over 7 pounds), allowing smaller, undersized fish to remain in the net pen, and limiting the area and duration of vacuum harvest. The pump creates a suction in the water and fish and water are pulled through the vacuum pump chamber discharged onto a sorting box on the vessel (pers. comm. email Kevin Bright, Cooke Aquaculture, Inc., May 12, 2020). The dewatering box has smooth bars with approximately one-inch openings between the bars that allows excess water and any small fish to fall through the bars. These small fish then flow through a pipe overboard with excess water. Harvestable fish are dispatched and placed in the hull of the vessel.

The vacuum pump used by Cooke Aquaculture, Inc. is a twin CanaVac Aqua, with a 10-inch diameter discharge hose. Based on the manufacturer's specifications for this pump (see Inventive Marine Products Limited 2020), typical max discharge velocity for fish in these systems is approximately 2.0 meters per second (6.56 feet per second). With the 10-inch diameter hose, this equates to 3.57 cubic feet per second (1,600 gallons per minute). Based on existing harvest at PS commercial net pens, we expect this to occur for two-hour harvest periods (192,000 gallons of water withdrawn/pumped per harvest period), which would be repeated one to three times per week for a two to five-month harvest period beginning after fish have been reared for approximately 12 to 15 months (pers comm. email Kevin Bright, Cooke Aquaculture, Inc., May 12, 2020). There is no expected seasonality to harvest cycles at the four PS commercial net pen sites, with a goal of providing marketable fish year round. Thus we anticipate that cumulatively at the PS commercial net pen facilities, harvest would occur year round.

This pump has a continuous flow through the suction and discharge hoses, and per the manufacturer's specifications ensures damage-free transfer of live and seined fish. The soft valve on the entrance and exit of the pump prevents physical damage to fish, and the fish never leave the water. According to the manufacturer, fish moving through this system never come into contact with moving parts or high pressure water streams, minimizing stress and preventing scale loss. As a commercial operation, the physical condition and appearance of farmed fish is a primary concern for operators.

At the PS commercial net pens, the most recent Atlantic salmon farming operations included vacuum harvest for two hours, one to three times per week for a 2 to 5 month harvest period at each net pen facility (pers. comm. email Kevin Bright, Cooke Aquaculture, Inc., May 12, 2020). Harvest may occur at any time of the year. We expect future rainbow trout/steelhead and sablefish net pens to use similar schedules and levels of effort for harvest.

Although the mechanical systems in place are designed to minimize injury to fish, and quickly return bycatch to the PS, we consider it reasonably likely that there would be some injury of fish entrained during harvest of the net pens. During the harvest process, fish could potentially be injured by an oxygen deficit, abrasion against hose walls or the sorting box, being crushed by larger fish while passing through the vacuum pump, from barotrauma by being brought quickly to the surface from depth, or through disorientation upon being returned to the PS.

Adult salmonids are too large to be affected by this element of the proposed action, however juvenile salmonids are small enough both to enter the nets and be entrained. Juvenile PS Chinook salmon are generally nearshore-oriented, foraging and migrating through shallow waters closer to shore than where the net pens are located. The nearshore area extends from the shoreline to a depth of light penetration (estimated as 10 m, or 33 feet below MHW; Cereghino et al. 2012). The nearest net pen facility (Fort Ward – Saltwater II) is 750 feet from the shore (at MLLW), with a minimum water depth of -45 feet (MLLW) (See Table 1). The shallowest location of any net pen facility (Fort Ward - Saltwater II and Orchard Rocks – Saltwater IV) is approximately -45 feet (MLLW). PS Chinook salmon are nearshore oriented, typically migrating within shallow nearshore and intertidal areas (Levings et al. 1991; Duffy et al. 2005; Heerhatz and Toft 2015), shallower than where net pens are located. Even if PS Chinook salmon juveniles enter deeper areas where pens are located, we expect that juvenile PS Chinook salmon would generally avoid swimming under or within the overwater and in-water structures because they would be aware of the larger fish in the pens that could prey upon them. The avoidance of in- and over-water structures by juvenile salmonids in the marine environment is well documented (e.g., Heiser and Finn 1970; Able et al. 1998; Simenstad 1988; Southard et al. 2006; Toft et al. 2013; Ono 2010).

Additionally, any migrating juvenile PS Chinook salmon that did swim through net pens would only be susceptible to entrainment if their presence coincided with harvest activities. If any were present during harvest, the use of seines to segregate larger fish for harvest from the smaller fish in the pens prior to harvest would reduce the number potentially exposed to the vacuum intake hose. We expect that, as relatively strong swimmers, juvenile PS Chinook salmon would move away from the disturbance caused by harvest activities (e.g., crowding of larger farmed fish, vacuum hose placement and artificial suction, pump noise, etc.), and avoid entrainment.

There is no available bycatch monitoring data for PS commercial net pens, but documented evidence of low levels of by-catch of salmonids during net pen vacuum harvest in the Pacific Northwest is provided by British Columbia monitoring data. The Canadian government compiles incidental finfish bycatch within the marine finfish aquaculture farms of British Columbia (DFO 2019; Government of Canada 2020). Facility operators report quarterly all wild fish caught during harvest and transfer events. From July 2011 to November 2019 there were 1,287 bycatch incidents reported at 99 facilities for a total of 713,056 fish. However, 406,366 of these fish (all Pacific herring) were from two incidents that resulted from intentional depopulation of net pens to control the spread of IHNV. Of the remaining 306,690 total bycatch over this approximately seven-and-a-half-year period a total of 308 salmonids (Chinook, chum, coho, pink and unidentified Pacific salmon) were reported by 99 net pen facilities. Because habitat characteristics, structures at each facility and net pen operations are not identical to the four commercial net pen facilities in the PS, we are not able to draw direct comparisons, particularly given the far greater number of net pen facilities operating in British Columbia. However, they are similar in general structures and operations, and also located within the northeastern Pacific Ocean, like that action area. Therefore, this data supports our expectation that very few salmonids, including PS Chinook salmon, would be caught as by-catch during vacuum harvest at the four PS commercial net pen facilities.

For these reasons, we expect infrequent exposure of PS Chinook juveniles to entrainment during harvest, and when exposure does occur, it would be of a small number of individuals at each occurrence. In those circumstances of exposure, we consider the risk of injury or mortality of fish entrained during vacuum harvest to be low. The pump system and sorting box used for vacuum harvest is expected to minimize the risk of injury to entrained fish. The pump used for harvest is designed for live fish transfer operations, with a goal of transferring large numbers of fish while also minimizing the risk of injury. As stated by the manufacturer, "The CanaVac Aqua was designed specifically as a live fish transfer pump, suitable for all aspects of live fish pumping. The Aqua can transfer all sizes from smolt to adult fish without any damage, scale loss or stress" (see Inventive Marine Products Limited 2020).

However, taking a conservative approach, we expect a small number of fish may be injured by oxygen deficit, abrasion against hose walls, the sorting box or other structures, being crushed by larger fish while passing through the vacuum pump or as a result of disorientation upon being returned to the PS. As described above, we anticipate a low number of injuries to fish from moving from the water through the hoses and vacuum pump due to the low water velocity, and soft structures to prevent abrasive injury. The rounded bars on the sorting box would also minimize abrasion. We do not expect juvenile salmonids to experience barotrauma from entrainment since they generally occur within the upper layers of the water column, and thus would not be exposed to intense pressure changes caused by rapid ascent in the water column (or intake hose).

The relatively rapid return of fish from the sorting box to PS waters minimized the chance of an oxygen deficit, but could potentially initially disorient fish and increase predation risk. Disorientation or loss of equilibrium and increased predation risk of fish moving from high velocity environments to still ones is well documented at hydroelectric fish passage facilities (see Cada 2001). A study by Deng et al. (2010) of juvenile Chinook salmon carried by fast-moving water from a submerged turbulent jet into the slow-moving water of a flume observed minor to fatal injuries, but only at water velocities above 12.2 meters per second, well over the estimated 2 meters per second associated with the net pen vacuum pumps.

An example that is more similar to the conditions experienced by fish entrained in the vacuum harvest system are the transfer of fish in the tubular Whooshh Fish Transport System (see Whooshh Innovations, Inc. 2020), sometimes used to move fish around fish passage barriers. Tests of the Whooshh Fish Transport System found that juvenile Atlantic salmon (about 85 centimeter fork length) transferred between two tanks at a speed of 5 m per second (31 meter distance) observed that fish quickly attained a normal upright position and swam away at a leisurely pace (Erikson et al. 2016). Based on the manufacturers specifications, the fish entrained in the net pen vacuum harvest system, would move at no more than about 2 m per second, significantly slower than experienced in the study of the Whooshh system. Furthermore, since fish are transferred from the sorting box through a hose to the PS, fish would experience minimal forces otherwise associated with a higher velocity impact from being dropped from a distance to the water surface. Exposure and response of juvenile PS Chinook salmon to entrainment during net pen harvest is low.

Juvenile PS steelhead are more likely to swim nearer to the net pens than PS Chinook because they enter the marine environment as older/bigger fish, and are less dependent on the nearshore areas during their migration. Upon entering the PS from tributary natal rivers, juvenile PS steelhead quickly move offshore, migrating through offshore areas of the PS (Goetz 2016) where they may encounter net pens. Juvenile PS steelhead are surface oriented (Ruggerone et al. 1990), migrating through similar water depths as net pens—from the water surface down to a depth of about 50 feet (Table 1). The larger size of these fish in the marine environment, however, means that an even greater percentage of the juveniles are too large to enter the nets. And, like juvenile PS Chinook salmon, we expect that juvenile PS steelhead would generally avoid net pen in- and over-water structures to avoid the perceived predation threat by the farmed fish, particularly since the farmed fish are large at the time of harvest.

Assuming that harvest activities occur at any time during the year, they could coincide with outmigration of juvenile PS steelhead in the spring. The quick migration behavior from natal rivers through the PS to the Pacific Ocean, however, reduces the likelihood of encountering net pens during short-term, periodic harvest periods. The longest migration from river mouth (Nisqually River) to the SJDF has been documented to take as little as 10 days (Moore et al. 2015). Furthermore, since the net pens are not located immediately at the mouths of natal rivers we expect juvenile PS steelhead to be dispersed prior to any encounters with net pens.

The pre-harvest segregation of larger fish to be harvested with a size-graded seine reduces the potential for exposure of smaller fish, like juvenile PS steelhead, to the vacuum hose intake. We expect that, as relatively strong swimmers, juvenile PS steelhead would move away from the disturbance caused by harvest activities and avoid entrainment. Since 2011, no steelhead have been reported as by-catch during harvest or fish transfer operations at 99 net pens in British Columbia (Government of Canada 2020). We anticipate exposure to entrainment during harvest in PS net pens would be infrequent, and when it does occur, it would be only among a very low number of steelhead individuals.

When they are entrained during harvest, as described above or PS Chinook salmon, the use of the vacuum system, which is designed to minimize injury to fish and to return small fish, uninjured to the PS, is expected to result in few injuries. Based on the harvest practices and equipment, we expect that very few fish exposed to harvest activities would be injured or killed, and thus we consider there to be a low risk of effects to fitness. We expect both exposure and response of PS steelhead to entrainment during harvest to be low.

Exposure of PS/GB bocaccio and PS/GB yelloweye rockfish is more likely due to their size and behavior at the larval life stage. Larval rockfish are pelagic and are passively distributed by prevailing currents (Love et al. 2002). Thus they may encounter net pens, which are also located in the upper layers of the water column, and be exposed to vacuum harvest. Their mostly passive movement, and generally very weak swimming ability, make larval PS/GB bocaccio and yelloweye rockfish particularly susceptible to entrainment in the vacuum hose, unable to swim away and small enough to be entrained in high numbers. Entrainment of larval rockfish has been observed at power plant cooling water intakes, for example (Steinbeck et al. 2007).

Since vacuum harvest at net pens may occur at any time of the year, we assume there is co-occurrence with larval PS/GB bocaccio and yelloweye rockfish presence, which is expected to be greatest in the spring (Moser and Boehlert 1991; Palsson et al. 2009), but may occur at other times of the year as well (Beckman et al. 1998). Co-occurrence of larval rockfish and net pens is a consequence of individual larvae being carried by currents to a net pen. Because this distribution is passive, and net pens occupy a very small portion of the total habitat area of larval PS/GB rockfish and yelloweye rockfish habitat (i.e. the PS), we consider co-occurrence of a larvae and a net pen to be only moderately likely. Furthermore, for entrainment to occur during vacuum harvest, this co-occurrence would need to coincide with active vacuum harvest, and fish would need to be in close proximity to the intake hose.

A study conducted by Greene and Godersky (2012) estimated larval rockfish density (per 1000 cubic m) from April 2011 to February 2012 within the basins of the PS. The PS commercial net pen facilities are located within two of the basins delineated in this study – Central Basin (Rich Passage Saltwater I, Saltwater II and Saltwater IV facilities) and Whidbey Basin (Hope Island facility).

Because net pen harvest may occur at any time of the year, and to form a precautionary analysis, we use the highest monthly average density of larval rockfish recorded in each basin to estimate the number of fish that may be entrained during harvest. The highest monthly basin average of larval rockfish reported in Greene and Godersky (2012) is 107.1 fish/1000 cubic m (or per 264,172 gallons of water) in the Central Basin and 5.4 fish/1000 cubic m in the Whidbey Basin. Using rockfish survey data from 2014 and 2015, we are able to calculate likely larval rockfish proportions by species in the PS; 0.006% PS/GB bocaccio and 0.016% PS/GB yelloweye rockfish, presuming that the percentage of larval rockfish is equivalent to the percentage of adults (NMFS 2010; 2015). This is a conservative estimate, since the surveys targeted deep-water ESA-listed rockfish species, and the results may over represent their actual proportion of all rockfish species.

Using the pumping rates of the vacuum harvest pumps (96,000 gallons of water/hour) and the Greene and Godersky (2012) values, we calculated that during a typical 2-hour harvest period, pumping may entrain 77.840 larval rockfish at the net pen facilities in the Central Basin and 3.925 larval rockfish in the Whidbey Basin. By multiplying these values by the estimated proportion of PS/GB bocaccio and yelloweye rockfish, we are able to calculate the number of each species entrained during an hour of pumping; 0.234 PS/GB bocaccio and 0.623 PS/GB yelloweye rockfish larvae at each of the facilities (3) in the Central Basin and 0.012 bocaccio and 0.031 yelloweye rockfish at the Whidbey Basin facility (1). Assuming 2 hours of pumping occurs at each facility 1 to 3 times per week over a 2 to 5-month harvest period, approximate estimates of entrainment range from a low (i.e. 1 time per week for 2 months) of 4 to a high (i.e. 3 times per week for 5 months) of 30 PS/GB for larval bocaccio and 11 to 81 PS/GB for larval yelloweye rockfish at each of the three facilities in the Central Basin and 0 to 2 larval bocaccio and 1 to 4 larval yelloweye rockfish at the Whidbey Basin facility.

To estimate the entrained larval to adult equivalent we can use information on the fecundity of adult females. Yelloweye rockfish can produce between 1,200,000 and 2,700,000 larvae per year per female, and bocaccio produce between 20,000 and 2,298,000 eggs per year per female (Love et al. 2002). Although we do not expect all entrained larvae to be killed, taking a precautionary, worse-case approach, we can calculate adult equivalent mortality by considering that all entrained fish are mortalities. With this approach, we estimate that the level of mortality for larval populations is equivalent to the typical cohort of larvae from individual females (on an annual basis), by assuming that the death of larvae is synonymous with direct removal of fecundity. To calculate the adult equivalents, we thus divide the total number of entrained larvae by the high and low estimates of larvae produced per female, such that low larval output would result in a higher estimate for fish killed. Using the high estimates of larval rockfish entrainment for a complete harvest cycle of a net pen facility (harvest 3 times per week for 5 months), we calculate a worst-case scenario for adult equivalent mortality, as shown in Table 16.

Table 16. Estimates of adult equivalent mortalities from entrainment of larval PS/GB yelloweye rockfish and bocaccio during net pen harvest.

Species	Basin	High estimate of larval entrainment per facility harvest*	Adult equivalents (low estimate)[a]	Adult equivalents (high estimate)[b]
PS/GB yelloweye rockfish	Central	81	<0.0001	<0.0001
PS/GB yelloweye rockfish	Whidbey	4	<0.0001	<0.0001
PS/GB bocaccio	Central	30	<0.0001	0.0015
PS/GB bocaccio	Whidbey	2	<0.0001	0.0001

*Based on 2-hour harvest periods 3 times per week for 5 months; a. larval entrainment/high estimate of annual larvae produced per adult; b.larval entrainment/low estimate of annual larvae produced per adult

In both basins and for both species, the estimated adult equivalents are well below one adult fish. As mentioned above, we also expect the actual number to be lower, as we do not expect all entrained larvae to be killed. Furthermore, with a naturally high mortality rate of larval rockfish in the PS, we expect a very small proportion to reach adulthood. While very little is known about larval survival in the pelagic habitats of the action area, in a laboratory setting rockfish larvae experienced up to 70% mortality 7 to 12 days after birth, without the risk of predation (Canino and Francis 1989). Additionally, we can infer from stock assessment models of yelloweye rockfish along the outer Pacific coast that only a small fraction of individuals survive to reach the juvenile life history stage (Gertseva and Cope 2017).

In reality, because of low natural survival of larval and juvenile rockfish, an adult rockfish does not recruit out of every egg clutch. Yelloweye rockfish and bocaccio are r-selected species, meaning that they emphasize high growth rates and produce many offspring with a low probability of surviving to adulthood (see Adams 1980). In most years, no eggs from a clutch survive to the adult lifestage. Therefore, losing one clutch is not equivalent to losing one adult, and although already low, our estimates of adult equivalents are likely higher than reality.

Entrainment within the harvest vacuum hoses and pumps is likely to harm or kill larval PS/GB bocaccio and yelloweye rockfish as they would be removed from the water and then deposited in a dewatering box and sorted from larger fish. Because of their small size (less than about 20mm length; Palsson et al. 2009) we expect that many larvae fall immediately between the dewatering box bars and are returned to PS waters. However, there is uncertainty of how long they are out of the water during this process and larval rockfish are highly susceptible to physical injury and stress during the process. For example, larval rockfish were observed to be injured by strong water flow in laboratory-rearing environments (Canino and Francis 1989).

Rockfish are also susceptible to barotrauma if brought quickly from depth to the surface. Although most studies on barotrauma in rockfish is on adults, the susceptibility to both short-term and long-term health effects, including mortality, may be similar for larval and juveniles once they develop their swim bladder. Upon rapid decompression, rockfish suffer internal injury as a result of overexpansion of gases within their swim bladder and other vascularized tissues (Jarvis and Lowe 2008). Rockfish develop swim bladders early in their life (e.g., within 14 days of hatching) during the larval stage (M. Tagal, personal communication, June 9, 2020). Therefore, even larval rockfish may experience barotrauma if entrained in the lower depths of net pens.

A study by Jarvis and Lowe (2008) observed generally high levels of mortality from barotrauma in adults of 21 different species of rockfish. Although the degree of barotrauma was greatest for the two species caught deepest, mortality was also observed in species caught between 18 and 96 m. For adult yelloweye rockfish, documented mortality for surface-released fish caught between 0 and 60 feet is 21 and 22 percent, respectively (NMFS 2017a). For fish caught between 60 and 120 feet the mortality rate increases to 37 and 39 percent. Therefore, although the youngest larvae, and fish entrained from the upper layers of the water column may not experience barotrauma, and some would be likely to recover once released at the surface, we expect entrainment to injure or kill larvae. Exposure of larval rockfish is moderate, and response is high.

Non-larval juvenile PS/GB bocaccio are less likely to be entrained during net pen harvest because they are benthic, settling onto rocky or cobble substrates in the shallow nearshore at three to six months of age (approximately 1 to 3.5 inches) in areas that support kelp and other aquatic vegetation, and then move to progressively deeper waters as they grow (Love et al. 1991; Love et al. 2002; Palsson et al. 2009). Juvenile bocaccio also recruit to sandy zones with eelgrass or drift algae (Love et al. 2002). All the PS commercial net pens are located in areas with water depths less than 30 m (98 feet) at MLLW, where juvenile PS/GB bocaccio may occur. The net pens are also partially in deeper water habitat, or immediately adjacent to deeper habitat where juvenile PS/GB yelloweye rockfish may occur. Juvenile PS/GB yelloweye rockfish do not typically occupy nearshore waters (Love et al. 1991; Studebaker et al. 2009; NMFS 2017a), but settle in waters deeper than 98 feet (Yamanaka and Lacko 2001; NMFS 2017a). Since juvenile yelloweye rockfish and bocaccio are benthic, they are not expected to swim up into the net pens suspended above the sea floor.

From almost eight years of bycatch data from 99 net pen facilities in British Columbia, and over 713,056 fish reported as bycatch, there are no reports of bocaccio, and only one reported yelloweye rockfish (DFO 2019; Government of Canada 2020). Although 19,130 rockfish were reported that were not ID'd to species, we expect few to be yelloweye rockfish or bocaccio since juveniles of both species are generally easy to identify by their distinct coloration, patterning and structural traits, and thus would likely have been accounted for. In a recent risk assessment for rockfish conservation areas in BC, DFO "found very low relative risk to rockfish in Rockfish Conservation Areas from existing finfish aquaculture sites… based on the low incidental catch reported at those sites" (N. Ladell, personal communication, April 7, 2020). Although BC net pen aquaculture practices and habitat conditions are not directly applicable to the PS (BC net pens are typically in deeper waters where rockfish are more abundant), they are similar, and these findings support our expectation that very few juvenile bocaccio are caught as by-catch during vacuum harvest at PS net pens.

With regular cleaning of nets at PS commercial net pens to control biofouling, we do not expect growth of large kelp that attracts juvenile rockfish. Unlike larvae that primarily drift with prevailing currents, juvenile rockfish are more able swimmers and would be expected to avoid net pens with large (harvestable-size) fish that present a predation threat. As pelagic larval yelloweye rockfish and bocaccio progress to the juvenile stage and transition from pelagic to benthic habitat use, however, some may swim through net pens. For entrainment to occur, this would need to coincide with active vacuum harvest, which is infrequent at each net pen. Furthermore, the use of a seine to sort the harvestable larger fish from the smaller fish reduces the number of juvenile rockfish potentially exposed to the vacuum intake.

Those juvenile PS/GB yelloweye rockfish and bocaccio rockfish that are entrained within the harvest vacuum hoses and pumps would be expected be injured or killed. Entrained fish would be removed from the water and then deposited in a dewatering box and sorted from larger fish. Although many may be returned alive, and unharmed to the PS, they may experience injury from an oxygen deficit, physical contact with other fish or equipment, or barotrauma if brought from depth to the surface at a rapid rate. In British Columbia net pens, “DFO considers all incidentally caught rockfish to have 100% mortality even if released, due to severe barotrauma effects” (information from draft Rockfish Conservation Area risk assessment report provided by pers. comm. Email Neill Ladell, DFO, April 7, 2020). While we expect exposure of juvenile rockfish to be low, response at this life stage is high.

Table 17. Effects Matrix—summary of effects on species.

Stressor	Species	Species Analysis by Lifestage*							
		Lifestage	**Likelihood of exposure**	**Magnitude of response**	**Consequence of exposure and response**	**Lifestage**	**Likelihood of exposure**	**Magnitude of response**	**Consequence of exposure and response**
Predation by farm fish in net pen	PS Chinook salmon	Juvenile	Low	High	Low	Adult	NA		
	PS steelhead	Juvenile	Low	High	Low	Adult	NA		
	HCSR chum	Juvenile	Low	High	Low	Adult	NA		
	PS/GB yelloweye	Larval, juvenile	Low	High	Low	Adult	NA		
	PS/GB bocaccio	Larval, juvenile	Low	High	Low	Adult	NA		
Entrainment by harvest	PS Chinook salmon	Juvenile	Low	Moderate	Low	Adult	NA		
	PS steelhead	Juvenile	Low	Moderate	Low	Adult	NA		
	HCSR chum	Juvenile	Low	Moderate	Low	Adult	NA		
	PS/GB yelloweye	Larval, juvenile	Moderate, Low	High	Moderate, Low	Adult	NA		
	PS/GB bocaccio	Larval, juvenile	Moderate, Low	High	Moderate, Low	Adult	NA		
Entrainment or capture by escape response	PS Chinook salmon	Juvenile	Low	Moderate	Low	Adult	Low	High	Low
	PS steelhead	Juvenile	Low	Moderate	Low	Adult	Low	High	Low
	HCSR chum	Juvenile	Low	Moderate	Low	Adult	Low	High	Low
	PS/GB yelloweye	Larval, juvenile	Moderate, Low	High	Moderate, Low	Adult	NA		
	PS/GB bocaccio	Larval, juvenile	Moderate, Low	High	Moderate, Low	Adult	NA		
Pathogens	PS Chinook salmon	Juvenile	High	Moderate	Low	Adult	High	Moderate	Low
	PS steelhead	Juvenile	High	Moderate	Low	Adult	High	Moderate	Low
	HCSR chum	Juvenile	Low	Moderate	Low	Adult	Low	Moderate	Low

Stressor	Species	Species Analysis by Lifestage*							
		Lifestage	Likelihood of exposure	Magnitude of response	Consequence of exposure and response	Lifestage	Likelihood of exposure	Magnitude of response	Consequence of exposure and response
	PS/GB yelloweye	Larval, juvenile	High	Moderate	Low	Adult	High	Moderate	Low
	PS/GB bocaccio	Larval, juvenile	High	Moderate	Low	Adult	High	Moderate	Low
Genetics	PS steelhead	Juvenile	NA			Adult	Low	Low	Low
Competition and Predation with escaped fish	PS Chinook salmon	Juvenile	Moderate	Low	Low	Adult	Moderate	Low	Low
	PS steelhead	Juvenile	Moderate	Low	Low	Adult	Moderate	Low	Low
	HCSR chum	Juvenile	Moderate	Low	Low	Adult	Moderate	Low	Low
	PS/GB yelloweye	Larval, juvenile	Low	Low	Low	Adult	Low	Low	Low
	PS/GB bocaccio	Larval, juvenile	Low	Low		Adult	Low	Low	Low

*Color coding: low, moderate, high

3) *Entrainment or capture during response to fish escape*

In response to net pen failures or collapses that release farmed fish into the PS, measures may be implemented to recapture fish from the PS and tributary rivers. The Cypress Island Site 2 failure and response provides a recent example of efforts to recover fish escaped from PS commercial net pens. Clarke et al. (2017) provides an overview of the escape and response. At the time of the collapse, an estimated 305,000 Atlantic salmon were in the Cypress Island Site 2 net pens. Approximately 42,341 to 62,041 fish were initially harvested from the failed net pens using vacuum harvest pumps, and approximately 242,959 to 262,659 were released into the PS.

To recover fish released into the PS, seining and gillnetting was conducted by Cooke Aquaculture, Inc. and by Treaty Tribes (Clarke et al. 2017). As of January 15, 2018, Cooke Aquaculture, Inc. had recovered 388 fish from beach seining, the Treaty Tribes caught 51,300 fish in marine waters and 233 fish in rivers, 2,931 fish were recovered by public non-tribal commercial fisheries, and 1,958 catches were reported by recreation fisheries. In January 2020, Cooke Aquaculture, Inc. developed new Fish Escape Reporting and Response Plans (Cooke 2020d), which describes procedures for minimizing escapes, recapturing escaped fish and reporting escapements to regulatory agencies. We have based our assumptions for future escape response actions on the measures described in this plan and the response to the 2017 Cypress Island net pen failure.

In response to suspected accidental fish escape following a failure event, concurrent with actions to stop or reduce further escapement, Cooke Aquaculture, Inc. would contact WDFW to determine the feasibility of recovery measures. Cooke would work with state agencies (WDFW, Ecology, DNR and Department of Health) and tribal fisheries managers to determine the best methods for recapture. Authorization from WDFW must be obtained before commencing any recapture efforts. Recapture methods may result in by-catch of non-target species, such as PS Chinook salmon, PS steelhead, HCSRC, PS/GB yelloweye rockfish and PS/GB bocaccio. The 2021 Fish Escape Prevention, Response, and Reporting Plan will include a no-recovery option. If it is determined that to protect native salmonids this is the best option, there would be no potential for entrainment of adult PS Chinook salmon, PS steelhead or HCSRC. We assume this option would be selected if the escaped fish co-occurred in an area where high numbers of adult or juvenile wild salmonids occur (for example in the path of migration, or at a river mouth during peak run timing). With a no-recovery/no-capture response, the following analysis on recapture efforts thus overestimates impacts, but we are unable to determine with reasonable certainty when a no-capture option would be implemented, and therefore do not consider it in this determination of consequence.

Recapture efforts may include the deployment of one-inch mesh seine nets (used in regular net pen harvest/segregation but can also be used as beach seines), purse seines and gill netting, deployed by Cooke Aquaculture, Inc., contracted commercial harvesters or tribal fishery operators. With purse seining, non-target salmonids or other species can be manually removed by observing the fish being pumped across a de-watering table and then freed over the side of the vessel, or through a by-pass cute or pipe back to the water. Gill netting would typically target fish between three pounds and 15 pounds, allowing smaller fish to swim through the mesh openings, or not be fully gilled and fall off the nets when the nets are retrieved.

Cooke Aquaculture, Inc.'s Fish Escape Reporting and Response Plans (Cooke 2020d) state:

> *The time of year, location, size of the escaped fish, possible incidental by-catch, and/or Endangered Species Act (ESA) species concerns are considered in the decision process to determine the most suitable method for recapturing escaped fish. The goal is to recapture as many escaped fish as possible, while reducing the by-catch of non-target species*.

Depending on timing, location and site conditions, it is conceivable that in coordination with state agencies, Cooke may follow a no-recovery option. As stated by WDFW (2020): "an attempt to recover fish after an escape event might negatively affect native Pacific salmonids more than no attempt to recover fish." A new 2021 Fish Escape Prevention, Response and Reporting Plan is scheduled to be finalized December 2020. As stated in WDFW (2020), Cooke is required to work with WDFW, Ecology, DNR, affected treaty tribes and NOAA to include a no-recovery option in the new plan, which should include "when, where and under what conditions a recovery effort should not be attempted" for the purpose of protecting native salmonids. Therefore, we assume that in response to an escape, either the capture methods described above may be implemented to recover fish, or there may be no recapture effort extended should the risk to native salmonids be too high.

Recapture efforts could affect both juvenile and adult lifestages of salmonids, but this should occur only rarely (estimated as no more than one time in 50 years at each net pen site). Since 1985 there are only four known such events in the PS at commercial net pens. We anticipate that these events would continue to be very infrequent, based on the history of occurrence, as well as the more stringent monitoring, maintenance and reporting requirements required by NPDES permits, and additional protective measures implemented by Cooke Aquaculture Inc. since the Cypress Island Site 2 failure in 2017.

In the marine environment, only fish in the area around the failed net pen site would likely be exposed to recapture efforts. Beyond the immediate area of the net pen, escaped fish would be widely distributed and recapture efforts would likely be deemed infeasible, or the harmful effects on wild fish would likely outweigh benefits in which case recapture would not be conducted. For example, after the Cypress Island Site 2 failure, recapture efforts targeted the areas in close proximity. When undertaken, the targeted recovery efforts such as the use of seines, vacuum harvesters and gill netting would only be used for a short time after the escape (likely only days or weeks). For example, the Cypress Island Site 2 failure occurred on August 19, and recovery efforts ceased by mid-September of the same year. Therefore, based on the infrequency of recapture events, and the anticipated short-term localization of effort, even if recapture efforts were performed over several weeks, we consider there to be a low likelihood of listed salmonid exposure to recapture efforts.

Recapture of fish by *v*acuum removal would only occur in the net pen area, to target farmed fish. Effects would be consistent with harvest entrainment effects assessed previously in Section 2.6.2 Juvenile salmonids are expected to be smaller than the escaped fish targeted by recapture efforts, and would fit through the larger mesh size of seine nets, and gillnets. However, it's possible that seining (e.g., beach and purse seining), could capture some fish, particularly if smaller mesh sizes are used in response to juvenile farmed fish escaping. Because efforts would target only the escaped fish, we expect most juvenile fish to evade capture, or to be quickly released. Because of the infrequency of recapture efforts, the low likelihood of co-occurrence with recapture efforts, and the low likelihood of capture of juvenile salmonids, we consider both exposure and response of juveniles from all three salmonids species to entrainment or handling during recapture efforts to be low.

Recapture methods are expected to use seines and gill nets that target fish of similar size to adult salmonids, with mesh sizes too small for adult salmonids to fit through. Therefore, we anticipate that adult salmonids may be included in by-catch if they co-occur with recapture efforts. However, given the infrequency of net pen failure events and recapture events likelihood of exposure of adult salmonids is expected to be low. When adult salmonids are present at the time of recapture efforts, exposure to response could occur in several ways: It is possible that some wild salmonids could swim into the net pen, before nets are reestablished at the water surface to re-contain farmed fish, then become entrained during vacuum harvest. However, nets would likely be reattached at the surface within hours or days after a structural failure or collapse, limiting the opportunity for this occurrence. For example, Cooke Aquaculture, Inc. had secured the failed net pen, extracted all of the fish from the pen and salvaged much of the structure within just over two weeks following the Cypress Island Site 2 failure. For HCSRC adults, the four commercial net pen sites are over 20 miles from Hood Canal and the SJDF where HCSRC typically occur, and thus adults of this species have an extremely low likelihood of being entrained by a response to an escape around this single facility.

Some adult PS Chinook salmon and PS steelhead entrained by vacuum harvest pumps, or caught in seine or gill nets would be harmed or killed. Although some fish may not be killed and by-catch could be separated from farmed fish targeted by the recovery effort and returned to the PS, harm is likely. In particular, we anticipate that some fish caught in nets would experience an oxygen deficit, physical injury from handling or scale abrasion. Therefore, taking a conservative approach we assume all fish entrained or caught would be injured or killed. The likelihood of adult salmonids being exposed to entrainment or handling during recapture efforts is low, but the response is high.

We do not foresee any recovery efforts to include methods that target fish in the benthic environment where adult rockfish occur, and thus we do not anticipate effects on PS yelloweye rockfish or bocaccio. We expect entrainment of juvenile and larval rockfish to only occur as a result of vacuum removal, because they would be too small to be captured in nets and seines. Additionally, entrainment by vacuum removal only occurs within the net pen area, and therefore would be of similar magnitude and area to vacuum harvest, as described above. The likelihood of larval rockfish exposure to entrainment is moderate and the response to such entrainment is high. The likelihood of juvenile rockfish being entrained is low and the response to such entrainment is high.

4) <u>Pathogens transmission to wild fish</u>

All listed fish species considered in this opinion could be exposed to pathogens from the penned fish. Although there are many pathogens that could infect and cause disease in cultured fish held in marine net pens in Washington (Table 1), Cooke Aquaculture indicates that there are six that are most common in cultured Atlantic salmon. These common pathogens (and their associated diseases) are: *Tenacibaculum maritimum* (yellowmouth); *Aeromonas salmonicida* (furunculosis); *Vibrio anguillarum and V. ordali* (vibriosis); *Piscirickettsia salmonis* (salmon rickettsia syndrome, SRS); *Moritella viscosa* (winter ulcer); and Infectious Hematopoietic Necrosis Virus (IHNV; J. Parsons, personal communication, 2020; in WDFW 2020a).

Of these seven pathogens observed by Cooke Aquaculture, Inc. in Washington net pen Atlantic salmon, six are bacterial, for which antibiotics are the primary treatment (WDFW 2020a). Each of these bacteria, except for *A. salmonicida* and *P. salmonis,* are obligate marine or brackish water pathogens, and the fish become infected by these endemic pathogens only after they enter the marine environment. Vaccines are available for Atlantic salmon, rainbow trout/steelhead and sablefish to manage disease caused by four of these six bacteria: *A. salmonicida*, *V. anguillarum*, *V. ordali*, and *M. viscosa*. Net pen fish are particularly vulnerable to *T. maritimum* when they first enter salt water and are frequently given antibiotics to treat for yellowmouth; this is the most common disease for which antibiotics were applied to Atlantic salmon in PS. Experimental trials with culturing triploid steelhead trout in PS in 2012 showed that steelhead trout are more resistant to yellowmouth than Atlantic salmon (J. Parsons, personal communication, 2020; in WDFW 2020a), suggesting that Cooke's proposal to switch from Atlantic salmon to rainbow trout/steelhead may result in less disease and fewer applications of antibiotics.

Disease caused by the endemic IHN virus is managed through testing and a vaccine. The last outbreak of IHN in marine net pens in PS was in 2012, prior to the use of vaccination as a way to control the pathogen (J. Parsons, personal communication, 2020; in WDFW 2020a). Even though this outbreak led to mortality in the Atlantic salmon, it is unlikely to have had adverse effects on Pacific salmon and steelhead (Kurath 2017). Among the three IHNV clades identified in West Coast salmon, two occur in Washington State. These are the U clade, which is most pathogenic for sockeye and kokanee salmon, and the M clade for steelhead and rainbow trout (Kurath 2017). The IHNV clade identified in the 2012 outbreak was the U clade, which, based on host susceptibility, was unlikely to have caused clinical disease signs in Chinook salmon, steelhead, or other marine ESA-listed finfish species (e.g., rockfish, eulachon, and green sturgeon). However, Chinook salmon can be infected with the U clade and become a carrier (Hernandez et al. 2016). Still there is an IHNV vaccine that offers good protection for Atlantic salmon (Long et al. 2017). Cooke Aquaculture currently vaccinates all their cultured fish against IHNV, and their net pens have tested negative for IHNV since the 2012 IHN outbreak of unvaccinated Atlantic salmon (WDFW 2020a).

The following sections provide background on the aspects of pathogen/disease risk NMFS considered when forming our pathogen/disease risk conclusions for the foreseeable future associated with the Proposed Action. These sections cover; pathogen introductions, pathogen emergence, pathogen amplification/spread, evidence of pathogen transmission to wild fish, the use of therapeutants and disinfectants, and risk reduction measures.

Table 18. List of recognized and potential pathogens in Washington that could occur in the PS net pen operations.

Species/Disease	Pathogen Type	Other Listed Species Affected
Aeromonas salmonicida	Bacterium	Freshwater and marine fish
Vibrio anguillarum and V. ordalii	Bacterium	Freshwater and marine fish
Vibrio salmonicida	Bacterium	Marine fish
Piscirickettsia salmonis*	Bacterium	Freshwater and marine fish
Moritella viscosa	Bacterium	Marine fish
Photobacterium damselae sub. Piscicida	Bacterium	Marine fish
Renibacterium salmoninarum	Bacterium	All salmonids; experimental infections established in sablefish and Pacific herring
Carnobacterium piscicola	Bacterium	Freshwater and marine fish
Streptococcus spp.	Bacterium	Freshwater and marine fish
Tenacibaculum maritimum	Bacterium	Marine fish
Infectious Hematopoietic Necrosis Virus (IHNV)*	Virus	Salmonids
Erythrocytic Inclusion Body Syndrome (EIBS)	Virus	Salmonids
Aquabirnavirus (IPNV)*	Virus	Freshwater and marine fish
Viral Erythrocytic Necrosis (VEN)	Virus	Freshwater and marine fish
Viral Hemorrhagic Septicemia Virus (VHSV)*	Virus	Freshwater and marine fish
Piscine Orthoreovirus (PRV strains 1 and 3)*	Virus	Salmonids
Infectious Salmon Anemia Virus (ISAV)*	Virus	Atlantic salmon
Sprionucleus barkhanus, Hexamita salmonis	Parasite-diplomonad flagellate	Freshwater and marine fish
Icthyobodo salmonis (Costia)	Parasite-flagellate	Freshwater and marine salmonids
Trichodina, Apisoma, and Chilodonella	Parasite-ciliate	Freshwater and marine fish
Laminiscus strelkowi	Parasite-monogenean	Salmonids, catfish, cyprinids
Caligus clemensi, Lepeoptheirus salmonis	Parasite-sea lice	Salmonids, some rockfish, white sturgeon
Argulus spp.	Parasite-sea lice	Freshwater and marine fish
Nucleospora salmonis, Loma salmonae*	Parasite-microsporidian	Salmonids, lumpfish, Atlantic halibut
Ichthyophonus spp.(or I. hoferi) *Paramoeba pemaquidensis* *Parvicapsula* spp., *Kudoa thysites*	Parasite-protist Parasite-amoeba Parasite-myxosporean	Freshwater and marine fish Marine fish, salmonids Freshwater and marine fish, salmonids

Note: Bolded pathogens are those that are regulated by/reportable to USDA APHIS and OIE; those with an asterisk are regulated/reportable by the State of Washington (NWTT and WDFW 2006).
Source: AFS Blue Book; Isaksen et al. 2011; Purcell et al. 2018; Rozas and Enrıquez 2014.

Pathogen Introduction

The culture of finfish comes with a risk to wild fish of introducing nonendemic pathogens. This can occur in a number of ways, but the most common is if the finfish are infected and transported into a new area (Naish et al. 2007). Other ways include through movement of water containing pathogens (e.g., ballast water from boats), a vector such as a predatory bird that feeds on infected fish, or an infected wild fish that transmits the pathogen to cultured fish through the water.

Piscine orthoreovirus (PRV) is genetically detected among Atlantic salmon world-wide and has some association with disease (e.g., heart-skeletal muscle inflammation, or HSMI) in cultured fish, although many asymptomatic Atlantic salmon carry PRV (Polinski et al. 2020). Sequences from genogroup PRV-1 have been detected in all species of Pacific salmon and steelhead trout from the North Pacific (Polinski et al. 2020), but there is no clear association with pathology in these fish species. To minimize any risk of introducing a potentially pathogenic variant of PRV-1, Washington state implemented testing for specific variants of PRV-1 for Atlantic salmon in 2018 (WDFW 2020a), resulting in rejection of some stocks for transfer to net pens. Use of regionally derived steelhead and sablefish will greatly reduce the risk of non-native pathogen introduction.

Pathogen Emergence

In epidemiology, the epidemiological triad (Figure 8) is used to visualize the balance between the host, pathogen, and environmental factors (e.g., host susceptibility, pathogen virulence, and temperature) required for disease to occur. A disruption in any one component can change the frequency, severity, or distribution of disease occurrence. If these changes lead to increases in these disease characteristics, the underlying pathogen may be considered an emerging one. An emerging pathogen is the causative agent of an infectious disease whose incidence is increasing following its appearance in a new host population or whose incidence is increasing in an existing population because of long-term changes in its underlying epidemiology (Woolhouse and Dye 2001). Several factors associated with aquaculture can lead to the emergence of a pathogen (Kennedy et al. 2016) include rearing, densities that are higher than natural densities, host genetic diversity, the continued presence of susceptible hosts (through cycling of stocks), and endemic potential pathogens in the environment.

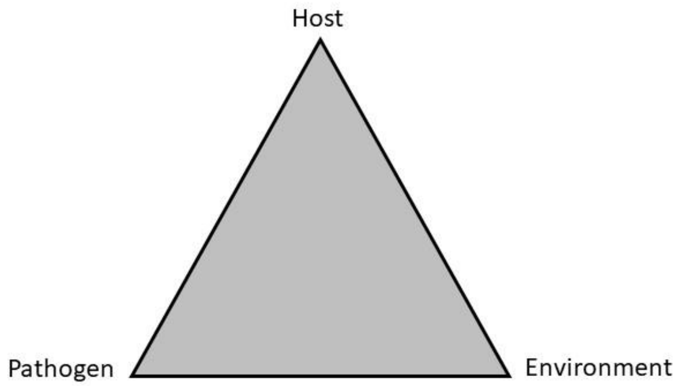

Figure 8. The epidemiological triad.

Genetics can affect the degree to which a host is susceptible to an emergent pathogen, and can involve different suites of genes depending upon the pathogen. For example, resistance to an intracellular pathogen may rely more heavily on a cell-mediated immune responses (e.g., activated macrophages) while resistance to an extracellular pathogen may depend upon a humoral (e.g., antibody-mediated) response. In addition to conventional selective rearing, identification of relevant genetic markers for disease susceptibility and resistance is a developing technology (Yañez et al. 2014). Although outbreeding is typically considered beneficial for disease resistance, outbreeding depression can result in increased susceptibility to a pathogen (e.g., Goldberg et al. 2005). Negative effects on susceptibility are better known for cases of inbreeding depression (e.g., Arkush et al. 2002; Smallbone et al. 2016), presumably due to locus homozygosity. At this time, there is no consistent ability to predict the disease susceptibility of a stock or population without direct challenge testing.

Another mechanism for an emerging pathogen is through changes in the pathogen itself. Infectious salmon anemia (ISA) was initially discovered in 1984 in Norway, and steadily spread throughout the Norwegian Atlantic salmon industry until production shifted to a single generation at each site (Håstein et al. 1999). Subsequent studies recognized that in addition to the disease-causing strain of infectious salmon anemia virus (ISAV), there was another variant that caused a transient infection with low pathogenicity (Christiansen et al. 2011). There is significant evidence indicating that this low virulence variant, HPR0, represents a source of the higher virulence variant, HPRΔ that emerged under culture conditions, and current recommendations include management tactics to reduce and eliminate HPR0 from cultured stocks (Nylund et al. 2019).

Good biosecurity measures, such as rapid removal of mortalities to prevent bacterial growth can greatly reduce the potential for the emergence of higher virulence bacteria. Although switching away from a non-native fish species (i.e. from Atlantic salmon to rainbow trout/steelhead) for culture can reduce the risk of importing an exotic or novel pathogen into PS, there is a different risk for culturing native fish species, namely susceptibility to enzootic (or endemic) pathogens.

Because there are differences in species vulnerability to infection and disease development, native fish species will be susceptible to pathogens already present in PS waters.

Pathogen Amplification and/or Spread

Conditions stressful to farmed fish are major contributors to pathogen amplification. While some of these conditions can be managed (e.g., rearing densities), others cannot (e.g., marine heatwaves). Biosecurity measures, such as transfer of healthy fish and adequate fallowing between stockings, can reduce pathogens among farmed fish, but transfer of pathogens from wild fish to net pen fish is difficult to explicitly manage. Evidence for directional pathogen transfer is sparse, and the likelihood of wild-to-farmed transmission is difficult to estimate. For example, Kurath and Winton (2011) identified six out of seven viral transmissions as originating from wild fish, whereas phylogenetic analysis of ISAV in Norway indicate little or no passage from wild to cultured fish (Nylund et al. 2020). Nonetheless, wild fish in proximity to net pens could potentially be exposed to pathogens in cultured fish or could expose cultured fish to pathogens.

Transfer of pathogens from an infected farm involve active and passive mechanisms. Good biosecurity measures can effectively manage active transfer mechanisms such as proper management of contaminated equipment and aquaculture vessel traffic frequency. Passive dispersal of pathogens from an infected farm is best managed by appropriate siting, and transfer kinetics depend on persistence of infectious pathogens outside of the host, particle transport features, and site-specific hydrodynamics.

In an extensive assessment of risk presented by common pathogens of aquacultured Atlantic salmon in the Discovery Islands of British Columbia, Canada, a detailed Finite Volume Community Ocean Model (FVCOM) was applied to simulate passive particle tracking from farms to estimate dispersal trajectories (Chandler et al. 2017; Foreman et al. 2015a; Foreman et al. 2015b). This type of information can be used prospectively to inform appropriate farm siting. Hydrologic models can be coupled to an epidemiologic model to inform relative positions of farms. Salama and Murray (2011) demonstrated how pathogen transmission between farms could be affected by current flow, farm size (expressed in tons), and pathogen shed (either peak, ½ peak, or ¼ peak). For farms ranging in size from ~1,000 to 3,000 tons, separation between farms to avoid persistent outbreaks varied depending on the pathogen: 20-40 km for *A. salmonicida*, 10-20 km for ISAV and 100-200km for IPNV (the distance between the two Cooke farms - Orchard Rocks and Rich Passage, in PS is ~110 km.). The study also highlighted the importance of rate of decay of the pathogen. Although both ISAV and IPNV are very small viral particles, the slower decay rate of IPNV resulted in a ten-fold larger recommended distance. Although that study concluded that larger, widely separated farms were preferred to smaller, clustered farms, such modeling efforts are most appropriately conducted on a site-specific basis.

A similar model construction was used by Stucchi et al. (2011) to describe the transport and concentrations of sea lice (*L. salmonis*) in the Broughton Archipelago in British Columbia. The authors compared the results of their models to wild fish survey results and found that in areas where the model predicted low concentrations of infective sea lice stages, wild juvenile salmonids had a low prevalence of sea lice infection. If researchers are able to quantify and validate this correlation, they can then further develop regional disease management strategies for a pathogen where a vaccine does not exist.

A study by Mordecai et al. (2021) suggests the transmission of PRV-1 from farmed net pen fish (Atlantic salmon) to wild Pacific salmon in the northeast Pacific, but it is unclear if the farmed fish were initially infected or if they became infected after transfer to marine net pens. However, PRV has been present in northeast Pacific salmonids prior to the introduction of aquaculture to the region, with the earliest detection in wild steelhead in 1977 (Marty et al. 2015). Furthermore, none of the Pacific salmonids that were PRV-positive displayed any disease symptoms. A different diagnostic study of more than 2,200 Pacific salmonids detected PRV genetic material in four of the six species, although none of those fish displayed any disease symptoms (Purcell et al. 2017). An important caveat of results based on genetic detection is that pathogen presence does not necessarily indicate disease. In the case of PRV, which has not yet fulfilled Koch's postulates as the etiological agent of disease in Pacific salmonids, the interpretation based solely on genetic detection should use caution.

Data from multiple locations world-wide strongly indicate that amplification of sea lice in salmon aquaculture has a negative effect on sympatric wild fish stocks, including population decline (Thorstad et al. 2015, Torrissen et al. 2013; Costello 2009). Although these conclusions are based primarily on correlations, the relationship is observed at multiple locations in the world and is associated with production cycles (e.g., Vollset et al. 2018). Because lice infestation is affected by temperature and salinity, farm siting criteria for salmonids should include considerations of both oceanographic and environmental conditions to reduce the potential for lice infestations (Brewer-Dalton et al. 2014). For example, sea lice survival and nauplii development is compromised at salinities below 29 and 25 parts per thousand, respectively (Bricknell et al. 2006; Johnson and Albright 1991), potentially explaining why sea lice are not problematic for Atlantic salmon net pens in PS. The negative effect of sea lice on the physiology and growth of cultured fish is a serious economic concern for aquaculture, and fish growers have a significant investment in minimizing and managing sea lice (Taranger et al. 2015). Programs for monitoring and controlling sea lice infestations, including integrated pest management (e.g., Brooks 2009), continue to be developed and tested worldwide (Torrissen et al. 2013).

Pathogen Transmission between Farmed and Wild Fish

As assessment of the impact of hatcheries on wild salmon in the US found that evidence for pathogen transmission between farmed and wild fish was equivocal (Naish et al. 2007). Although Kurath and Winton (2011) provide evidence for greater wild to farmed transmission of certain viruses, there is support for a directional transfer of parasites from farmed to wild fish (Taranger et al. 2015). Although disease monitoring among captive populations (e.g., hatcheries) is routine, surveillance for disease in free-ranging populations is usually synoptic, anecdotal, or not performed at all, and represents a major information gap in understanding the interaction of farmed fish with wild fish. Furthermore, reduced fitness for sick wild fish is expected to make them vulnerable to predation and other hazards that rapidly remove them from observation. Host tropism is an important consideration for horizontal transmission between farmed and wild fish of different species. Some species are more vulnerable to developing disease upon infection. For example, coho and Chinook salmon are more vulnerable to bacterial kidney disease (caused by *Renibacterium salmoninarum* than Atlantic salmon and rainbow trout (Starliper et al. 1997).

Aeromonas salmonicida has a broad marine host range (Wiklund and Dalsgaard, 1998) including sablefish (Evelyn, 1971). Viral hemorrhagic septicemia virus (VHSV) can infect at least 80 fish species, but genotype IVa is the only genotype found in the northeastern Pacific Ocean (Garver et al. 2013). VHSV IVa causes epizootics in nonsalmonids (Pacific herring, Pacific sandlance, Pacific sardine, Pacific hake, walleye pollack; Meyers et al., 1999; Traxler et al., 1999; Kocan et al., 2001), while *Oncorhynchus* species are negligibly susceptible to infection (Meyers and Winton, 1995).

Factors involved in pathogen transmission include distance between farmed and wild fish, type of interaction (i.e., swimming in proximity, physical contact, predation), level of pathogen provided (either through shedding into the water or physical transfer), and required infectious dose. It is the interaction of these factors that contribute to the likelihood of fish-to-fish pathogen transmission.

If net pen mesh size permits wild fish to directly interact with farmed fish, pathogen transfer could result from ingestion of infected fish or tissues (e.g., fecal-oral horizontal transmission of *R. salmoninarum*; Balfry et al. 1996) or infection from shed pathogen (e.g., viruses; Oidtmann et al. 2018) or actively moving pathogens (e.g., sea lice). If wild fish are excluded from the net pen, the same transfer mechanisms exist except for direct predation.

Inferring transfer between farmed and wild fish is difficult without empirical studies. Murray et al. (2017) identified potential disease interactions between farmed and wild fish, but these conclusions were based strictly on concurrent infection prevalences. A risk assessment of the four principal viral diseases in Norwegian salmon aquaculture evaluated the likelihood of farmed-to-wild fish transmission, concluding low risk for two viruses and moderate risk for two viruses (Taranger et al. 2015). However, the assessment relied on relative prevalences of virus detections and disease symptoms in farmed and wild fish as well as pathogen-specific factors such as environmental persistence rather than demonstrated transmission, highlighting an important information gap even in a country with a large aquaculture industry. One tool with potential to address pathogen transfer is DNA sequencing and phylogenetic analyses of time-series sampling of pathogens.

A review by Kurath (2017) on a 2012 IHN outbreak in PS Atlantic salmon farms found that the outbreak was caused by UP subgroup IHN virus (es) introduced from sockeye salmon in the PS and that juvenile Chinook salmon or steelhead that may have been exposed to the UP viruses. However, the review determined that the probability of this exposure led to infection of some juvenile Chinook salmon and steelhead is moderate or low, based on low susceptibility of these species to U group IHNV. The author concluded that for any Chinook salmon or steelhead that did become infected, the probability of the infection progressing to cause disease or mortality is extremely unlikely. This was based on the host-specificity of UP viruses, which are very rarely detected in Chinook salmon or steelhead in the wild, and do not cause significant disease in controlled laboratory experiments.

An important factor in horizontal transmission between farmed and wild fish is the required infectious dose. This has been determined for some salmonid pathogens, and can vary depending upon species and life history stage. For example, the waterborne minimum infectious dose of

IHNV for Atlantic salmon smolts is 10 plaques per mL (pfu/mL) (Garver et al. 2013), and 100 pfu/mL for sockeye salmon smolts (Long et al. 2017), an order of magnitude difference between species. In addition to infectious dose, duration of exposure is important. Waterborne challenges with *Aeromonas salmonicida* of 20-35 g fish show that Atlantic salmon required exposure to 3 x 10^5 colony forming units per mL (cfu/mL) for a day (Rose et al. 1989), rainbow trout required 10^4 to 10^5 cfu/mL for 12 hours (Perez et al. 1996), and sockeye salmon required 3.6 x 10^6 cfu/mL for 15 minutes (Roon et al. 2015) to initiate disease and mortality. Because there is a major knowledge gap about the concentration of pathogens in the water around an infected net pen, there is no credible way to calculate the likelihood of transmission to wild fish associated with the net pen.

Pathogen Infection and Disease Risk Reduction Measures

Prevention, minimization, and mitigating pathogen introduction, dissemination, and the consequences include regular veterinary inspections and surveillance with validated diagnostic methods; maintaining good quality broodstock, eggs, and juveniles, including rapid removal of moribund fish and mortalities; vaccination when feasible and rapid response to outbreaks; biosecurity measures to eliminate or minimize cross-contamination; separation of year classes; adequate fallowing time between stockings; and depopulation when necessary (Jones et al. 2015). Kurath and Winton (2011), also suggest that transport or escape of infected fish, untreated effluent, and attraction of wild fish to net pens could increase the risk of pathogen transmission to wild fish. The National Aquaculture Health Plan and Standards (USDA APHIS 2021) provides guidance for reporting, surveillance, diagnostics, biosecurity, event response, data management, education, and training for consistent approaches to maintaining the health and safety of aquatic livestock. Voluntary participation in the Commercial Aquaculture Health Program Standards, managed by USDA APHIS, provides additional assurance of a science-based approach to health assessment and status.

While there will always be some level of disease risk associated with rearing fish in PS nets pens, Cooke Aquaculture, Inc. has incorporated several mitigating measures into its existing and proposed operations (e.g., see Cooke 2018; WDFW 2020a):

- Both species expected for net pen rearing (rainbow trout/steelhead and sablefish) are native to the PS. The rainbow trout cultured by Troutlodge originate from the collection of natural-origin fish from the Puyallup River in the 1960s. The sablefish originate from annual collections of wild sablefish off the Washington Coast from about 2008 to the present.
- Once fish are harvested, the net pen would remain fallow for at least 42 days and would be thoroughly cleaned (see disinfectants section), which would limit the availability of susceptible hosts, a necessary element for infection and disease to occur.
- All eggs are disinfected at the Troutlodge facility, and then are tested for regulated pathogens (see Table 1) 30 days post-swim-up after hatching, and again before being transported to the marine net pens.
- Footbaths, as well as equipment specific to each site (i.e., storage containers for fish mortalities, nets, feed containers, etc.) are used to maintain biosecurity.

- When shared equipment among locations is unavoidable (i.e., fish transport vessels), all equipment of this type would be thoroughly disinfected and/or fallowed after use.
- During net pen residence, daily observations of fish behavior, feeding, and net pen water conditions would be conducted. Any moribund fish would be assessed for physical damage and signs of disease and a post-mortem necropsy would be conducted to determine the cause of mortality (Cooke 2018, disease plan). A trained fish health technician conducts this assessment, and if anomalous results are identified, the Veterinarian of Record (VOR) would be consulted.
- Fish would also be vaccinated against IHNV, *A. salmonicida*, *V. anguillarum*, *V. ordali*, and *M. viscosa*. Although vaccines rarely have an efficacy rate of 100%, the vaccines should provide protection for a majority of the net pen fish (H. Mitchell, personal communication, March 26 2020). Furthermore, the IHNV vaccine is effective for both the U and M clades (Peñaranda et al. 2011), so should prove effective in rainbow trout/steelhead, for up to two years (Kurath et al. 2006).
- If medicated feed is needed to treat bacterial infections, there are multiple options available that should limit the ability of the bacteria to develop antibiotic resistance
- Only a single cohort of fish are stocked at a farm at a time, which minimizes risk to pathogen transmission because naïve fish hosts are not constantly being introduced (Kurath and Winton 2011).

In addition, the state of Washington has imposed several mitigating provisions on Cooke's net pen operation as part of the state's approval of an aquaculture permit (WDFW 2020a):

- Cooke must ensure that all state and federal Veterinary-Client-Patient-Relationship (VCPR), Veterinarian of Record (VOR), and Veterinary Feed Directive (VFD) rules and laws are followed (e.g., WAC 246-933-200, 21 CFR 514, 21 CFR 558).
- In accordance with WAC 220-370-080 and 220-370-130 authorized WDFW employees shall have access to freshwater hatchery facilities and marine net pen facilities to conduct inspections, to collect samples for disease surveillance, and to inspect net pen infrastructure.
- Net pen facilities must remain fallow for 42 days after the last fish are harvested and the last containment net is removed for cleaning and repair. This number can be increased per determination of WDFW veterinarian due to disease prevalence just prior to or at the time of harvest.
- Net pen facilities must be managed as single-generation stocking.
- Broodstock (parents) of embryos or fish going to Cooke Aquaculture freshwater rearing facilities would be sampled and tested at a certified lab for Washington Regulated Pathogens (see Table 1 below) at the 2% Approved Pathogen Prevalence Level (APPL) annually within three months of transfer from Troutlodge to Cooke's freshwater facility.
- Lots of pre-marine smolts, before transfer from Cooke's freshwater faculties to marine net pens, would be sampled and tested at a certified testing lab for Washington state regulated and reportable pathogens (see #2 above) at the 2% APPL.
- Cooke's freshwater and marine facilities are subject to inspections by WDFW to ensure proper biosecurity, fish health, and pathogen sampling. Sampling levels can be modified by WDFW in response to pathogen findings.

- Under no conditions should fish carcasses be removed from the net pens and returned into waters of PS.
- All disease outbreaks, unexplained mortality, and regulated, reportable, or exotic pathogen findings must be reported to the WDFW Fish Health Supervisor, Lead Veterinarian, or Aquaculture Coordinator within 24 hours.
- A fish health evaluation report written by a certified fish health inspector must be submitted to WDFW each year, no later than January 31, summarizing fish health inspections, laboratory tests, and the presence of pathogens, for the previous calendar year, at each net pen facility.

Summary of risk for all species and life stages

The likelihood of farmed fish being exposed to enzootic pathogens in marine waters of the action area is high, because they exist naturally in the environment. Thus the potential for exposure of wild fish to pathogens in reared net pen fish is also high, except for HCSRC (low risk of exposure) because they are not expected to occur near the four net pen sites. If exposure results in infection, the magnitude of the response depends on the pathogen the individual fish is exposed to, duration of exposure and the characteristics of the environment at the time of exposure. The risk of exotic or introduced pathogen exposure is substantially reduced by the use of native fish, initially cultured in a pathogen-free setting. However, if the farmed fish become infected by wild fish or pathogens present in the environment, the high density of farmed fish within net pens could amplify transmission within net pens, as well as to wild fish in proximity to the pens.

Numerous risk reduction measures mentioned above have been implemented by Cooke Aquaculture to reduce pathogen exposure (e.g., vaccination, judicious use of multiple antibiotics, biosecurity measures to limit pathogen spread, fallow period, an all-in-all-out operation, etc.). Furthermore, the additional measures mandated by WDFW in association with their January 2020 Aquaculture Permit are likely to minimize the risks even further by ensuring timely reporting and increased accountability. Based on the disease history for the PS net pens and the information considered above, we believe the consequences of response of all listed species exposed to pathogens are likely to be low.

The likelihood of exposure of all life stages of wild salmon and steelhead to enzootic pathogens in freshwater portions of the action area (PS tributary rivers) is high because they exist naturally in the environment. However, compared to the marine portions of the action area, we anticipate a much lower risk (moderate) of exposure of wild fish to escaped farmed rainbow trout/steelhead in rivers with relatively few expected to migrate into freshwater tributaries (see results of the OMEGA model in the genetics section below). If exposure results in infection, the magnitude of the response depends on the pathogen the individual fish is exposed to and the characteristics of the environment at the time of exposure. However since relatively few escapees are expected to migrate into freshwater, we believe the response of salmon and steelhead to pathogens exposure is also likely to be low**.**

5) *Genetic Effects of Interbreeding of Escaped Farmed Fish with Wild Fish*

The genetic risks of hatchery reared salmon/steelhead to wild populations have been extensively studied. Our review of potential impacts described below is largely based on literature related to hatchery salmon/steelhead and in some cases studies of hatchery or escaped farmed Atlantic salmon. The degree and type of genetic effects depends on a number of factors including: (1) the degree of genetic differences between farmed and wild fish; (2) likelihood of farmed fish encountering and interbreeding with wild fish; (3) number of escapes; and (4) relative reproductive success of farmed and wild fish. Since the genetic risk is largely affected by the ability of fish to breed successfully, a method that is used to mitigate genetic risks of escaped farmed fish is to farm sterile fish (Baskett et al. 2013).

Gene flow from hatchery or farmed fish can alter established allele frequencies (and co-adapted gene complexes) and disrupt important population-specific adaptations, a phenomenon called outbreeding depression (Edmands 2007; McClelland and Naish 2007). In general, the greater the geographic separation between the source or origin of hatchery fish and the recipient natural population, the greater the genetic difference between the two populations (ICTRT 2007), and the greater potential for outbreeding depression.

Additionally, unusual rates of straying can have a homogenizing effect, decreasing intra-population genetic variability (e.g., Vasemägi et al. 2005), and increasing risk to population life history and genetic diversity, one of the four attributes measured to determine population viability (McElhany et al. 2000). There is a growing appreciation of the extent to which life history diversity contributes to a "portfolio" effect (Schindler et al. 2010), and lack of among-population diversity is considered a contributing factor to the depressed status of California Chinook salmon populations (Carlson and Satterthwaite 2011; Satterthwaite and Carlson 2015).

We typically use the proportion of hatchery-origin spawners (pHOS) as a surrogate measure of gene flow between hatchery- and natural-origin fish populations. The Hatchery Scientific Review Group (HSRG) developed and promulgated this approach throughout the Pacific Northwest. For net pen reared fish that may inadvertently escape, NMFS likens those to a segregated hatchery program, where no natural-origin fish are used as broodstock and fish are not intended to spawn naturally. Guidelines for segregated programs are based on pHOS and importance of the recipient population to conservation. For example, when the underlying natural population is of high conservation importance (i.e., primary), the guidelines are a pHOS of less than 2 percent for segregated programs on a population of high conservation value (i.e. primary) (HSRG 2014). Another scientific team reviewed California hatchery programs, and recommended a pHOS of less than 5 percent for fish from segregated programs. Furthermore, researchers investigating modeled fitness changes in wild Atlantic salmon populations due to spawning of farmed escapees found that low levels of pHOS (5-10%) resulted in weak changes in the recipient wild population's phenotypic and demographic characteristics (Castellani et al. 2018). The HSRG (2004) offered additional guidance regarding segregated programs, stating that risk increases as the level of divergence increases, especially if the hatchery stock has been selected directly or indirectly for characteristics that differ from the natural population.

Appropriate cautions and qualifications should be considered when using this proportion to analyze outbreeding effects. First, adult salmon may wander on their return migration, entering and then leaving tributary streams before spawning (Pastor 2004). These "dip-in" fish may be counted as strays, but may eventually spawn in other areas, resulting in an overestimate of the number of strays that potentially interbreed with the natural population (Keefer et al. 2008). Second, caution must be taken in assuming that strays contribute genetically in proportion to their abundance. Several studies demonstrate little genetic impact from straying despite a considerable presence of strays in the spawning population (Blankenship et al. 2006; Säisä et al. 2003). The factors contributing to low breeding success of strays are likely similar to those responsible for reduced productivity of hatchery-origin fish when spawning in nature, including differences in run and spawn timing, spawning in less productive habitats, and reduced survival of their progeny (Leider et al. 1990; Reisenbichler and McIntyre 1997; Williamson et al. 2010).

Because sablefish are not an ESA-listed species, and do not interbreed with ESA-listed species under NMFS jurisdiction, we determined there would be no genetic effects of escaped farmed sablefish to ESA-listed species. The following sections focus only on the potential genetic effects between farmed rainbow trout/steelhead and wild ESA-listed steelhead individuals and populations.

Hatchery-influenced selection effects

Hatchery-influenced selection (often called domestication), occurs when selective pressures imposed by artificial spawning and rearing differ greatly from those imposed by the natural environment. This causes genetic change that is passed on to natural populations through interbreeding with hatchery-origin fish. Hatchery-influenced selection encompasses a number of mechanisms, including: relaxation of selection that would normally occur in nature, selection for different characteristics in hatchery and natural environments, and intentional selection for desired characteristics (Waples 1999). Concerns about these effects, often noted as performance differences between hatchery- and natural-origin fish have been recorded in the scientific literature as long as 60 years ago (Vincent 1960, and references therein).

The degree of genetic change and fitness reduction resulting from hatchery-influenced selection depends on:

1. Factors that contribute to selection and degree of heritability of traits under selection;
2. Exposure or amount of time fish spend in the hatchery environment;
3. Number of generations that fish are propagated by the program; and
4. Whether the hatchery program integrates natural-origin fish into the breeding population.

Although numerous papers in the scientific literature document behavioral, morphological and physiological differences between natural- and hatchery-origin fish (see below in the competition section), the most influential research has focused on relative reproductive success (RRS) of hatchery-origin fish compared to natural-origin fish determined through pedigree analysis. The influence of this type of research derives from the fact that it addresses fitness, the ability of the fish to reproduce in nature and produce offspring that survive. The method is simple: genotyped natural- and hatchery-origin fish are released upstream to spawn, and their progeny (juveniles, adults, or both) are sampled genetically and matched with the genotyped parents. In some cases, multiple-generation pedigrees are possible.

RRS studies can be easy to misinterpret (Christie et al. 2014). First, they often have little experimental power because of limited sample sizes and enormous variation among individual fish in reproductive success (most fish leave no offspring and a few leave many). This can lead to lack of statistical significance for hatchery: natural comparisons even if a true difference does exist. Kalinowski and Taper (2005) provide a method for developing confidence intervals around RRS estimates that can shed light on statistical power. Second, an observed difference in RRS may not be genetic. For example, Williamson et al. (2010) found that much of the observed difference in reproductive success between hatchery and natural fish was due to spawning location; the hatchery fish tended to spawn closer to the hatchery. Genetic differences in reproductive success require a multiple generation design, and only a handful of these studies are available. Finally, the history of the natural population in terms of hatchery ancestry can bias results. Only a small difference in reproductive success of hatchery and natural fish might be expected if the population had been subjected to many generations of high pHOS (Willoughby and Christie 2017).

As mentioned above, few studies have been designed to unambiguously detect a genetic component in RRS. Two such studies have been conducted with steelhead and both detected a statistically significant genetic component in steelhead (Araki et al. 2007; Christie et al. 2011; Ford et al. 2016), but the two conducted with “stream-type” Chinook salmon have not (Ford et al. 2012; Janowitz-Koch et al. 2018). This suggests that perhaps the impacts of hatchery-influenced selection on fitness differs between species.[8] Berejikian et al. (2012) have hypothesized that steelhead hatchery rearing practices that produce unnatural life history phenotypes could contribute to reduced fitness and behavioral divergence of hatchery steelhead populations. The possibility that steelhead may be more affected by hatchery-influenced selection than Chinook salmon by no means suggest that effects on Chinook salmon are trivial, however. A small decrement in fitness per generation can lead to large fitness loss (see Araki et al. 2008). As described in the following sections, the expected triploidy of farmed fish would also likely reduce both their survival and reproductive success, compared to diploid hatchery fish reared for supplementation programs in the PS.

The OMEGA Model

The Offshore Mariculture Escapes Genetic/Ecological Assessment (OMEGA) model was developed by NOAA and ICF International (ICF) as a tool for use by scientists and resource managers to help with understanding the potential negative impact of farmed fish escapees on their wild conspecifics (OMEGA 2020a). The purpose of OMEGA is to identify and weigh environmental risks of escapes of marine aquaculture fish to their wild conspecifics. OMEGA is intended to: (1) provide insights about factors affecting risks associated with escapes from aquaculture operations; (2) help identify research priorities; (3) explore options for the design of

[8] This would not be surprising. Although steelhead are thought of as being quite similar to the “other” species of salmon, genetic evidence suggests the two groups diverged well over 10 million years ago Crête-Lafrenière, A., L. K. Weir, and L. Bernatchez. 2010. Framing the Salmonidae family phylogenetic portrait: a more complete picture from increased taxon sampling. PLoS ONE 7(10).

sustainable aquaculture programs; and (4) inform policy and management decisions related to the genetic and ecological risks of aquaculture.

OMEGA simulates a user-defined scenario of aquaculture escapees and their effect on population dynamics of wild conspecifics over time. We have employed the OMEGA model to help inform our analyses of effects. For our analyses we modeled effects over 50 years. This duration of operations was selected for modeling purposes, but the results (below) can be extrapolated to a shorter or longer timeframe of future net pen operations. The model refers to fish contained in the aquaculture pens as farmed or cultured fish, fish that escape from the pens are escapees, and fish that are born in nature are wild fish. OMEGA includes a 'natural production' component that describes recruitment, survival, growth, and age of the wild population. The model allows the user to view changes in population response by varying culture operations and model parameters, and saving them as scenarios. The abundance, frequency and size of aquaculture fish escaping from an operation is defined by model inputs that specify the number, length of time, and size of fish held in pens, and the likely magnitude and frequency of escapes of farmed fish. Effects of genetic and ecological interactions are calculated under a user-specified set of assumptions. These assumptions define the survival of escapees in nature, their likelihood of encountering conspecifics, and the breeding success of escapees (OMEGA 2020b).

We use the number of rainbow trout/steelhead that escape and encounter wild conspecific populations in the marine environment for our analysis of effects on wild steelhead, and apply this to other ESA-listed species such as Chinook salmon and rockfish. Our consideration of interactions is informed by many more factors than are explicitly included in the model, and these factors are relevant for all listed species (i.e., diet, habitat overlap, etc.).

Parameters

The parameters used to create a natural-origin steelhead population in the OMEGA model were provided by consultants at ICF, and are available in the parameter file (NMFS and ICF 2021). The parameters derived from the expected net pen operations concerning rainbow trout/steelhead reared in the net pen are summarized in Table 20 and Table 21. However, some of these require further explanation such as the large-scale production loss, the large-scale failure rate, the small episodic events and leakage escape rates, size bins, survival post-escape, and the encounter rate.

Large-scale Episodic Events

The large-scale structural failure parameter was estimated based on data from Cooke's Cypress #2 net pen collapse in 2017. The total number of fish in Cypress Pen #2 at the time of collapse was 305,000 fish, or 30,500 fish per cage in the 10-cage pen. Total production of 915,000 fish at the Cypress site was calculated based on the total number of cages over the three pen structures at this location, 30 cages each with approximately 30,500 fish each (Pen #1 – 8 cages, Pen #2 – 10 cages, and Pen #3 – 12 cages) (Clark et al. 2017). The WDFW estimated that 262,659 fish escaped into PS from Cypress Pen #2 (Lee et al. 2018). Based on the total production of this site, this large-scale structural failure led to the escape of 29% of the total production of fish at the Cypress site (262,659 / 915,000).

For the purpose of running the OMEGA model we used this well-documented account of a major structural failure to model similar failures at each of the sites using 29% of fish escaping based on maximum total production. This is a conservative (meaning a higher potential impact for the purposes of this modeling) approach given the preventative measures proposed by Cooke Aquaculture at PS commercial net pens; however, this represents the best available information of large-scale structural failure events in PS. Because escapes are largely caused by failures in fish farming equipment (Føre and Thorvaldsen 2021; Jensen et al. 2010), we expect that improvements in aquaculture operations and net pen technology to increase structural integrity, as well as increased monitoring required by WDFW's aquaculture permit, would reduce the occurrence of large-scale failures. Therefore, our modeled effects determinations, based on historic data, are a high estimate, and we expect that adverse effects resulting from large-scale structural failures and escapes would be no greater than those described herein.

Large-scale Failure Rate

The frequency of a large-scale event occurring was based on the four recorded events (see Amos and Appleby 1999; Hawkins et al. 2019; WDFW 2020a) occurring over the course of 35 years. This yielded an 11.4% chance of an event occurring (or one large-scale event every 8.77 years). We then divided this by the number of net pen sites (four) because the probability of a failure happening at any one site is independent of all the others. Thus, we used a large-scale event rate of 2.9% for each site. This rate, although based on data from the historical operations of the commercial net pens in the PS, does not account for improvements in net pen technology and aquaculture operation, or the increased monitoring required by WDFW's aquaculture permit that we expect to take place with all future operations. Furthermore, all but one of the four recorded large-scale events occurred prior to 2000; there was a period of over 17 years with no recorded large-scale escape events. Thus, we consider using historic accounts to estimate risk in the OMEGA model to be a conservative approach.

Small Episodic Events and Leakage Escape Rates

The small episodic escapement rates and base leak rates from a farm are important parameters in the OMEGA model because they determine the number of escapees that may occur on an annual basis. Episodic escape events occur due to individual cage-failures (due to mechanical issues), or can result from medium to large tears in the net (e.g., due to predation). Small episodic incidents are events when a portion of fish in single cage or multiple cages may escape. Base leak escapes largely result from handling errors, small holes in nets, and other actions that may lead to loss of a single or few fish at a time, but happen frequently. Escapes of this type are inevitable, but are exceedingly difficult to estimate.

Skilbrei et al. (2015) used a variety of tag-release/recapture experiments of farmed salmon in Norway to quantify the difference between reported losses and the number of escaped fish recorded. This study determined that reported escapes were unable to account for the number of estimated escapees in Norwegian waters. The authors explored multipliers of 2-4x applied to the reported escapes to account for the low-level small episodic and leakage of fish from pens. They concluded a 4x multiplier best accounted for observed escapees. Escape rates incorporating this multiplier were used in recent modeling of Atlantic salmon escapes in Canada (Bradbury et al.

2020) and Iceland (MFRI Assessment Report 2020). These assessments used a single escape rate estimate of 0.3% (of total farmed salmon; also equivalent to 0.8 escapes/metric ton of production). This estimate applies the 4x leakage escapement multiplier to the average number of reported annual escapees since 2008 in Norway (i.e., both the episodic and base leakage escapement accounted for in a single estimate). However, since this number is an average, it does not capture the specific impacts of potential large-scale escape events observed in PS. To account for those effects, large-scale failure events were modeled separately in OMEGA.

This 0.3% annual escape rate estimate is based on the best available data, to date, on salmon escapement from net pen farms, and we believe this estimate is an appropriate estimate to use in the OMEGA model. We consider this a conservative approach, recognizing this may overestimate both leakage and episodic escape events because it is an average and episodic events do not occur every year; because the reference literature for the 0.3% rate includes an average of all escapes, including both large-scale failures and smaller episodic events; and because of net pen structure improvements (e.g., anti-predator netting that rises ~8 ft. above the waterline, jump walls with nets ~6 ft. out of the water to prevent jumping; see Figure 1), operational changes (e.g., divers checking in-water nets at least 3 times a week), and increased regulatory oversight (e.g., required inspections and monitoring). Although Cooke uses electrical and mechanical counters to record fairly accurate initial stocking and harvest numbers, there is a margin of error around mortalities and possible escapes between transfer and harvest (J. Parsons, personal communication, June 5, 2020). For example, only pieces of fish may remain in the pens following outside predation events (e.g., by seals or sea lions following a breach in predator nets) and during mass mortality events when large numbers of fish are being quickly removed from pens. Although Cooke Aquaculture, Inc. thought a lower combined escape rate (including all escapes from non-large-scale events) of 0.05% of all fish reared was more accurate (J. Parsons, personal communication, June 5, 2020), we believe the more conservative rate of 0.3% was the best estimate to use for modeling purposes based on existing literature and limited monitoring data for PS commercial net pen aquaculture facilities.

Figure 9. Net pen structures. Top left: 1985 Norwegian aquaculture cage company brochure with early cage technology. Note minimal floatation and no additional predation barrier netting around stock nets. Top right: Example photo of Viking Steel Cage systems which were the second-generation steel pens being developed in the late 1980s to late 90s. Steel cage systems had hinged steel walkways with plastic foam filled floats. Bottom: Outside view of outer walkways showing perimeter predation barrier on the outside of the blue floats lashed tightly to the outer walkway rail used at PS Cooke Aquaculture, Inc. facilities. Predation barrier jump panels are ~7 to 8 ft. above the waterline, and stock net jump walls are ~5 to 6 ft. above the waterline. Bird netting is sewn to the handrails and stretched tightly across the surface of each pen (Parsons 2020).

Size Bins

OMEGA allows a user to specify how many bins, and which size range of net pen fish should go into each one. In consultation with experts from ICF who have used this model in other marine net pen operations, we modeled three bins with one bin containing rainbow trout/steelhead from 0.2-0.5 kg, a second bin containing rainbow trout/steelhead from 0.5 to 3.0 kg, and a third bin containing rainbow trout/steelhead from 3.0 to 3.5 kg harvestable size. In doing this, we were able to use different survival estimates for the three size classes of rainbow trout/steelhead post-escape (Table 19).

Survival

The survival of farmed rainbow trout/steelhead in each size bin is assessed within the first year post-escape. In absence of data on marine survival of escaped triploid farmed rainbow trout/steelhead we used available literature on diploid *O. mykiss* and one lab study of triploid rainbow trout/steelhead. Survival of rainbow trout/steelhead in the smallest bin of 11% was based on studies of early marine steelhead survival throughout PS (Appendix 3; NMFS 2019a). Survival in the second size bin of 35% was based on triploid steelhead survival in a controlled laboratory study of smolt physiology, growth and survival after 15 months in seawater in captivity in absence of predators (Johnson et al. 2019). In the largest size bin, we used a 50% survival rate of escaped diploid rainbow trout/steelhead based on the work of Blanchfield et al. (2009). This study by Blanchfield et al. (2009) assessed the survival and behavior, including dispersal, of rainbow trout released from an experimental aquaculture operation in a lake. Although not completely aligned with expected PS commercial net pen operations, because the Blanchfield study used fish at a size of 1 kg, and the fish in our largest size class were 3 to 5 times larger, and because the expected rainbow trout/steelhead farming uses triploid and not diploid *O. mykiss*, this study seemed the best proxy, given the studies that were available.

Encounter Rate and Contribution to Spawning

In OMEGA, there are two methods used to apply encounter rates[9] of escaped fish and wild fish. The first is simple and allows the user to select a single encounter rate across all three size bins of fish reared in net pens. This rate is applied after accounting for post-escape survival. The second method is more complex and allows the user to estimate encounter rates by size class based on; distance and direction angle to wild population, attraction angle, attraction strength, wild population target size, and size class dispersal rates.

We have decided to use the first method. Wide spread occurrence of wild steelhead populations in PS suggests an encounter rate method based on distance and direction angle to wild steelhead would not be appropriate. We considered the effects of triploidy on migration behavior of triploid salmon. Cotter et al. (2000) estimated the rate of released all female and mixed sex triploid Atlantic salmon entering coastal areas and river systems compared to released diploid all female and mixed sex Atlantic salmon. While this information pertains to Atlantic salmon, the effect of triploidization on behavior of escaped farmed fish to enter coastal areas and river systems, relative to diploid escaped fish, could reasonably be applied to other salmon species. Since Cotter et al. included all female diploid and triploid fish we had a reasonable comparison to all female triploid rainbow trout/steelhead that Cooke proposes to rear. However, Cotter et al. did not evaluate if differences in rates were due to differences in behavior or survival. Johnson et al. (2019) evaluated differences in survival rates of triploid and diploid steelhead trout held in

[9] Encounter rate is the proportion of surviving escapees that would migrate to a nearby river or stream in PS and would encounter a wild population of steelhead during spawning season. The number of escapees in a river system encountering a wild population is a combination of post escape survival assumption and encounter rate. The number of escapees encountering a wild steelhead in marine waters is simply the post escape survival assumption.

saltwater tanks for 15 months and found survival of triploid fish was approximately half that of diploid fish. This study suggests the disparate rates reported in Cotter et al. 2000 are likely due both to differences in survival of escaped triploid fish relative to diploid fish, and differences in behavior.

From the Cotter et al. (2000) research, we used the most conservative of the cage-released estimates for all-female stocked scenarios (Cage II AF3N from Table 3 in Cotter et al. 2000; 7.78% and 1.35% diploid and triploid fish, respectively, returning to the coast from a cage release); this gives us a 5.76-fold decrease in encounters with wild steelhead in a river[10] compared to all female diploid fish. We decided to assume that 100% of the surviving diploid fish would enter rivers and encounter spawning wild conspecifics; the 5.76 fold decrease in encounter rate for triploid fish would then represent an encounter rate of 17.4% for triploid fish (1/5.76 = 17.4%). However, this is likely a high estimate of potential contribution to spawning of diploid steelhead as they may be entering rivers at times when wild steelhead are not spawning, and would likely have a hypothesized reduced relative reproductive success relative to wild steelhead because of the well documented reduced RRS of hatchery steelhead even after a single generation of hatchery rearing (Araki et al. 2007, 2008).

Our output files included information on the number of escaped fish, the number of escaped fish surviving in the marine environment the year of and year following the escape that may encounter wild steelhead in marine areas, and the number of farmed escaped steelhead trout that may migrate into freshwater and encounter wild spawning steelhead. The number of reproductively mature females that may spawn with wild steelhead considered the effectiveness of triploid induction to induce sterility, which was assumed to be 99.8% effective for planning purposes (Troutlodge 2018). We assumed 0.2% of the farmed steelhead in the river would be diploid and fertile. A subsequent analysis of 397 fish sampled by Cooke Aquaculture, Inc. from the first eggs received from Troutlodge found a 100% triploidy success rate (Jim Parsons, personal communication, February 17, 2020). Thus, our assumption that 0.2% of fish would be diploid may be conservative.

Table 19. Parameter values in common across all four facilities. Survival for each class is measured within one-year of escape.

Parameter	Value	Source
No. of size (kg) bins	3: 0.2-0.5; 0.5 -3.0; 3.0 -3.5	Expert opinion
Survival of smallest fish	0.11	NMFS 2019a
Survival of medium fish	0.35	Johnson et al. 2019
Survival of largest fish	0.5	Blanchfield et al. 2009
Encounter rate with natural fish	100% of diploids; 17.4% of triploids (5.76 fold decrease)	See text above; Cotter et al. 2000
Small episodic events and leakage escape rates	0.3%	See text above

[10] The Cage II data for AF3N in Cotter et al. (2000) Table 3 was for recovery of fish in coastal waters not in rivers. They did not recover AF2N or AF3N fish in rivers from Cage II releases reported in Table 3. The reported 5.74 fold decrease is for fish returning to the coast. Our conservative approach assumes all fish could enter the river.

Model results

Across all four net pen facilities, in a “normal” year without a large-scale failure, the model estimates that 0.3% (7,283) rainbow trout/steelhead could escape from the facilities. Of those that escape, the model estimates that 33.9% (2,469 across all four locations) farmed rainbow trout/steelhead survive to encounter the wild steelhead population in marine waters during the first year post-escape, and far fewer, 5.9% (429 across all four locations; accounting for the 17.4% encounter rate) would attempt to enter the rivers. (Table 20). In a year where a large-scale event occurs at a net pen site (see parameter section above for large-scale failure and loss rates), the model estimates that a maximum of 236,735 (29.6%) fish could escape from the largest producing sites (Rich Passage – Clam Bay and Rich Passage – Orchard Rocks) (Table 21). We believe that these estimates err on the conservative-side, again meaning a higher potential impact than may be the reality. These encounters would also likely be spread out to some degree across PS and the SJDF based on the geographical placement of each of the net pen sites.

The Hope Island site is located closest to the Skagit and Sauk River populations. Our most recent status review (NWFSC 2015) estimated the total spawning abundance in the Skagit River population to be 5,123 steelhead; there was no abundance estimate available for the Sauk River population. For the Skagit River, this is likely to be primarily natural-origin fish since there is no steelhead hatchery program in the Skagit River. The modeled pHOS falls well below the 2% threshold provided by the HSRG (2014) (see above section 2.5.3.2, Genetic Effects of Interbreeding of Escaped Farmed Fish with Wild Fish). Assuming all surviving diploid escapees (0.2% triploidization sterility failure rate) spawn the year following a large-scale structural failure escape event (~1.45 times every 50 years at this site; Table 19) this would equate to an effective pHOS between 0.08% and 0.43% for the Skagit River [4/(5123+4); 22/(5123+22)]; Table 21). The pHOS attributable to net pen escapees in a year without a large-scale event (small episodic events and leakage) is estimated to be less than 0.02% for the Skagit River (1/(5123+1); Table 21). It is important to note here that pHOS is a proxy for gene flow, and we are assuming that fertile escaped fish would spawn. It is important to consider, that although domesticated fertile farmed rainbow trout/steelhead may migrate into rivers, the reproductive success is likely to be greatly reduced, as has been reported for hatchery steelhead (c.f. Araki 2006, 2007).

The Rich Passage net pen sites are located closest to the East Kitsap Tributaries natural steelhead population in South PS where we do not have population abundance information (NWFSC 2015). This makes it impossible to calculate an effective pHOS estimate based on the potential number of spawners for the Rich Passage sites. Similar to the Hope Island site, we anticipate that none of the Rich Passage sites would have more than one large-scale failure over a 50-year period.

Table 20. The model-estimated number of farmed all-female rainbow trout/steelhead that escape due to small episodic events and base leakage, number of fish surviving in PS, number of fish potentially entering the rivers, and number of fish that may be fertile diploid females (based on triploidization failure rate of 0.2%) able to spawn in rivers in a "normal" year that excludes large-scale events.

Facility/ Location	Production # fish	Production (mt)	# Fish Escaping Small Events and Leakage	# Surviving in Puget Sound	# Entering Rivers	# Potential Spawners in Rivers
Skagit Bay - Hope Island	390,000	1,365	1,188	399	69	<1
Rich Passage - Clam Bay	800,000	2,800	2,438	828	144	<1
Rich Passage - Fort Ward	400,000	1,400	1,219	414	72	<1
Rich Passage - Orchard Rocks	800,000	2,800	2,438	828	144	<1

Notes: Small events and leakage are an annual estimate of escape into PS and are summed across the four sites to get total number of farmed fish in PS; Production numbers provided by J. Parson, personal communication, June 23, 2021.

Table 21. The model-estimated number of farmed all-female triploid rainbow trout/steelhead that escape during a large-scale event, survive in PS, enter rivers, and could potentially spawn with wild populations (for the 0.2% fertile fish). The variation in number surviving in PS, entering rivers, and potential spawners is because a large event may mean the loss of small fish, pre-harvest fish, or harvest size fish, each has a different survival assumption. The # range of values for number escaping is based on number transferred to pens to meet harvest number, accounting for mortality in pens.

Facility/ Location	# Fish Escaping Large Events			# Surviving in Puget Sound			# Entering Rivers			# Potential Spawners in Rivers		
	Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.
Skagit Bay - Hope Island	114,362	113,421	115,408	41,477	12,695	62,382	7,217	2,209	10,855	14	4	22
Rich Passage - Clam Bay	234,589	232,659	236,735	85,080	26,041	127,962	14,804	4,531	22,265	30	9	45
Rich Passage - Fort Ward	117,295	116,329	118,367	42,540	13,020	63,981	7,402	2,266	11,133	15	5	22
Rich Passage - Orchard Rocks	234,589	232,659	236,735	85,080	26,041	127,962	14,804	4,531	22,265	30	9	45

Notes: Large events are independent events modeled at each site because it is not likely that a large event would occur at more than one site in a year. The variation in number surviving in PS, entering rivers, and potential spawners is because a large event may mean the loss of small fish, pre-harvest fish, or harvest-size fish, which each have a different survival assumption; The range of values for number of fish escaping is based on number transferred to pens to meet production number, accounting for mortality in pens.

Conclusions

Our analysis above leads us to conclude that the likelihood of exposure, magnitude of the response, and the consequences to natural-origin steelhead populations in PS, WA of rearing triploid, all female rainbow trout/steelhead is low for a number of reasons. First, even if we assume that all of the farmed rainbow trout/steelhead capable of spawning would migrate into a single population, we expect extremely low effective pHOS values in most years. Effective pHOS is the effective proportion of aquaculture origin fish in the naturally spawning population. Percentages are below the HSRG guidelines (< 2%) for segregated programs on a population of high conservation value (i.e., primary) (HSRG 2014). Second, as stated earlier, effective pHOS is a proxy for gene flow, and even though fish may be on the spawning grounds, this does not mean they successfully spawned

Third, many of the input values included in our modeling are based on literature from hatchery or farmed Atlantic salmon and not on empirical data from the expected net pen operations for rainbow trout/steelhead. Thus, some research and monitoring, such as a telemetry study for "escaped" fish movement, or estimates of base leakage, could alter our parameter inputs. As we mentioned earlier, Charles et al. (2017), found that farmed rainbow trout had an affinity for the farm site, and although this may be reflected to some degree in our recovery estimates (Lee et al. 2018), a targeted study is likely to improve our knowledge base on movement of triploid rainbow trout/steelhead into rivers and streams where they may encounter spawning wild steelhead.

Fourth, the State of Washington imposed many implementation terms on Cooke Aquaculture upon issuing their state Aquaculture Permit in January 2020 that are likely to reduce the risk of large-scale structural failure, and small episodic and base leakage escapes. Many of these terms deal with the structural integrity of the rafts and cages, which was a contributing factor to the Cypress 2 failure in 2017. For example, Cooke Aquaculture, Inc. must hire a marine engineering firm approved by the state to conduct inspections of each net pen every two years and routine monitoring and reporting of integrity of net pen structures by Cooke Aquaculture, Inc. (WDFW 2020a). Thus, as described above, our estimates of escape rates and large-scale structural failures are conservative, and we anticipate that effects would be no greater than those described herein. As summarized in Waples et al. 2012, "… the successful containment of genetic risks associated with marine aquaculture should focus on two general strategies: 1) prevent escapes and 2) ensure that individuals that do escape have a low probability of surviving to reproduce in the wild." Both of these strategies are being implemented and monitored in anticipated PS commercial net pen operations.

6) <u>Competition and Predation</u>

Predation, either direct or indirect (increases in predation by other predator species due to enhanced attraction), can result from farmed fish escaping into the wild. In general, the threat from predation is greatest when natural populations of salmon and steelhead are at low abundance, when spatial structure is already reduced, when habitat, particularly refuge habitat, is limited, and when environmental conditions favor high visibility.

Competition between listed natural-origin salmonids and farmed fish that might escape could also occur. Direct interactions occur when farm-origin or escaped farmed fish interfere with accessibility to limited resources by natural-origin fish. For example, if returning farm-origin adult fish spawn earlier than natural-origin adults, offspring from farmed fish may take up residency before naturally produced fry emerge from redds. Indirect interactions occur when the utilization of a limited resource by farmed fish reduces the amount available for fish from the natural population (Rensel et al. 1984), such as food and rearing sites (NMFS 2011b).

Several factors influence the risk of competition posed by famed fish: whether the interaction is intra- or interspecific; the duration of co-occurrence (both spatial and temporal) of farmed and natural-origin fish; relative body sizes of the two groups; prior residence of shared habitat; environmentally induced developmental differences; and density in shared habitat (Tatara and Berejikian 2012). Intraspecific competition would be expected to be greater than interspecific, and competition would be expected to increase with prolonged co-occurrence. Tatara and Berejikian (2012) further reported that hatchery-influenced developmental differences from co-occurring natural-origin fish are variable and can favor both hatchery- and natural-origin fish. They concluded that of all factors, fish density of the composite population in relation to habitat carrying capacity likely exerts the greatest influence on natural-origin fish. Below we consider spatial and temporal co-occurrence, diet and feeding, and behavior and physiology of farmed salmon and steelhead compared with ESA-listed natural-origin salmon and steelhead in PS.

Spatial and Temporal Co-occurrence

Farmed fish can escape at any point during their rearing cycle, and the timing of the escape event affects the potential for competition and predation. A number of studies have found that escaped net pen reared fish had an affinity for the farm site, especially during scheduled feeding times (Blanchfield et al. 2009; Bridger et al. 2001; Charles et al. 2017). They also tended to occupy the surface of the water column (top 15 ft.) (Blanchfield et al. 2009; Charles et al. 2017). However, other studies have found that escaped farmed Atlantic salmon and rainbow trout/steelhead can disperse quickly, and can be found up to thousands of km away from the farm site (Hansen and Youngson 2010; Lindberg et al. 2009; Whoriskey et al. 2006).

Interactions between escaped farmed fish and wild PS steelhead are limited by the temporal presence of wild fish within the action area. Myers et al. (2015) summarizes the life history of adult natural-origin steelhead in PS. Winter-run steelhead return to freshwater tributaries from December through April, while summer-run steelhead return from June through October. Thus, exposure of adult wild fish to escaped fish would be limited to these periods. For juvenile steelhead, evidence indicates that PS steelhead smolts migrate quickly to the ocean and their presence is mostly limited to mid-April through mid-June (Moore et al. 2015). Populations entering the main basin of PS emigrate in approximately 10 days, with some variation depending on their location (Moore and Berejikian 2017). The short-duration and seasonality of juvenile migration through the PS sound limits potential exposure to any escaped fish.

Similarly, interactions between farmed fish and wild PS Chinook salmon are limited by the temporal presence of wild fish within the PS. Natural-origin fall Chinook salmon in the Green River typically enter freshwater rivers from July to September, and spawn from mid-September to early November. Spring Chinook salmon typically return to freshwater from March through July, with spawning occurring from August through October (SSPS 2007). Juvenile Chinook salmon may rear in PS for one to seven weeks, but certain stocks may become resident in the Salish Sea and remain there until maturity (commonly called "blackmouth"; Simenstad et al. 1982). Duffy et al. (2005) found that wild ocean-type Chinook salmon out-migrate to PS waters from March to July, with a peak in June and July, although some are still present in shoreline habitats through at least October.

Likewise, interactions between escaped farmed fish and wild HCSRC are also limited by the temporal presence of wild fish within the PS, including Hood Canal, the SJDF and tributary rivers. Adult HCSRC generally return to the SJDF and Hood Canal from July through September, and enter streams to spawn late August through mid-October (Tynan 1997). Fry begin to emerge from late December and peak in March and April, and immediately migrate downstream to the marine environment (Tynan 1997; Weinheimer et al. 2017; Tuohy et al. 2018). They then reside in the estuary for one to four weeks (late December to early May) before migrating to deeper waters and completing seaward migration by the end of June (Tynan 1997; Tuohy et al. 2018).

Behavior and physiological differences in domesticated fish and triploid fish

The rainbow/trout steelhead and sablefish anticipated in PS commercial net pens would be of hatchery origin. Hatchery-influenced selection can alter the behavior, development, and physiology of fish relative to their natural-origin counterparts. Triploid fish have also been shown to differ from their diploid counterparts in growth, behavior and physiology. We included a few examples of studies from a vast amount of literature here for context. Diploid fish that have undergone hatchery-influenced selection are also likely to have a reduced response to predation risk even in natural environments (Tymchuk et al. 2007), and thus may be more likely to be preyed upon post-escape. In addition, domesticated diploid fish have demonstrated a reduction in swimming performance compared to natural-origin fish (Reinbold et al. 2009). However, the tradeoffs with these behavioral differences seem to be that domesticated fish have higher growth rates and higher condition factors, which are desirable for aquaculture (Reinbold et al. 2009). Furthermore, diploid escaped farmed rainbow trout have been shown to have a low probability of finding suitable spawning habitats with about 48% of them being detected in lakes and running water, but none of them found in rivers or streams with suitable spawning habitats (Lindberg et al. 2009). This led the authors to hypothesize that the long period of domestication (90 years), may have contributed to their inability to find suitable spawning locations.

In a review of triploid fish, Fraser et al. (2012) concluded that triploid fish are less aggressive and have a poorer foraging and competitive abilities for food compared with their diploid counterparts. Johnson et al. (2019) suggested that, in a controlled study of triploid and diploid steelhead reared together in tanks for over 15 months, the reduced growth and survival of triploid steelhead is, at least, in part due to competition with diploid fish.

In terms of reproductive behavior and physiology of triploid fish, there are sex differences in the effects of triploidy on reproductive physiology. In fishes, triploid males are generally morphologically indistinguishable from diploid males at maturity and produce functional sperm, but the sperm are aneuploid (e.g., have an unusual number of chromosomes), and their offspring die shortly after fertilization because of abnormal chromosome numbers. In contrast, triploid females do not develop normal ovaries or produce eggs and retain characteristics of sexually immature fish (Benfey 2016; Benfey et al. 1989; Piferrer et al. 2009). Fraser et al. (2012) cited evidence that triploid females rarely participate in spawning migrations, while males migrate to spawning grounds, exhibit courtship behavior, and mate with female diploid fish. For the Troutlodge strains of triploid female steelhead captive-reared and selected for desirable growth traits for 60 years, it is unlikely they would move into fresh water. This is because triploid females fail to develop normal ovaries (Piferrer et al. 2009), would be expected to have reduced motivation to migrate upstream to spawning grounds and would not exhibit behaviors associated with reproduction (Warrillow et al. 1997). This is supported by a release-recapture study of farmed triploid and diploid Atlantic salmon (Cotter et al. 2000) that showed substantially reduced recovery of triploid females released from caged sites compared to diploids and few or no female triploid fish recovered in fresh water depending on whether the fish were released from the hatchery or from caged sites.

Although there is the potential for escaped farmed rainbow trout/steelhead to migrate into fresh water as adults to spawn, this is very unlikely given the review of literature above, and also demonstrated by the results of the OMEGA model (see “Spawners” in tables 21 and 22). However, migration into fresh water raises a few additional competition effect pathways; competition for spawning sites and redd superimposition. Although males compete for access to females, female spawners compete for spawning sites. Essington et al. (2000) found that aggression of both sexes increases with spawner density, and is most intense with conspecifics. However, females tended to act aggressively towards heterospecifics as well. In particular, when there is spatial and temporal overlap between natural-and farmed spawners, the potential exists for farmed fish to superimpose or destroy the eggs and embryos of ESA-listed species. Redd superimposition has been shown to be a cause of egg loss in pink salmon and other species (e.g., Fukushima et al. 1998). Impacts of superimposition from farmed fish would only come from reproductively competent females (triploids are not) that ascended spawning streams and attempted to construct redds during embryonic development of wild salmon or steelhead.

Diet and feeding

Initially after escaping juvenile net pen reared fish may be less likely to take advantage of the most nutrient-rich natural prey sources. Although hatchery fish, which are reared within land-based hatcheries before being released as juveniles, differ from marine-reared net pen fish, they may offer some insight into feeding behavior, as they are both habituated to regular feeding of pellet food. Studies of stable isotope signatures from muscle and liver tissues from hatchery (marked) compared to natural-origin (unmarked) juveniles showed that unmarked juveniles had derived 24–31% of their diets from terrestrially sourced prey, while terrestrial insects only made up 2–8% of hatchery fish diets. This may explain why unmarked fish had stomach contents that were 15% more energy-rich and were in better condition than hatchery fish (Davis et al. 2018). Chinook salmon in the marine environment become more piscivorous as they grow. Chinook salmon residing in the nearshore waters of PS prey on insets and amphipods. Their diet shifts as they move offshore to crab larvae and fish, primarily Pacific herring (Duffy et al. 2010). Other common prey of steelhead in the marine environment include euphasiids, crabs, amphipods, copepods, pteropods, rockfishes, greenlings, sculpins, sablefish, and Pacific sand lances (Daly et al. 2014). Furthermore, low predation rates on natural-origin salmon and steelhead have been reported for steelhead juveniles released from hatchery programs (Hawkins and Tipping 1999; Naman and Sharpe 2012).

When measured one month after escape, juvenile farmed rainbow trout had forage ratios that were similar to other wild anadromous salmonids in the same marine area, their weight increased, and their condition factor was stable (Rikardsen and Sandring 2006). Charles et al. (2017) found that farmed rainbow trout released into a freshwater lake were able to adapt to a natural environment and showed high fidelity to the commercial site during production. Once production ceased, fish moved into the littoral zone where food is relatively abundant.

In contrast, adult hatchery rainbow trout escaping into the marine environment in Norway saw a reduced condition factor and forage rations of 0.05 to 0.77 compared to wild anadromous salmonids over a 15-month sampling period. In addition, about 70% of their diet was composed of indigestible items such as seaweed and wood that are similar in shape to commercial net pen feed sources. Based on these findings, the researchers concluded that older/larger fish have a harder time adjusting to feeding on natural prey (Rikardsen and Sandring 2006). As described in Section 2.5.3.2 (regarding predation by fish in net pens), a study in Tasmania by Abrantes et al. (2011) documented the stomachs of approximately 63% of escaped farmed were empty, 21% contained commercial feed pellets, and only about 24% contained native animals.

Sablefish

Diet

Sablefish are opportunistic predators and thus have a very diverse diet including crustaceans, cephalopods, salps, and fish. In the 13-41 cm size range, sablefish diet was made up largely of euphasiids (krill), but also included salps (tunicates), cnidarians, and fish off the coast of Washington State. As sablefish grow into the 40-80 cm size range, their diet shifts to become predominantly composed of fish, especially Pacific herring (Buckley et al. 1999). In the surveys conducted North of Cape Blanco, OR, Buckley et al. found that of the identifiable fish species consumed in summer of 1989, Pacific herring were most common, with less than 1% of either rockfish or salmon. In the fall of 1992, sablefish diets shifted to consume predominantly longspine thornyhead and Pacific Hake; no *Oncoryhnchus spp.* were identified in sablefish gut contents. However, other rockfish species, excluding longspine thornyhead, accounted for about 3% of sablefish diet.

However, diet can vary widely based on geography, with diet reflecting the species available in a particular location. Diet may also change with the season, but limited information is available to support this idea. Some studies cited in Buckley et al. (1999) show that diet shifts from predominantly fish in the spring to shrimp, ctenophores, and some benthic organisms in the summer, and back to fish in the fall. There has also been documented cases of diet shifts inter-annually. For example, Sturdevant et al. (2009), demonstrated that in one year of their annual survey, conducted since 1997, sablefish did have a high proportion of pink, chum, and sockeye salmon in their diets within the northern region of Southeast Alaska. The authors state that interactions between sablefish and salmon are uncommon, and speculate that an unusually high sablefish abundance may have led to large proportions of salmon in sablefish diets.

Spatial and Temporal Distribution

Sablefish are a marine species that inhabit deeper water as they grow larger. In the wild, juvenile sablefish inhabit pelagic waters and grow rapidly. By about a year and a half typically 38 cm, they become demersal on the continental shelf in waters < 200 m. Adult sablefish inhabit the outer shelf and continental slope in waters ranging in depth from 200–1,500 m, although they move into shallower waters in the summer and inhabit deeper waters in the fall through spring where they spawn. Adults can grow up to 50 cm and live for over 50 years (Buckley et al. 1999).

Conclusions

Sablefish

There is a very low likelihood of exposure to competition and predation in the marine environment of ESA-listed salmon and steelhead from farmed sablefish for three reasons. One, the data we have for large-scale escape events for any one of the four net pen facilities shows that such escapes are rare. Second, operators transfer sablefish to net pens at about 24 cm, and harvest them at about 60 cm (Rick Goetz, personal communication, June 8, 2020). In the event of an escape, which habitat we expect farmed sablefish to occupy is likely to depend in part on their size; sablefish less than 38 cm are typically pelagic and occupy water depths of < 200 m. When sablefish exceed 38 cm they become demersal and occupy water depths below 200 m. Because Smith et al. (2015) found that Chinook salmon occupied marine waters at depths 50 m and above, we expect escaped farmed sablefish would be most likely to overlap with salmon and steelhead if escape events occurred when sablefish are in the pelagic size range. Third, Buckley et al. (1999) found less than 1% of sablefish guts contained salmon or steelhead. Thus, any interaction between farmed sablefish and ESA-listed salmon or steelhead would most likely be competition for food, especially with Chinook salmon who also eat euphasiids as juveniles and Pacific herring when piscivorous.

ESA-listed rockfish exposure to competition and predation of escaped farmed sablefish on ESA listed rockfish is likely to be low. This is because we expect large-scale escape events to be rare, and even though they occupy similar depths, rockfish are commonly associated with rocky structures (NMFS, 2017). Because Buckley et al. (1999) found that sablefish diets had less than 3% rockfish, with the exception of the non-listed longspine thorneyhead, we anticipate the most likely interactions to be over prey resources. However, even though rockfish and sablefish prey on similar fish species (e.g., herring), they are likely to encounter their prey in different habitats.

Rainbow Trout/Steelhead

There is a moderate likelihood of exposure to competition and predation in the marine environment of ESA-listed salmon and steelhead species from farmed rainbow trout/steelhead. The likelihood of exposure for PS/GB bocaccio and yelloweye rockfish is very low due to differences in habitat requirements. For example, rockfish inhabit deeper water (> 30 m; NMFS 2017a), and rocky structures, making them less likely to overlap with ESA-listed salmon and steelhead in habitat, which tend to stay closer to the surface (< 50 m; Collis et al. 2001; Smith et al. 2015) and are pelagic.

Based on the results of the OMEGA model, in a year with no large-scale failures, an estimated 7,283 rainbow trout/steelhead could escape from the four net pen sites (Table 20). Of those that escape, the model predicts that 2,469 farmed rainbow trout/steelhead survive to encounter natural-origin steelhead in marine waters during the first year post-escape. However, this could be tempered by the apparent inability of escaped farmed fish to adapt to feeding on natural-prey sources, as well as escaped fish likely being younger/smaller fish (Rikardsen and Sandring 2006). This is particularly important in the marine environment because Fresh (1997) summarized information concerning competition in marine habitats and concluded that food is the most limiting resource in marine habitats. However, in studies of post-release migration and survival for natural and hatchery-origin steelhead smolts in Hood Canal and Central PS, predation by birds, marine mammals, and perhaps, other fish appears to be the primary factor limiting abundance of smolts reaching ocean rearing areas, not competition (Moore et al. 2010).

For farmed rainbow trout/steelhead interactions with Chinook salmon, encounter rates may differ when considering the possible resident life history of a portion of natural-origin Chinook salmon, the longer presence of juvenile Chinook salmon in estuaries and the nearshore environments during rearing as compared to steelhead. However, Chinook salmon also tend to have shorter run times and interspecific differences make it less likely for different species to interact (Tatara and Berejikian 2012). Considering all of the available information, we conclude that the overall consequence to the natural-origin salmon and steelhead populations from competition/predation in the marine environment is low.

There is a low likelihood of exposure to competition and predation in the freshwater environment of ESA-listed salmon and steelhead species from farmed rainbow trout/steelhead. The likelihood of exposure for PS/GB bocaccio and yelloweye rockfish is likely low due to their marine only habitat requirements. Researchers have looked for evidence that marine area carrying capacity can limit salmonid survival, with some evidence suggesting density-dependence in the abundance of returning adult salmonids (Bradford 1995; Emlen et al. 1990; Lichatowich 1993), and/or associated with cyclic ocean productivity (Beamish and Bouillon 1993; Beamish et al. 1997; Nickelson et al. 1986). Naish et al. (2007) could find no systematic, controlled study of the effects of density on natural-origin salmon, or of interactions between natural- and hatchery-origin salmon, nor on the duration of estuarine residence and survival of salmon. In studies of post-release migration and survival for natural and hatchery-origin steelhead smolts in Hood Canal and Central PS, predation by birds, marine mammals, and perhaps, other fish appears to be the primary factor limiting abundance of smolts reaching ocean rearing areas, not competition (Moore et al. 2010).

Escapes that occur closest to the spawning period and of the largest size-class of fish are the most likely to compete for spawning sites and to superimpose redds. However, the findings of Lindberg et al. (2009) that farmed rainbow trout are not able to find rivers or streams with suitable spawning habitat, and Warrillow et al.'s (1997) observation that triploid females have been shown to rarely participate in spawning migrations, supports the idea that spawning site competition and redd superimposition have a very low probability of occurrence. While the magnitude of the response to competition and predation is likely to be high for the individual fish that are affected, the consequences to the salmon and steelhead populations is likely to remain low in freshwater portions of the action area.

Summary

Overall, interactions in the marine environment seem most likely, especially since farmed fish (i.e. rainbow trout/steelhead and sablefish) may survive for years post-escape (Blanchfield et al. 2009). Interactions are likely to be with other salmon and steelhead, but the following aspects are likely to minimize interactions with wild fish:

- Farmed fish have an affinity for the net pen site when in operation
- A temporal disconnect exists between presence of wild and farmed juvenile fish in the marine environment, when fish escapes occur outside of the smolt migration window
- Farmed fish have lower foraging success than wild fish
- The decreased ability of farmed fish to successfully migrate to natural spawning areas
- For sterile triploid female rainbow trout/steelhead, the rare likelihood of participating in spawning migrations
- The reduced swimming abilities of domesticated fish
- The less aggressive nature of triploid fish

Furthermore, the implementation terms WDFW has imposed associated with their Aquaculture permit issued to Cooke Aquaculture, especially those associated with the structural integrity of the pens may help reduce leak rates (e.g., through more frequent finding and repair of net pen tears) and large-scale failures. WDFW also requested a great deal of monitoring data in their Aquaculture permit to help estimate net pen leakage including:

- The number of fish that leave the hatchery—this is assessed electronically using a counter that has an accuracy rate of 98-100% (Parsons 2020)
- The number of fish transferred to each net pen (also assessed electronically)
- The number of known mortalities during net pen rearing—divers check the pens at least three times per week during rearing (Parsons 2020)
- The number of fish that were harvested at the farm site—this is done using a machine with a counter (Parsons 2020)
- The number of fish that were received by the processing plant
- Any known escapes of fish during rearing

2.5.4 Effects on Population Viability

We assess the importance of effects in the action area to the Evolutionarily Significant Units (ESUs)/Distinct Population Segments (DPS) by examining the relevance of the effects among individuals to the populations they comprise, through evaluating influence on the viability parameters of abundance, population growth rate (productivity), spatial structure, and diversity. While these characteristics are described as unique components of population dynamics, each characteristic exerts significant influence on the others. For example, declining abundance can reduce spatial structure and diversity of a population. Further, if effects were concentrated on individuals from a single population, the abundance in that population could decline sufficiently to reduce productivity, spatial structure, or diversity. When effects are likely to occur at lower levels across multiple populations, then the robustness or weakness of particular populations at a baseline level may yield different level of significance of those effects at the population scale.

We anticipate that, as a consequence of the action, PS commercial net pens would have a persistent negative effect on the habitat and individual fitness of PS Chinook salmon, PS steelhead and HCSRC, and that based on the location of the net pens and patterns of behavior upon the rare instances of escape, no particular population would be more significantly affected than any other. Because exposure is low for almost all of the effects described in this analysis, even where response is high, only minor changes in abundance are expected.

Among PS/GB bocaccio and PS/GB yelloweye rockfish we lack population structure and review at the species scale. However, with the low frequency of exposure to harmful effects of net pens anticipated, even where response is moderate or high, we expect only small numbers of fish to be harmed.

Table 22. Consequence of exposure and response at the population level.

PBF/Habitat or Direct Effect	**Species**	**Consequence on action area's conservation value**	**Consequence of exposure and response at the population level (A, P, SS and D*)**
Forage	PS Chinook salmon	Low	Low
	PS steelhead	Low	Low
	HCSRC	Low	Low
	PS/GB yelloweye rockfish	Low	Low
	PS/GB bocaccio	Low	Low
Cover	PS Chinook salmon	Low	Low
	PS steelhead	Low	Low
	HCSRC	Low	Low
	PS/GB yelloweye rockfish	Low	Low
	PS/GB bocaccio	Low	Low
Water Quality	PS Chinook salmon	Low	Low
	PS steelhead	Low	Low
	HCSR chum	Low	Low
	PS/GB yelloweye rockfish	Low	Low
	PS/GB bocaccio	Low	Low
Predation in net pens	PS Chinook salmon	NA	Low
	PS steelhead	NA	Low
	HCSRC	NA	Low

PBF/Habitat or Direct Effect	Species	Consequence on action area's conservation value	Consequence of exposure and response at the population level (A, P, SS and D*)
	PS/GB yelloweye rockfish	NA	Low
	PS/GB bocaccio	NA	Low
Pathogens	PS Chinook salmon	NA	Low
	PS steelhead	NA	Low
	HCSRC	NA	Low
	PS/GB yelloweye rockfish	NA	Low
	PS/GB bocaccio	NA	Low
Competition and Predation	PS steelhead	NA	Low
	PS Chinook salmon	NA	Low
	PS steelhead	NA	Low
	HCSRC	NA	Low
	PS/GB yelloweye rockfish	NA	Low
	PS/GB bocaccio	NA	Low

*A = Abundance, P = Productivity, SS = Spatial Structure, D = Diversity

Abundance

Although numbers cannot be ascertained, we expect very few PS Chinook salmon, PS steelhead and HCSRC to be injured or killed as a result of PS commercial net pens structures and operations. Juvenile salmonids are considered the most likely life-stage to be harmed (i.e. entrainment and predation). Juvenile fish killed would represent a decrease in abundance of an even smaller number of adults, based on typical low juvenile to adult survival of Chinook salmon (Duffy and Beauchamp 2011), steelhead (Moore et al. 2015) and HCSRC (see Duffy and Beauchamp 2011) in the PS. For example, Gamble et. al (2018) estimated marine survival of subyearling Chinook salmon in the PS to be between 0.18% and 11.7%. Moore et al. (2015) estimated that in the PS, only about 16% of wild and 11% of hatchery steelhead smolts survive the migration from the mouths of their natal rivers to the Pacific Ocean. Once in the ocean, many more would die before reaching adulthood and returning to natal streams to spawn.

A small number of juvenile PS Chinook salmon and PS steelhead are expected to be killed by entrainment, and by predation in net pens or by escaped fish. Because juvenile HCSRC are not expected to encounter PS commercial net pen sites, we do not expect any to be killed by entrainment, and a small number to be harmed by predation by escaped fish. A very small number of adult PS Chinook salmon, PS steelhead and HCSRC are expected to be harmed or killed as a result of pathogens, competition for resources with escaped fish, genetic interaction, or entertainment during future escape response actions. Therefore, we do not anticipate any discernible effect on abundance of salmonids at the population level.

Similarly, while we cannot ascertain numbers, we anticipate a small number of PS/GB yelloweye rockfish and bocaccio to be harmed or killed as a result of PS commercial net pens. An extremely small number are expected to be killed as a result of changes to forage, cover or water quality, or as a result pathogen exposure, predation by farmed fish or competition with escaped fish. The most likely effect to result in harm or death is the entrainment of larval and juvenile rockfish by vacuum harvest.

We expect a small number of larval, and even smaller number of juvenile PS/GB bocaccio and yelloweye rockfish to be entrained and harmed or killed by vacuum harvest relative to the total population, and total volume of water in the PS that may contain larvae. Depending on size and age, a female yelloweye rockfish produces up to 2,700,000 larvae and bocaccio up to 2,298,000 larvae annually (Love et al. 2002; NMFS 2017a). Mortalities from entrainment would have a proportionally small effect on the overall DPS population abundance and productivity, with generally poor larval survival in the PS, and thus only a small number of larvae becoming reproductive adults (see NMFS 2017a). For example, a study by Canino and Francis (1989) showed that rockfish larvae experienced 70 percent mortality seven to 12 days after birth in a laboratory setting, without the risk of predation. The mean natural mortality rate for rockfish varies by species and environmental conditions. The mean natural mortality rate is approximately three percent per year for yelloweye rockfish and eight percent per year for bocaccio (see NMFS 2017a). Therefore, we do not anticipate any discernible effect of net pen facilities or operations on abundance of rockfish at the population level.

Productivity

As described above, we anticipate a small number of juvenile salmonids, and larval and juvenile rockfish to be harmed or killed as a result of PS commercial net pen effects. Given the low larval/juvenile to adult rate of survival for these species (Duffy and Beauchamp 2011; Moore et al. 2015; NMFS 2017a; Gamble et. al 2018), we do not anticipate any measurable effect on adult populations. We expect that an extremely small number of adult PS Chinook salmon, PS steelhead and HCSRC would be harmed or killed as a result of PS commercial net pen structures and operations. Therefore, we do not anticipate any discernible effect of net pen facilities and operations on adult spawning and productivity of populations even when accounting for these chronic effects through time and climate change effects.

Spatial Structure and Diversity

With no overall declines in population abundance and productivity anticipated, we do not expect any decline in the spatial extent of habitat utilized for spawning, rearing or migration by PS Chinook salmon, PS steelhead, HCSRC, PS/GB yelloweye rockfish or PS/GB bocaccio. Salmonid populations spread across the nearshore and mix when they enter PS (Fresh 2006).

Since the net pens are not located throughout the action area (i.e. central and northern PS and the SJDF) and not immediately at the mouths of natal rivers, juvenile fish from multiple different populations may be exposed to localized net pen effects as they migrate through the PS to the Pacific Ocean. Therefore, we expect any effect of net pen facilities and operations on populations to be indiscriminate, with no effect on population spatial structure or diversity.

Although larvae rockfish are widely dispersed by currents, unique oceanographic conditions within the PS likely result in most larvae staying within the basin where they are released (Drake et al. 2010). Unlike ESA-listed salmonids, we have not identified biological populations of each species below the DPS level, instead we use the term "populations" to refer to groups within each of the five identified basins of the action area (See Section 2.2.1 Status of the Species). We expect that any larval and juvenile bocaccio and yelloweye rockfish harmed or killed as a result of PS commercial net pen effects would primarily be from the San Juan/Juan de Fuca Strait, Main and South PS basins since the net pens are located in those basins. Given the relatively small number of larvae and juveniles expected to be harmed or killed, we do not anticipate a measurable effect of net pen facilitis or operations on population spatial structure or diversity.

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 and 402.17(a)). 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 2.4).

The action area, all waters of PS, the SJDF and tributary rivers, is influenced by actions within PS marine waters, along the shoreline, and in tributary watersheds. Some types of human activities that contribute to cumulative effects are expected to have adverse impacts on populations and PBFs, many of which are activities that have occurred in the recent past and had an effect on the environmental baseline. These can be considered reasonably certain to occur in the future because they occurred frequently in the recent past, especially if authorizations or permits have not yet expired. Within the freshwater portion of the action area, non-federal actions are likely to include human population growth, water withdrawals (i.e., those pursuant to senior state water rights), and land use practices. In marine waters within the action area, state, tribal, and local government actions are likely to be in the form of legislation, administrative rules, or policy initiatives, shoreline growth management, and resource permitting. Private activities include continued resource extraction, vessel traffic, development, and other activities which contribute to poor water quality in the freshwater and marine environments of PS.

Although these factors are ongoing to some extent and likely to continue in the future, past occurrence is not a guarantee of a continuing level of activity. That will depend on whether there are economic, administrative, and legal impediments (or in the case of contaminants, safeguards). Therefore, although NMFS finds it likely that the cumulative effects of these activities will have adverse effects commensurate to those of similar past activities, as described in the Environmental Baseline, these effects may occur at somewhat higher or lower levels than those described in the Baseline.

Based on current trends, there will continue to be a net reduction in the total amount of shoreline armoring in PS (PSP 2019). Changes in tributary watersheds that are likely to affect the action area include reductions in water quality, water quantity, and sediment transport. Future actions in the tributary watersheds whose effects are likely to extend into the action area include operation of hydropower facilities, flow regulations, timber harvest, land conversions, disconnection of floodplain by maintaining flood-protection levees, effects of transportation infrastructure, and growth-related commercial and residential development. Some of these developments will occur without a federal nexus, however, activities that occur waterward of the OHWM require a COE permit and therefore involve federal activities, which are not considered in this section.

All such future non-federal actions, in the nearshore as well as in tributary watersheds, will cause long-lasting environmental changes and will continue to harm ESA-listed species and their critical habitats. Especially relevant effects include the loss or degradation of nearshore habitats, pocket estuaries, estuarine rearing habitats, wetlands, floodplains, riparian areas, and water quality. We consider human population growth to be the main driver for most of the future negative effects on salmon and steelhead and their habitat.

The human population in the PS region is experiencing a high rate of growth. The central PS region (Snohomish, King, Pierce and Kitsap counties) has increased from about 1.29 million people in 1950 to over 4.2 million in 2020, and projected to reach nearly 6 million by 2050 (PS Regional Council 2020). Thus, future private and public development actions are very likely to continue in and around PS. As the human population continues to grow, demand for agricultural, commercial, and residential development and supporting public infrastructure is also likely to grow. We believe the majority of environmental effects related to future growth will be linked to these activities, in particular land clearing, associated land-use changes (i.e., from forest to impervious, lawn or pasture), increased impervious surface, and related contributions of contaminants to area waters. Land use changes and development of the built environment that are detrimental to salmonid habitats are likely to continue under existing regulations. Though the existing regulations minimize future potential adverse effects on salmon habitat, as currently constructed and implemented, they still allow systemic, incremental, additive degradation to occur.

Several not for profit organizations and state agencies are also implementing recovery actions identified in the recovery plans for PS Chinook salmon, HCSRC, PS steelhead, and PS/GB yelloweye rockfish and bocaccio. The state passed House Bill 1579 that addresses habitat protection of shorelines and waterways (Chapter 290, Laws of 2019 (2SHB 1579)), and funding was included for salmon habitat restoration programs and to increase technical assistance and enforcement of state water quality, water quantity, and habitat protection laws. Other actions included providing funding to the Washington State Department of Transportation to complete fish barrier corrections. Although these measures won't improve prey availability in 2020/2021, they are designed to improve conditions in the long-term.

Notwithstanding the beneficial effects of ongoing habitat restoration actions, the cumulative effects associated with continued development are likely to have ongoing adverse effects on all the listed salmonid and rockfish species addressed in this opinion, and abundance and productivity that outpace the effects of restoration activities. Only improved low-impact development actions together with increased numbers of restoration actions, watershed planning, and recovery plan implementation would be able to address growth related impacts into the future. To the extent that non-federal recovery actions are implemented and offset ongoing development actions, adverse cumulative effects may be minimized, but will probably not be completely avoided.

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) appreciably diminish the value of designated or proposed critical habitat as a whole for the conservation of the species; or (2) reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing its numbers, reproduction, or distribution.

2.7.1 Effects to Critical Habitat

Critical Habitat is designated for PS Chinook salmon, PS steelhead and HCSRC in freshwater environments, and for PS Chinook and HCSRC in the marine environment. Throughout the designated area, multiple features of habitat are degraded, but despite such degradation, many accessible areas remain ranked with high conservation value because of the important life history role it plays. Limiting factors (impaired or insufficient PBFs) include; riparian areas and LWD, fine sediment in spawning gravel, water quality, fish passage and estuary conditions. Loss of freshwater and nearshore critical habitat quality is a limiting factor for all three species. Current state and local regulations do not prevent much of the development that degrades the quality of nearshore critical habitats. There is no indication these regulations are reasonably certain to change in the foreseeable future.

Critical habitat for PS/GB bocaccio and yelloweye rockfish in the PS includes hundreds of square miles of deep-water and nearshore areas. Habitat has been degraded by, and continues to be threatened by, water pollution and runoff, nearshore development and in-water construction, dredging and disposal of dredged material, climate-induced changes to habitat and population dynamics, degradation of rocky habitat, loss of eelgrass and kelp, and the introduction of non-native species that modify habitat.

Given the rate of expected population growth in the PS area, cumulative effects are expected to result in mostly negative impacts on critical habitat quality for PS Chinook salmon, PS steelhead, HCSRC, PS/GB yelloweye rockfish and PS/GB bocaccio. While habitat restoration and advances in best management practices for activities that affect critical habitat could lead to some improvement of PBFs, adverse impacts created by the intense demand for future development is likely to outpace any improvements.

To this degraded baseline, including anticipated cumulative effects and the effects of tribal enhancement and federal research net pen facilities evaluated contemporaneously,[11] we add the habitat effects we expect to result from the action, or in this case, consequences of the action (PS commercial net pen structures and operations). Because net pen sites are within and/or in close proximity to critical habitat for PS Chinook salmon, PS/GB yelloweye rockfish and PS/GB bocaccio, we anticipate net pen facilities and operations would directly degrade quality of critical habitat for these species. Effects to critical habitat for these three species includes reduced forage resulting from benthic disturbance by structures, sediment quality degradation by bio-deposits and contaminants; reduced cover by benthic disturbance by structures; and degraded water quality by bio-deposits, contaminants and turbidity. Although we do not anticipate any direct habitat effects on PS steelhead and HCSRC critical habitat, since no commercial net pens are located within critical habitat for these species, escaped farmed fish may move into critical habitat and compete for resources, reducing the forage PBF. Alone, the scale of these adverse effects would be spatially constrained and infrequent, so that the overall consequence on critical habitat would be low. However, the degraded baseline, anticipated cumulative effects added to the effects of the proposed action result in continued degradation of critical habitat and a prolonged period of recovery of listed species. Nevertheless, the conservation onservation value of the critical habitat for PS Chinook salmon, PS steelhead, HCSRC, PS/GB yelloweye rockfish and PS/GB bocaccio is largely retained.

The isolated effects of PS commercial net pens on habitat conditions (i.e. water quality, forage and cover) are expected to be minor, and intermittent. Effects would be highly localized relative to the broader action area, and expanse of critical habitat within the action area. Therefore, despite a degraded baseline and anticipated cumulative effects primarily associated with population growth and development, we do not expect the habitat effects of PS commercial net pens to appreciably diminish the conservation value of critical habitat for PS Chinook, PS steelhead, HCSRC, PS/GB yelloweye rockfish or PS/GB bocaccio.

2.7.2 Effects to Species

PS Chinook salmon are currently listed as threatened with generally negative recent trends in status. Widespread negative trends in natural-origin spawner abundance across the ESU have been observed since 1980. Productivity remains low in most populations, and hatchery-origin spawners are present in high fractions in most populations outside of the Skagit watershed. Although most populations have increased somewhat in abundance since the last status review in 2016, they still have small negative trends over the past 15 years, with productivity remaining low in most populations (Ford 2022). All PS Chinook salmon populations continue to remain well below the TRT planning ranges for recovery escapement levels, and that most populations

[11] WCRO-2021-03087

remain consistently below the spawner-recruit levels identified by the TRT as necessary for recovery.

The most recently completed 5-year status review (NWFSC 2015; NMFS 2017c) for Pacific salmon and steelhead noted some signs of modest improvement in PS steelhead productivity since the previous review in 2011, at least for some populations, especially in the Hood Canal and SJDF MPG. However, several populations were still showing dismal productivity, especially those in the Central and South PS MPG. The 2022 biological viability assessment (Ford 2022) identified a slight improvement in the viability of the PS steelhead DPS since the PS steelhead technical review team concluded that the DPS was at very low viability in 2015, as were all three of its constituent MPGs, and many of its 32 DIPs (Hard et al. 2015). Ford (2022) reported observed increases in spawner abundance in a number of populations over the last five years, which were disproportionately found within the South and Central PS, SJDF and Hood Canal MPGs, and primarily among smaller populations. The viability assessment concluded that recovery efforts in conjunction with improved ocean and climatic conditions have resulted in an increasing viability trend for the PS steelhead DPS, although the extinction risk remains moderate (Ford 2022).

HCSR chum salmon have made substantive gains towards meeting this species' recovery plan viability criteria. The most recently completed 5-year status review (NWFSC 2015; NMFS 2017c) for this ESU notes improvements in abundance and productivity for both populations that make up the ESU. The 2022 biological viability assessment (Ford 2022) reported that natural-origin spawner abundance has increased since ESA-listing and spawning abundance targets in both populations have been met in some years. Implementation of recovery plan actions for HCSR chum salmon, including development of an in-lieu fee program for projects that impact critical habitat for this species, represent positive steps toward addressing habitat limiting factors for this species.

However, Ford (2022) found that productivity has been down for the last three years for the Hood Canal population, and for the last four years for the SJDF population, following prior increased productivity reported at the time of the last review (NWFSC 2015). Based on productivity of individual spawning aggregates, Ford (2022) identified viable performance for only two of eight aggregates. However, spatial structure and diversity viability parameters, as originally determined by the TRT have improved and nearly meet the viability criteria for both populations. Ford (2022) finds that although substantive gains have been made towards meeting viability criteria, the ESU still does not meet all of the recovery criteria for population viability. Therefore, Ford (2022) concludes that the HCSRC ESU remains at moderate risk of extinction, with viability largely unchanged from the prior review.

PS/GB bocaccio are listed as endangered and abundance of this species likely remains low. PS/GB yelloweye rockfish are listed as threatened but likely persist at abundance levels somewhat higher than bocaccio. Lack of specific information on rockfish abundance in PS makes it difficult to generate accurate abundance estimates and productivity trends for these two DPSs. Available data does suggest that total rockfish declined at a rate of 3.1 to 3.8 percent per year from 1977 to 2014 or a 69 to 76 percent total decline over that period. The two listed DPSs declined over-proportional compared to the total rockfish assemblage. Habitat degradation has limited the carrying capacity of habitat for these species and continued threats inhibit recovery. Other factors, such as overfishing, are more significant threats to PS/GB yelloweye rockfish and bocaccio. While ongoing habitat restoration and advances in best management practices may slow further habitat degradation and reduce direct take, a trajectory for recovery of populations remains uncertain, particularly given anticipated impacts of climate change.

When we evaluate the cumulative effects on these species over the time period of anticipated ongoing net pen operations and their impacts, we anticipate additional stress added to existing stressors in the baseline in both fresh and marine environments from anthropogenic changes in habitat (increased recreational use in fresh and marine waters, increased stormwater inputs in fresh and marine waters), and increasingly modified conditions related to climate change (warmer temperatures, and more variable volume and velocities in freshwater, changing temperature, pH, and salinity in marine waters). All of these are likely to exert negative pressure on population abundance and productivity.

In this context we add the effects of the proposed action. Even considered over multiple years, with highly variable ocean conditions and climate change stressors, only a small number of fish relative to the affected populations would be killed or injured by the effects that result from PS commercial net pen structures and operations, so that the reductions in abundance would not rise to create effects on productivity, diversity and spatial structure at discernible levels. Therefore, the proposed action is unlikely to alter the current or future trends for PS Chinook salmon, PS steelhead, HCSRC, PS/GB yelloweye rockfish or PS/GB bocaccio population viability even when cumulative effects and baseline conditions are added to the proposed action..

In other words, we expect that the total effects of the action on individual fish identified in this opinion would be indiscernible at the population level because although these species are currently well below historic levels, they are distributed widely enough and are presently at high enough abundance levels that the loss of individual fish resulting from the action would not alter their spatial structure, productivity, or diversity. Therefore, when considered in light of species status and existing risk, baseline effects, as described above in Section 2.7.1 (Effects to Critical Habitat) and cumulative effects, the action (and consequences of the action) itself does not increase risk to the affected populations to a level that would reduce appreciably the likelihood for survival or recovery of PS Chinook salmon, PS steelhead HCSRC, PS/GB yelloweye rockfish and PS/GB bocaccio.

2.8 Conclusion

When analyzed into the future, with variable ocean conditions and climate change stressors, only a small number of fish relative to the affected populations would be killed or injured by the effects that result from net pen structures and operations. Further, despite a degraded baseline and anticipated cumulative effects primarily associated with population growth and development, we do not expect the habitat effects of the net pens to appreciably diminish the conservation value of critical habitat for PS Chinook, HCSRC, PS/GB yelloweye rockfish or PS/GB bocaccio.

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, the effects of other activities caused by the proposed action, and cumulative effects, it is NMFS' biological opinion that the proposed action is not likely to jeopardize the continued existence of PS Chinook salmon, PS steelhead, HCSRC, PS/GB yelloweye rockfish or PS/GB bocaccio, or adversely modify their 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). "Harass" is further defined by interim guidance as to "create the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering." "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 Incidental Take Statement (ITS).

This ITS provides a take exemption to the EPA and Washington state agencies for any incidental take caused by consequences of the proposed action. A take exemption is not provided to third parties that are subject to WAC-173-204, including the owners or operators of commercial marine finfish rearing facilities in the PS. ESA coverage for commercial operators may be available either through a separate Section 7 consultation for which they are an applicant (e.g., if they request a permit from the Army Corps of Engineers under Section 10 of the Rivers and Harbors Act or Section 404 of the Clean Water Act) or if they request an incidental take permit as part of an ESA Section 10 process.

2.9.1 Amount or Extent of Take

When take is in the form of harm from habitat degradation, it is often impossible to enumerate the take that would occur because the number of fish likely to be exposed to harmful habitat conditions is highly variable over time, influenced by environmental conditions that do not have a reliably predictable pattern, and the individuals exposed may not all respond in the same manner or degree. Where NMFS cannot quantify take in terms of numbers of affected fish, we instead consider the likely extent of changes in habitat quantity and quality to indicate the extent of take as surrogates. The best available indicators for the extent of take, proposed actions are as follows.

As described in our effects analysis, NMFS has determined that take is reasonably certain to occur as follows:

- Harm of juvenile and adult PS Chinook salmon, HCSRC, PS steelhead, and adult, juvenile, and larval PS/GB bocaccio and yelloweye rockfish resulting from a large-scale net pen failure;
- Harm of juvenile and adult PS Chinook salmon, HCSRC and PS steelhead resulting from co-occurrence with farmed fish that escape during PS commercial net pen operations (not including escapes resulting from large-scale failures); and
- Harm of juvenile and adult PS Chinook salmon, HCSRC, PS steelhead, and adult, juvenile, and larval PS/GB bocaccio and yelloweye rockfish resulting from habitat effects and direct effects on species of PS commercial net pen operations.

Specifically, we expect that the following amounts and types of take would occur:

Large-scale net pen failure event

As a result of a large-scale net pen failure, take is reasonably likely to occur as follows:

- Temporary reduction in forage for juvenile and adult PS Chinook salmon, PS steelhead, PS/GB yelloweye rockfish and PS/GB bocaccio resulting from disturbance of the benthos by the movement and deposition of net pen debris, and clean-up and recovery activities;
- Temporary reduction in cover for juvenile and adult PS Chinook salmon, PS steelhead, PS/GB yelloweye rockfish and PS/GB bocaccio resulting from damage or displacement of subtidal macroalgae by the movement and deposition of net pen debris, and clean-up and recovery activities;
- Entrainment and capture of juvenile and adult PS Chinook salmon, and PS steelhead, larval and juvenile PS/GB bocaccio, and larval yelloweye rockfish during efforts to recover escaped fish. This includes removal with vacuum harvest pumps, seining and other netting;
- Predation and competition of juvenile PS Chinook salmon, HCSRC and PS steelhead, and larval and juvenile PS/GB yelloweye rockfish and PS/GB bocaccio by escaped farmed fish in marine and freshwater portions of the action area;
- Reduced reproductive success for adult PS Chinook salmon, HCSRC and PS steelhead from competition for spawning sites and redd superimposition by escaped farmed fish (rainbow trout/steelhead) in freshwater portions of the action area; and
- Reduced fitness and survival of PS steelhead from outbreeding depression and hatchery-influenced selection effects by interbreeding with escaped farmed rainbow trout/steelhead in freshwater portions of the action area.

For these take pathways, as a surrogate take indicator we use the expected frequency of large-scale net pen failures as follows:

> *No more than one large-scale failure event [defined as the escape and loss (i.e. not recaptured/recovered) of more than 29% of the maximum production number of fish at that site] to occur at any of the net pen sites (4) over any 50-year period of time.*

This surrogate is representative of take described above resulting from large-scale net pen structural failure and escape of fish, since the magnitude of direct and indirect effects are proportional to the number of large-scale structural failures and the number of escaped fish. This take surrogate can be reliably measured and monitored through monitoring of the number of fish within net pens and routine structural inspections of net pens. Take would be exceeded if *more than one large-scale structural failure event [defined as the escape and loss (i.e. not recaptured/recovered) of more than 29% of the maximum production number of fish at that site] occurred at any of the net pen sites (4) over any 50-year period of time*; such an exceedance would trigger a need for reinitiation of this ESA Section 7 consultation. This ITS exempts take resulting from this number and nature of large-scale structural failures.

Net pen Operations

As a result of PS commercial net pen operations, take is reasonably likely to occur as follows:

- Reductions in forage production for juvenile and adult a PS Chinook salmon, PS steelhead, PS/GB yelloweye rockfish and PS/GB bocaccio from sediment quality degradation occurring as a result of bio-deposits and contaminants;
- Harm to juvenile and adult PS Chinook salmon and PS steelhead, and larval, juvenile and adult PS/GB yelloweye rockfish and PS/GB bocaccio as a result of degraded water quality from bio-deposits, contaminants and turbidity;
- Predation of juvenile PS Chinook salmon and PS steelhead, and larval PS/GB yelloweye rockfish and PS/GB bocaccio by farmed fish within the four PS commercial net pen facilities;
- Predation and competition of juvenile PS Chinook salmon, HCSRC and PS steelhead, and larval and juvenile PS/GB yelloweye rockfish and PS/GB bocaccio by farmed fish that escape as a result of small escape and leakage events in marine and freshwater portions of the action area;
- Reduced reproductive success for adult PS Chinook salmon, HCSRC and PS steelhead from competition for spawning sites and redd superimposition by escaped farmed fish (rainbow trout/steelhead) as a result of small escape and leakage events in freshwater portions of the action area;
- Reduced fitness and survival of juvenile and adult PS steelhead from outbreeding depression and hatchery-influenced selection effects by interbreeding with escaped farmed rainbow trout/steelhead as a result of small escape and leakage events in freshwater portions of the action area;
- Entrainment of juvenile PS Chinook salmon and PS steelhead, larval and juvenile PS/GB bocaccio, and larval yelloweye rockfish during harvest (vacuum pump) of farm fish at the four PS commercial net pen facilities; and
- Reduced fitness and survival from the transmission of pathogens to juvenile and adult PS Chinook salmon, HCSRC, PS steelhead, PS/GB bocaccio and PS/GB yelloweye rockfish from farmed fish.

For the above take pathways associated with operations, excluding those resulting from escaped fish, as a surrogate take indicator we use the maximum number of fish reared at the four PS commercial net pen facilities:

No more than 2,390,000 individual fish or 17,600,000 pounds of fish reared at any time within PS commercial net pens.

Our analysis, in deference to ESA-listed species, has assumed a maximum of 2,390,000 individual fish or 17,600,000 pounds of fish (Table 1 and Table 20) reared at the four PS commercial net pen sites based on expected farming operations. The absolute number of fish reared within net pens is proportional to take we identified in this opinion resulting from effects of net pen operations. This ITS exempts take expected from this level of farming. Counting of fish as they are placed into the net pens and when they are removed for harvest, as well as frequent monitoring of the fish and net pen structures during rearing, provides the information necessary to ensure the take surrogate can be reliably measured and monitored. Take would be exceeded if at any time more than 2,390,000 individual fish or 17,600,000 pounds of fish are being reared within PS commercial net pens at any given time. This would trigger a need for reinitiation of this ESA Section 7 consultation.

2.9.2 Effect of the Take

In the biological opinion, NMFS determined that the amount or extent of anticipated take, coupled with other effects of the proposed action, is not likely to result in jeopardy to PS Chinook salmon, PS steelhead, HCSRC, PS/GB yelloweye rockfish or PS/GB bocaccio, or destruction or adverse modification of critical habitat.

2.9.3 Reasonable and Prudent Measures

"Reasonable and prudent measures" (RPMs) are measures that are necessary or appropriate to minimize the impact of the amount or extent of incidental take (50 CFR 402.02). NMFS believes that the full application of the reasonable and prudent measure described below is necessary and appropriate to minimize the likelihood of incidental take of ESA-listed species, the EPA shall:

1. Provide NMFS with monitoring reports to confirm that incidental take surrogates are not exceeded.

2.9.4 Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the ESA, the federal action agency must comply (or must ensure that any applicant complies) with the following terms and conditions. The EPA (or any applicant) has a continuing duty to monitor the impacts of incidental take and must report the progress of the action and its impact on the species as specified in this ITS (50 CFR 402.14). If the entity to whom a term and condition is directed does not comply with the following terms and conditions, protective coverage for the proposed action would likely lapse.

1. The following term and condition implements reasonable and prudent measure 1:

The EPA shall coordinate annually with NMFS to review the publically available monitoring data and reports required by the WDFW and Ecology permits for commercial net pen facilities and operations in the PS. Information describing any structural failures and the total numbers and total pounds of fish reared within each of the net pen facilities shall be assessed to confirm that incidental take surrogates have not been exceeded. The frequency of EPA coordination and review of data and reports with NMFS may be adjusted as needed, greater or reduced frequency, so long as the EPA continues to confirm that take surrogates are not exceeded.

2.10 Conservation Recommendations

Section 7(a)(1) of the ESA directs federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of the threatened and endangered species. Specifically, conservation recommendations are suggestions regarding discretionary measures to minimize or avoid adverse effects of a proposed action on listed species or critical habitat or regarding the development of information (50 CFR 402.02).

To address the uncertainty around hydrodynamics and pathogen spread specifically in PS and the SJDF, we recommend that the EPA work with state agencies to implement the following:

- Develop a study plan to better understand the role of net pen site hydrodynamics as they relate to pathogen spread. This information should be considered for any future net pen facility siting. Because the Rich Passage sites are the closest together, looking for correlations in infection/disease occurrence could be useful for narrowing the initial scope of a study. We recommend that results be reported to NMFS.
- Document and maintain thorough pathogen infection and disease outbreak records and communication, as well as records of treatment frequency and treatment effectiveness for farm operations. This would be immensely helpful in tracking if similar increased disease severity and mortality trends are occurring in the net pens that are the focus of the proposed action. The WDFW has already identified the need for Cooke to report this information. We recommend that all records be shared with NMFS.

2.11 Reinitiation of Consultation

This concludes formal consultation for the reinitiation of consultation for the Environmental Protection Agency's Approval of Washington state Department of Ecology's Sediment Management Standards (WAC 173-204-412) regarding marine finfish rearing facilities.

As 50 CFR 402.16 states, reinitiation of consultation is required and shall be requested by the federal agency or by the Service 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 identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in the biological opinion, or (4) a new species is listed or critical habitat designated that may be affected by the action.

2.12 "Not Likely to Adversely Affect" Determinations

When evaluating whether the proposed action is not likely to adversely affect listed species or critical habitat, NMFS considers whether the effects are expected to be completely beneficial, insignificant, or discountable. Completely beneficial effects are contemporaneous positive effects without any adverse effects to the species or critical habitat. Insignificant effects relate to the size of the impact and should never reach the scale where take occurs. Effects are considered discountable if they are extremely unlikely to occur. When effects are beneficial, insignificant and/or discountable, these species are not likely to be adversely affected by the proposed action and we present our justification for that determination separately from the biological opinion since no take, jeopardy, or adverse modification of critical habitat would reasonably be expected to occur. We concur with the EPA's NLAA determinations for Southern Resident killer whale (SRKW) and their designated critical habitat, the Central America DPS and Mexico DPS of humpback whale and their critical habitat, the southern DPS of green sturgeon and their critical habitat, and the southern DPS of eulachon and their critical habitat. All of these species and designated critical habitat occur within the action area. We describe here those listed resources and critical habitat that we consider not likely to be adversely affected by the proposed action in this case.

2.10.1 Southern Resident Killer Whale and their Designated Critical Habitat

Southern Resident killer whale was listed as endangered on November 18, 2005 (70 FR69903) and critical habitat was designated on November 29, 2006 (71 FR 69054) and expanded on August 2, 2021 (86 FR 41668). A 5-year review under the ESA completed in 2016 concluded that SRKWs should remain listed as endangered and includes recent information on the population, threats, and new research results and publications (NMFS 2016d). As of the summer of 2020, there were 72 SRKW, and during fall 2020 two more calves were born (L. Barre, personal communication, October 2, 2020).

Critical habitat is designated throughout the marine portions of the action area, excluding Hood Canal. PBFs for SRKW are:

- Water quality to support growth and development;
- Prey species of sufficient quantity, quality, and availability to support individual growth, reproduction, and development, as well as overall population growth; and
- Passage conditions to allow for migration, resting, and foraging.

For the reasons outlined above in Section 2.5.3, any changes to water quality are expected to be localized and minor, with no implications on the health of SRKW. We do not anticipate water quality conditions to be degraded to such a degree that SRKW are harmed, particularly given the mobility of SRKW and limited time spent in one localized area. We do not expect any accumulation of toxic chemicals as a result of PS commercial net pen operations that could harm SRKW.

Potential benthic disturbance (Section 2.5.1) is also expected to be minor and localized, and the proposed action is expected to have an insignificant effect on the quantity and quality of salmonids and other potential prey species (e.g., squid, halibut) (see Section 2.5). Adult Chinook salmon have been identified as the preferred prey of SRKW (Hilborn et al. 2012; PFMC. 2020; Hanson et al. 2021) and thus a decrease in the abundance of PS Chinook salmon could reduce available forage. While take of individual PS Chinook salmon is likely to occur as described in the analysis, most effects are likely to occur at sublethal levels. Furthermore, the majority of anticipated effects of PS commercial net pen structures and operations on PS Chinook salmon and their habitat (e.g., predation by escaped fish, reduced forage and reduced cover) would affect juvenile fish. As described in Section 2.5.4 (Effects on Population Viability) juvenile PS Chinook salmon killed would represent a decrease in abundance of an even smaller number of adults (i.e. preferred SRKW prey), based on typical low juvenile to adult survival (Duffy and Beauchamp 2011). A very small number of adults are expected to be harmed or killed as a result of pathogens, competition for resources with escaped fish, genetic interaction, or entertainment during future escape response actions. Therefore, we do not anticipate a reduction in abundance or quality of Chinook salmon as a prey item to occur at levels or frequency to cause any discernible effect to the forage PBF of SR killer whale critical habitat.

Steelhead are known to make up only a very small portion of their SRKW diet, even during winter months when preferred prey (Chinook salmon) are less prevalent (see Hanson et al. 2021). Therefore, in light of similar effects on steelhead as Chinook as discussed above, and because steelhead are not a preferred prey for SRKW, we do not anticipate effects of PS commercial net pens on PS steelhead to have a measurable effect on SRKW diet composition, or forage availability.

We also expect the feeding opportunity on escaped net pen fish to be too small to have a measurable effect on the composition of SRKW diet (forage). Following the Cypress Island net pen failure and escape event, the presence of Atlantic salmon was documented in a SRKW fecal sample (B. Hanson, personal communication, October 9, 2020). Since steelhead make up only a very small portion of SRKW diet we do not anticipate escaped rainbow trout/steelhead having a measureable effect on SRKW diet composition.

We expect vessels servicing the net pens to travel between the shore and the pens on a daily basis. State and federal regulations for marine vessels would reduce the risk of encounters with whales. Within the inland waters of Washington State, it is unlawful under federal regulations for any person to cause a vessel to approach, in any manner, within 200 m of any killer whale, or to position a vessel to be in the path of any killer whale at any point located within 400 m of the whale. State regulations also mandate protections for SRKWs (see RCW 77.15.740, mandating 300-400 yard approach limits, 7 knots or less speed within ½ nautical mile of the whales). Additionally, NMFS and other partners have outreach programs in place to educate vessel operators, including the fishing community, on how to avoid impacts to whales. Thus we anticipate interactions between vessels moving to and from net pens to not interfere with SRKW movement or behavior. The presence and movement of vessels associated with net pens is insignificant to both SRKW and their CH.

The location of the PS commercial net pens would not inhibit or interfere with passage of SRKW for migration, resting or foraging because of the small scale of the structures relative to the action area, and because they are not located within any constricted migration corridors. We are not aware of any SRKW interactions with PS commercial net pens, and given the small footprint of structures relative to surrounding waters, we do not anticipate a detectable effect on passage conditions.

Regular inspections and maintenance of the net pen facility mooring systems and nets, as required by NPDES permits, reduces the potential for loose cables or netting in the water column. Large-scale structural failure events are also expected to be very infrequent. Therefore, we do not anticipate any entanglement of SRKW in net pen structures. We are aware of no whale entanglements in PS net pens, and none are documented in the NMFS entanglement response database or in our national database for stranding records (K. Wilkinson, personal communication, October 8, 2020). The predator barrier nets prevent marine mammals, including killer whales, from making direct contact with the fish containment nets, eliminating potential entanglement. The barrier nets are bite and tear resistant, and are weighted down to maintain rigidity (J. Parsons, personal communication, June 5, 2020).

Because all potential effects on PBFs of SRKW critical habitat are expected to be insignificant or discountable, the proposed action is not likely to adversely affect critical habitat for SRKW. With no significant indirect habitat effects to SRKW, nor measureable direct effects to SRKW, any potential effects to SRKW are expected to be insignificant

2.10.2 Central America DPS and Mexico DPS Humpback Whale and their Designated Critical Habitat

The humpback whale was listed as endangered in 1973 when the ESA was enacted. On September 8, 2016, we revised the ESA listing for humpback whale to identify 14 DPSs, which included the listing of the Central America DPS as endangered and the Mexico DPS as threatened (81 FR 62259). Both DPSs occur within the action area. Critical habitat was designated for the Central America and Mexico DPSs on April 21, 2021 (86 FR 21082). Only prey was identified as an essential feature (i.e. PBF) of humpback whale habitat in the critical habitat designation.

The only portion of the action area to include designated critical habitat is the SJDF, and thus there is no critical habitat near PS commercial net pens. Sediment and water quality effects would be localized to net pen sites and would therefore not extend into humpback critical habitat. As described in effects analysis (Section 2.5), we anticipate that any impact to benthic conditions or water quality from net pen waste products or other contaminants would be minor and localized, with no measurable effect on forage potential (e.g., krill and small schooling fish) for humpback whale. We do not anticipate effects of PS commercial net pens on humpback prey species abundance or quality within their designated critical habitat.

The only effects of net pens that would potentially occur within designated critical habitat is the movement of escaped fish into the SJDF. We consider it extremely unlikely that foraging by escaped fish would have a measureable effect on the abundance of humpback whale prey species. Therefore we consider there to be a discountable effect on humpback critical habitat.

Humpback whales do occasionally venture further into the action area where they may encounter net pen structures. We do not expect individual whales to interact with the net pens because while humpbacks do prey on schools of fish, the fish inside these are generally larger than the preferred prey fishes of humpback (e.g., herring, anchovies, etc.). As described previously, through anticipated regular monitoring and maintenance of mooring systems and nets, we do not expect loose nets or mooring lines to be present in the water column and we anticipate that any entanglement of whales to be extremely unlikely. We are unaware of direct humpback whale interactions with PS commercial net pens. As described above for SRKW, we do not anticipate any detectable effect on migration, and consider the risk of entanglement to be discountable. Therefore, we consider it unlikely that PS commercial net pen facilities or operations would adversely affect humpback whales.

<u>2.10.3 Southern DPS Green Sturgeon and their Designated Critical Habitat</u>

The southern DPS of green sturgeon was listed as threatened on April 7, 2006 (50 CFR 223) and critical habitat was designated in 2009 (74 FR 52299; 10/09/09). Within the action area, critical habitat is designated in coastal areas (within 60 fathom depth) along parts of the southern side of the SJDF and northern PS. None of the PS commercial net pens are located within designated critical habitat. In the designation documents, the PS is called out as an occupied area possessing PBFs, however most of the PS (south of Port Townsend and east of Whidbey Island) is excluded from the designation for economic reasons. The ESA designation (50 CFR 223) states the following:

> *Observations of green sturgeon in Puget Sound are much less common compared to the other estuaries in Washington. Although two confirmed Southern DPS fish were detected there in 2006, the extent to which Southern DPS green sturgeon use Puget Sound remains uncertain. Puget Sound has a long history of commercial and recreational fishing and fishery-independent monitoring of other species that use habitats similar to those of green sturgeon, but very few green sturgeon have been observed there. In addition, Puget Sound does not appear to be part of the coastal migratory corridor that Southern DPS fish use to reach overwintering grounds north of Vancouver Island (internal citation omitted), thus corroborating the assertion that Southern DPS do not use Puget Sound extensively.*

As described in the effects analysis (Section 2.5), we expect habitat effects of net pen structures and operations to be localized to the immediate vicinity of net pens. Therefore, only anticipated effects of net pens that would potentially occur within designated critical habitat are associated with the movement of escaped fish into these areas. The PBFs for green sturgeon critical habitat (see 50 CFR 226.219) include:

- Coastal marine waters with adequate dissolved oxygen levels and acceptably low levels of contaminants (e.g., pesticides, PAHs, heavy metals that may disrupt the normal behavior, growth, and viability of sub-adult and adult green sturgeon).
- Abundant prey items for sub-adults and adults, which may include benthic invertebrates and fish.
- A migratory pathway necessary for the safe and timely passage of Southern DPS fish within estuarine habitats and between estuarine and riverine or marine habitats.

The PS region is not a spawning area for green sturgeon, but the species spends significant time in coastal regions of Washington and may use the action area for feeding and migration (Erickson and Hightower 2007; Lindley et al. 2008; Lindley et al. 2012; NMFS 2018c). However, it appears that only a small number migrate through the SJDF, with few documented within the Strait or PS (Erickson and Hightower 2007; Lindley et al. 2008; Lindley et al. 2012). Observations of green sturgeon in PS are much less common compared to the other estuaries in Washington, and monitoring data for tagged green sturgeon show few detections in PS (NMFS 2009). During over 1,700 bottom trawls conducted by WDFW between 1987 and 2011 in the PS and SJDF, including several sites within a mile of the Port Angeles site, only one green sturgeon was caught (WDFW 2012; P. Doukakis, personal communication, April 4, 2017).

As described in Section 2.5.3, we expect any measurable changes to water quality to be minor, localized, infrequent and of short duration. Any potential diminishment of water quality at the four PS commercial net pen sites (e.g., low DO) would not extend to green sturgeon designated critical habitat. We do not anticipate water quality conditions to be degraded to such a degree that Southern DPS green sturgeon that encounter net pens are harmed, particularly given their mobility and limited time spent in one localized area within the action area.

Effects on benthic conditions from benthic disturbance by net pens structures or by bio-deposits and other contaminants are expected to be highly localized and minor, and would not extend to Southern DPS green sturgeon critical habitat (see Section 2.5). We also do not expect any accumulation of toxic chemicals as a result of PS commercial net pen operations that could harm Southern DPS green sturgeon.

Green sturgeon prey includes benthic invertebrates and fish, such as shrimp, clams, crabs, anchovies and sand lances (Moyle et al. 1995; Erickson et al. 2002; Moser and Lindley 2007; Dumbauld et al. 2008). Given the relatively small number of escaped fish likely to co-occur with and compete for forage with green sturgeon in the SJDF we expect no measurable effect on the abundance of these prey items (see Section 2.5). Thus we do not expect any measurable effect on the forage PBF of Southern DPS green sturgeon, nor effects on the species related to any change in prey abundance or quality. There would also be no interference with migration of Southern DPS green sturgeon associated with PS commercial net pens since the net pen structures do not create barriers to migration. Therefore, we do not expect any measureable effects on habitat quality for Southern DPS green sturgeon, nor adverse effects on the species. Effects to green sturgeon as a result of the proposed action is discountable.

2.10.4 Southern DPS Eulachon and their Designated Critical Habitat

The southern DPS of eulachon was listed as threatened on March 18, 2010 (75 FR 13012) and critical habitat was designated on October 20, 2011 (76 FR 65323). Southern DPS eulachon migrate through the SJDF on their migrations to and from spawning grounds in the Fraser River in British Columbia, and the Elwha River in Washington (NMFS 2017b). The Elwha River is the only known spawning site in the action area, and also the only designated critical habitat within the action area. The river is approximately 50 miles from the nearest net pen site (Hope Island). Eulachon occupy nearshore waters to approximately 1,000 feet in depth. Dealy and Hodes (2019) did extensive eulachon sampling on the Canadian side of the SJDF and found that Strait likely provides important year-round habitat for feeding and growth, as well as being a migration corridor.

Over the continental shelf, it is generally believed that eulachon stay at depth (approximately 100 to 200 m deep) and rarely come to the surface. In the SJDF, Dealy and Hodes (2019) caught eulachon at depths of 81 to 227 m, with the highest catch per unit effort at bottom depths of between 117 and 170 m. However, as demonstrated during night-time surface trawls in the Columbia River plume, they may occur near the surface at natal river mouths and estuaries (Litz et al. 2013). Larval eulachon may also be distributed by prevailing currents in the action area, but would be most concentrated near natal river mouths and estuaries.

The PBFs for southern DPS eulachon critical habitat that may occur within the action area include:

- Freshwater spawning and incubation sites with water flow, quality and temperature conditions and substrate supporting spawning and incubation.
- Freshwater and estuarine migration corridors free of obstruction with water flow, quality and temperature conditions supporting larval and adult mobility, and with abundant prey items supporting larval feeding after the yolk sac is depleted.

Within the action area, critical habitat for southern DPS eulachon is only designated within the Elwha River. Because of the distance of the Elwha River from the closest commercial net pen facility (approximately 50 miles), we anticipate that any potential effects would be a result of escaped rainbow trout/steelhead entering the Elwha River. We do not expect any water or sediment quality effects of commercial net pen operations in the Elwha River or near the river mouth in the SJDF. Because of the distance from commercial net pen facilities, we would expect only a very small number of escaped fish, if any, to enter the Elwha River, and thus we do not expect any measureable effect on eulachon forage from competition for resources.

Because there are no natal streams in close proximity to the PS commercial net pens, the occurrence of eulachon, either adult or juvenile, near the net pens is unlikely. Given their depth preference in marine waters, and the distance of their closest natal stream (Elwha River) from PS commercial net pen sites, we do not expect any measurable effect of net pen facilities or operations on forage availability. Likewise, because of the distance of the Elwha River from PS commercial net pens and eulachon preference for waters deeper than where the net pens are located, we consider exposure to localized degraded sediment or water quality conditions to be unlikely. We also do not expect water quality to be degraded to such a degree that any eulachon that do encounter net pens would be harmed. This is particularly true given their mobility and likely brief exposure to net pens that are located in shallower waters than where they typically occur. Therefore, we do not anticipate any adverse effects to the southern DPS of eulachon or their designated critical habitat and consider effects to be discountable.

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

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," and includes the physical, biological, and chemical properties that are used by fish (50 CFR 600.10). 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. Such recommendations may include measures to avoid, minimize, mitigate, or otherwise offset the adverse effects of the action on EFH [CFR 600.905(b)]

This analysis is based, in part, on the EFH assessment provided by the EPA and descriptions of EFH for Pacific Coast groundfish (Pacific Fishery Management Council [PFMC] 2005), coastal pelagic species (CPS) (PFMC 1998), and Pacific Coast salmon (PFMC 2014) contained in the fishery management plans developed by the PFMC and approved by the Secretary of Commerce.

3.1 Essential Fish Habitat Affected by the Project

The environmental effects of the proposed action may adversely affect EFH for Pacific Coast salmon, Pacific Coast groundfish and coastal pelagic species EFH, all of which are present in the action area. The action area also contains Habitat Areas of Particular Concern (HAPC) for Pacific Coast salmon in marine and freshwater portions of the action area, and for Pacific Coast groundfish in marine areas. Impacts to EFH include benthic disturbance by structures, sediment quality degradation by bio-deposits and contaminants, and water quality degradation by bio-deposits, contamination and turbidity.

3.2 Adverse Effects on Essential Fish Habitat

The features of EFH of Pacific Coast salmon, Pacific Coast groundfish and coastal pelagic species would include diminishments in water quality, sediment quality, forage, and kelp which is a vegetation that serves as cover. These effects would occur within PS to varying degrees. Additional effects to EFH could occur in freshwater for Pacific Coast Salmonids, with disruption of spawning areas. These adverse effects are associated with the habitat impacts of net pen structures (from future net pen structural failures) and operations for the commercial rearing of finfish in the PS.

As a result of a large-scale net pen structural failure [defined as the escape and loss (i.e. not recaptured/recovered) of more than 29% of the maximum production number of fish at that site] we anticipate the following habitat effects:

- Temporary reduction in forage resulting from disturbance of the benthos by the movement and deposition of net pen debris, and clean-up and recovery activities;
- Temporary reduction in cover resulting from damage or displacement of subtidal macroalgae by the movement and deposition of net pen debris, and clean-up and recovery activities; and
- Temporary reduced forage for adult and juvenile PS Chinook salmon, HCSRC and PS steelhead from competition with escaped farmed fish.

As a result of PS commercial net pen operations, we anticipate the following habitat effects:

- Reductions in forage production from sediment quality degradation occurring as a result of bio-deposits and contaminants; and
- Degraded water quality from bio-deposits, contaminants and turbidity.

3.3 Essential Fish Habitat Conservation Recommendations

To avoid and minimize the adverse effects to EFH described above, we recommend the following conservation measures:

1) To address the uncertainty around hydrodynamics and pathogen spread specifically in PS and the SJDF, we recommend that the EPA work with state agencies to implement the following:
   a. Develop a study plan to better understand the role of net pen site hydrodynamics as they relate to pathogen spread. This information should be considered for any future net pen facility siting. Because the Rich Passage sites are the closest together, looking for correlations in infection/disease occurrence could be useful for narrowing the initial scope of a study. We recommend that results be reported to NMFS.
   b. Document and maintain thorough pathogen infection and disease outbreak records and communication, as well as records of treatment frequency and treatment effectiveness for farm operations. This would be immensely helpful in tracking if similar increased disease severity and mortality trends are occurring in the net pens that are the focus of the proposed action. The WDFW has already identified the need for Cooke to report this information. We recommend that all records be shared with NMFS.

2) Compile all publically available PS commercial net pen facility maintenance and inspection reports; fish stocking, mortality and harvest reports; and sediment and water quality monitoring reports. We recommend that all records be shared with NMFS.
3) Based on the information collected through the implementation of conservation measures 1 and 2 above, work with state agencies and NMFS to develop new or modified BMPs that further reduce adverse habitat effects of PS commercial net pen structures and operations.

Fully implementing these EFH conservation recommendations would protect, by avoiding or minimizing the adverse effects described in section 3.2, above, designated EFH for Pacific Coast salmon, Pacific Coast groundfish and coastal pelagic species under and in areas adjacent to commercial finfish rearing net pen facilities in the PS.

Statutory Response Requirement

As required by section 305(b)(4)(B) of the MSA, the EPA must provide a detailed response in writing to NMFS within 30 days after receiving an EFH Conservation Recommendation. Such a response must be provided at least 10 days prior to final approval of the action if the response is inconsistent with any of NMFS' EFH Conservation Recommendations unless NMFS and the federal agency have agreed to use alternative time frames for the federal agency response. The response must include a description of measures proposed by the agency for avoiding, minimizing, mitigating, or otherwise offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with the Conservation Recommendations, the federal agency must explain its reasons for not following the recommendations, including the scientific justification for any disagreements with NMFS over the anticipated effects of the action and the measures needed to avoid, minimize, mitigate, or offset such effects (50 CFR 600.920(k)(1)).

In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, NMFS established a quarterly reporting requirement to determine how many conservation recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, we ask that in your statutory reply to the EFH portion of this consultation, you clearly identify the number of conservation recommendations accepted.

3.4 Supplemental Consultation

The EPA 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 EPA and NMFS. Other interested users could include permit or license applicants, citizens of affected areas, and others interested in the conservation of the affected ESUs/DPSs. Individual copies of this opinion were provided to the EPA. The document will be available within two weeks at the

NOAA Library Institutional Repository [https://repository.library.noaa.gov/welcome]. The format and naming adheres to conventional standards for style.

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 opinion and EFH consultation 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 MSA implementation, and reviewed in accordance with West Coast Region ESA quality control and assurance processes.

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