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

National Marine Fisheries Service (NMFS) Evaluation of Twelve Hatchery and Genetic Management Plans for Nooksack River basin and Georgia Strait Salmon under Limit 6 of the Endangered Species Act Section 4(d) Rule

NMFS Consultation Number: WCR-2024-00669

Action Agencies: National Marine Fisheries Service
U.S. Fish & Wildlife Service
U.S. Bureau of Indian Affairs
Army Corps of Engineers

Affected Species and Determinations:

ESA-Listed Species	Status	Is Action Likely to Adversely Affect Species?	Is Action Likely to Jeopardize the Species?	Is Action Likely to Adversely Affect Critical Habitat?	Is Action Likely to Destroy or Adversely Modify Critical Habitat?
Puget Sound Chinook salmon (*Oncorhynchus tshawytscha*)	Threatened	Yes	No	Yes	No
Puget Sound steelhead (*Oncorhynchus mykiss*)	Threatened	Yes	No	Yes	No
Hood Canal Summer-run chum salmon (*Oncorhynchus keta*)	Threatened	No	No	No	No
Lake Ozette sockeye salmon (*Oncorhynchus nerka*)	Threatened	No	No	No	No
Lower Columbia River Chinook Salmon (*Oncorhynchus tshawytscha*)	Threatened	No	No	No	No

Snake River Fall-run Chinook Salmon (*O. tshawytscha*)	Threatened	No	No	No	No
Upper Willamette River Chinook Salmon (*O. tshawytscha*)	Threatened	No	No	No	No
Upper Columbia River spring-run Chinook Salmon (*O. tshawytscha*)	Endangered	No	No	No	No
Snake River spring/summer-run Chinook Salmon (*O. tshawytscha*)	Threatened	No	No	No	No
Lower Columbia River Coho Salmon (*O. kisutch*)	Threatened	No	No	No	No
Columbia River Chum Salmon (*Oncorhynchus keta*)	Threatened	No	No	No	No
Snake River Sockeye Salmon (*Oncorhynchus nerka*)	Endangered	No	No	No	No
Upper Columbia River steelhead (*O. mykiss*)	Threatened	No	No	No	No
Snake River Basin steelhead (*O. mykiss*)	Threatened	No	No	No	No
Middle Columbia River steelhead (*O. mykiss*)	Threatened	No	No	No	No
Upper Willamette River steelhead (*O. mykiss*)	Threatened	No	No	No	No
Lower Columbia River steelhead (*O. mykiss*)	Threatened	No	No	No	No

Fishery Management Plan That Describes EFH in the Project Area	**Does the Action Have an Adverse Effect on EFH?**	**Are EFH Conservation Recommendations Provided?**
Pacific Coast Salmon	Yes	Yes

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

Issued By:

Ryan J. Wulff
Assistant Regional Administrator for Sustainable Fisheries

Date: March 7, 2025

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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 U.S.C. 1531 et seq.), as amended, and implementing regulations at 50 CFR part 402.

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 part 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 2 weeks at the NOAA Library Institutional Repository [https://repository.library.noaa.gov/welcome]. A complete record of this consultation is on file at Lacey, WA.

1.2. Consultation History

Among the Puget Sound region Hatchery and Genetic Management Plans (HGMPs) that have been submitted for NMFS consideration under the ESA 4(d) rule for threatened salmon and steelhead are twelve plans developed by the Lummi Nation, Nooksack Indian Tribe, and Washington Department of Fish and Wildlife (WDFW) describing hatchery programs for Chinook salmon, coho salmon, and chum salmon in the Nooksack River Basin, Samish River, Whatcom Creek, and Orcas Island. The co-managers had previously submitted ten HGMPs for review under 4(d) rule, limit 6 on January 25, 2016, describing programs for Chinook, coho, and chum salmon that would release juvenile fish from hatcheries located in the Nooksack River basin, Samish River, and Whatcom Creek (WDFW 2014c; 2014a; LN 2015a; 2015c; 2015b; Lummi Nation 2015b; 2015a; WDFW 2015). NMFS had also received two HGMPs describing hatchery programs releasing Chinook (LLTK 2017) and coho salmon from Glenwood Springs Hatchery operating on Orcas Island. The Glenwood Springs Hatchery coho salmon program was subsequently terminated and the HGMP retracted (Jones 2016). Although NMFS issued a sufficiency letter for the eleven HGMPs submitted on January 25, 2016, and the Glenwood Springs Hatchery Chinook program, on February 10, 2016 (Jones 2016), the co-managers determined these programs operating as described in the HGMPs were not adequate for meeting shared watershed and fishery objectives and requested consultation pause while the programs were re-evaluated and new HGMPs were drafted (Jefferson Sr. et al. 2021). NMFS then received twelve HGMPs with a request to process them under limit 6 of the 4(d) rule as a joint co-manager plan on September 3, 2021 (Jefferson Sr. et al. 2021). This Opinion is based on information provided in these twelve HGMPs as well as information provided by the co-managers as the actions proposed in the HGMPs were analyzed.

Updates to the regulations governing interagency consultation (50 CFR part 402) were effective on May 6, 2024 (89 Fed. Reg. 24268). We are applying the updated regulations to this consultation. The 2024 regulatory changes, like those from 2019, were intended to improve and clarify the consultation process, and, with one exception from 2024 (offsetting reasonable and prudent measures), were not intended to result in changes to the Services' existing practice in implementing Section 7(a)(2) of the Act. 89 Fed. Reg. at 24268; 84 Fed. Reg. at 45015. We have considered the prior rules and affirm that the substantive analysis and conclusions articulated in this Opinion and incidental take statement would not have been any different under the 2019 regulations or pre-2019 regulations.

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).

The Proposed Actions are: (1) the National Marine Fisheries Service's (NMFS) determination under limit 6 of the ESA 4(d) rules for Puget Sound Chinook salmon and Puget Sound steelhead (50 CFR § 223.203(b)(6)) concerning the Lummi Nation, Nooksack Indian Tribe, and the Washington Department of Fish and Wildlife (WDFW) hatchery programs in the Nooksack River basin, the Samish River, Whatcom Creek, and Orcas Island; (2) the Bureau of Indian Affairs' (BIA) and US Fish and Wildlife Service (USFWS) ongoing disbursement of funds for salmon hatchery programs listed in Table 1. Pursuant to the letter received by NMFS from the BIA, NMFS is the designated lead agency for the conduct of this consultation (Speaks 2013); and (3) the Army Corps of Engineers (ACOE) is proposing to permit under Section 404 of the Clean Water Act (CWA) conducting improvements at the Skookum Creek fish hatchery owned and operated by the Lummi Nation. Collectively, NMFS, ACOE, USFWS, and the BIA are the "Action Agencies."

The act of funding various hatchery activities does not have an immediate direct effect on listed salmonids beyond the operation of the programs themselves. NMFS finds that the indirect effects of Federal funding are coextensive with the proposed implementation of the HGMPs. The indirect effects from funding are evaluated and considered below in the context of NMFS' overall determination under Limit 6 of the ESA 4(d) rule (50 CFR § 223.203(b)(6)).

NMFS describes a hatchery program as a group of fish that have a separate purpose and that may have independent spawning, rearing, marking and release strategies (NMFS 2008d). The operation and management of every hatchery program is unique in time and specific to an identifiable stock and its native habitat (Berejikian et al. 2004). In this specific case, the proposed hatchery salmon programs described in the co-manager HGMPs were determined to be sufficient for formal consultation. Three of the hatchery programs release ESA-listed Chinook salmon, three of the hatchery programs release fall Chinook salmon that are not included in the Puget Sound Chinook salmon Evolutionarily Significant Unit (ESU), and the other six propagate non-ESA listed coho and chum salmon into, or in the immediate vicinity of, the Nooksack River basin, Samish River, Whatcom Creek, and Orcas Island. All of the programs are currently operating. Three Chinook, all three coho, and all three chum salmon programs raise fish native or naturalized to the Nooksack River basin or nearby independent creeks. The fall Chinook salmon propagated at Samish, Whatcom, and Glenwood Springs hatcheries originated from transfers of Green River stocks. Adult Chinook salmon produced by these three programs are not intended to spawn naturally and are not intended to establish, supplement, or support any Chinook salmon populations occurring in the natural environment.

The operators describe the primary purpose of these hatchery programs as helping to meet adult fish loss mitigation responsibilities, off-setting adverse impacts to natural-origin salmon abundances that historically sustained Tribal, commercial, and recreational fisheries. In meeting this purpose, the hatchery programs would be implemented applying actions designed to minimize risks of adverse effects on listed fish species. Key premises of the programs are that habitat that once sustained abundant natural salmon populations has been lost and degraded by past and on-going human activities in the Nooksack River basin, and natural salmon and their habitat are further threatened by climate change. The goals for the twelve programs are therefore to provide Chinook, coho, and chum salmon for harvest to support regional fisheries, including Treaty-reserved fishing rights recognized by the Federal courts, meet Pacific Salmon Treaty harvest sharing agreements with Canada, and provide prey to ESA-listed Southern Resident Killer Whales. The Skookum Creek (Lummi Nation 2024d) and Kendall Creek (WDFW 2024c) Hatchery Chinook salmon programs are conservation programs that will assist in rebuilding the depleted South Fork (SF) Nooksack and North Fork/Middle Fork (NF) Nooksack salmon populations to harvestable levels. All of the programs would implement salmon population monitoring activities in marine and freshwater areas that are important for tracking the status of ESA-listed fish populations and the effects of the hatchery programs.

The Lummi Nation, Nooksack Indian Tribe, and WDFW, as co-managers, propose to operate twelve hatchery programs that release Chinook, coho, and chum salmon into the Nooksack River basin, Samish River, Whatcom Creek, and from Orcas Island (Table 1). As described in Section 1.8 of each HGMP (Lummi Nation 2024c; 2024d; 2024b; 2024a; 2024e; WDFW 2024b; 2024a; 2024c; 2024e; 2024d; 2024f; WDFW and Lummi Nation 2024), all of the hatchery programs are operated for conservation of the species they respectively release and harvest augmentation purposes.

Chinook salmon propagated through two of these hatchery programs, the Kendall Creek (WDFW 2024c) and Skookum Creek (Lummi Nation 2024d) Chinook salmon programs, are included as part of the ESA-listed Puget Sound Chinook salmon ESU (NMFS 2016c). “Hatchery programs with a level of genetic divergence relative to the local natural population(s) that is no more than what occurs within the ESU are considered part of the ESU and will be included in any listing of the ESU” (NMFS 2005d). For a detailed description of how NMFS evaluates and determines whether to include hatchery fish in an ESU or Distinct Population Segment (DPS), see NMFS (2005d). NMFS considers the Chinook salmon from these hatchery programs to be integrated[1] because they are derived from the ESA-listed natural NF and SF populations that are native to the Nooksack River basin, contain genetic resources that represent the ecological and genetic diversity of the Nooksack Chinook salmon populations, and because the hatchery programs incorporate natural-origin fish for hatchery broodstock. Chinook salmon propagated at

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[1] These terms are defined in Section 2.5.1.

Lummi Bay Hatchery originate from transfers of NF Nooksack Chinook salmon reared at Kendall Creek Hatchery. The Lummi Bay Chinook salmon program is intended to operate as a genetically linked stepping stone program–where hatchery-origin fish returning from an integrated program are used as broodstock for a second program so the two programs are in genetic equilibrium–to the Kendall Creek Hatchery Chinook salmon program as it uses hatchery origin adults from this program as broodstock.

The fall Chinook salmon propagated at Samish Hatchery originated from transfers of Green River stock (WDFW 2024a) and are not considered part of the Puget Sound ESU. Fall Chinook salmon released from Whatcom Creek Hatchery are of Samish Hatchery origin and may be transferred as eggs or juveniles from Samish Hatchery (WDFW 2024a). The fall Chinook salmon propagated at Glenwood Springs Hatchery also originated from transfers of the stock reared at Samish Hatchery (WDFW 2024d). NMFS considers these programs to be segregated[1] as natural-origin fish are not collected nor incorporated as broodstock and Chinook salmon reared by these three hatchery programs are not included as part of the ESA-listed Puget Sound Chinook salmon ESU.

Coho and chum salmon in Puget Sound, including the coho and chum salmon from the hatchery programs considered in this Opinion, are not listed under the ESA. NMFS considers the coho salmon from the Skookum Creek (Lummi Nation 2024c) and Kendall Creek (WDFW 2024e) hatchery programs, derived from stocks native to the Nooksack River basin, to be integrated[1] with the natural populations of coho salmon in the Nooksack basin because natural-origin fish are incorporated as broodstock to maintain genetic equilibrium between the natural and hatchery population components. NMFS also considers the Kendall Creek Hatchery chum program (WDFW and Lummi Nation 2024), also derived from the stock native to the Nooksack basin, to be integrated[1] with the natural population of chum salmon in the Nooksack basin because natural-origin fish are incorporated as broodstock to maintain genetic equilibrium between the natural and hatchery populations. Lummi Bay coho salmon program (Lummi Nation 2024b) rears fish derived from stock native to the Nooksack basin, but natural-origin fish are not incorporated as broodstock so NMFS considers this to be a segregated[1] program. NMFS considers the Lummi Bay and Whatcom Creek hatchery chum programs to be segregated because, although they rear fish derived from stock native to the Nooksack basin, natural-origin fish are not intentionally incorporated as broodstock, however, these programs may be re-founded using natural-origin chum salmon and would incorporate natural-origin adults until the new stocks become self-sustaining.

Table 1. Hatchery programs associated with the Proposed Action, including program operator and primary funding agency. NMFS=National Marine Fisheries Service, BIA = Bureau of Indian Affairs, WSFR = Wildlife and Sport Fish Restoration-Dingle Johnson, LLTK= Long Live the Kings, DNR= Department of Natural Resources.

Hatchery and Genetics Management Plan (HGMP)	Program Operator	Funding Agency*
Skookum Creek Hatchery Chinook Salmon Program	Lummi Nation	Lummi Nation, NMFS, BIA
Kendall Creek North/Middle Fork Nooksack Native Spring Chinook Salmon Restoration Hatchery Program	WDFW	NMFS, WA DNR, WDFW, WSFR, BIA
Lummi Bay Hatchery Chinook Salmon	Lummi Nation	Lummi Nation, BIA
Samish Fall Chinook Salmon Hatchery Program	WDFW	WSFR, WDFW
Whatcom Creek Hatchery Fall Chinook Salmon Program	BTC	BTC, WDFW, Lummi Nation, BIA
Glenwood Springs Hatchery Fall Chinook Salmon Program	LLTK	WDFW, LLTK
Skookum Creek Hatchery Coho Salmon Program	Lummi Nation	Lummi Nation, BIA
Kendall Creek Hatchery Coho Salmon Program	WDFW	WDFW, WSFR, BIA
Lummi Bay Hatchery Coho Salmon Program	Lummi Nation	Lummi Nation, BIA
Kendall Creek Hatchery Nooksack Fall Chum Salmon Program	WDFW	WDFW, WSFR, Lummi Nation, BIA
Lummi Bay Hatchery Chum Salmon Program	Lummi Nation	Lummi Nation, BIA
Whatcom Creek Hatchery Chum Salmon Program	BTC	BTC, WDFW, Lummi Nation, WSFR, BIA

Finally, the Proposed Action includes funding by the USFWS provided to WDFW through its Sportfish Restoration Act grants program and funding BIA provides to support tribal fisheries. USFWS provides grants to WDFW for hatchery facility operations, which include at least a portion of the funding for operation of the Kendall Creek, Samish, and Whatcom Creek hatchery programs. Because the funding of the programs under consideration does not result in any actions or effects not already under consideration as part of NMFS' review of the programs themselves, this Opinion will not separately discuss the funding action other than to note its inclusion in the consultation. USFWS has no other active role in the Proposed Action. The Proposed Action also included ACOE permit for construction to upgrade the intake structure at Skookum Creek Hatchery.

In determining whether there are other activities that are caused by the proposed action and should be considered in this consultation, NMFS has considered whether fisheries impacting

Nooksack River basin, Whatcom Creek, Samish River, or Orcas Island hatchery program-origin salmon are caused by the Proposed Action.

Tribal commercial, ceremonial and subsistence, and non-Tribal recreational and commercial fisheries target salmon produced by the proposed hatchery programs and commingled natural-origin salmon. These fisheries are managed by the WDFW, Lummi Nation, and the Nooksack Tribe and occur within the Nooksack River, Samish River, and Whatcom Creek watersheds as well as within Puget Sound terminal area marine waters of Bellingham Bay, Samish Bay, Lummi Bay, and the southern Strait of Georgia. The proposed hatchery salmon programs analyzed in this Opinion also contribute to pre-terminal fisheries outside of these watersheds. Fisheries to which these hatchery programs contribute fish support the tribal Treaty-reserved fishing rights recognized by the Federal courts, support harvest sharing agreements between Tribal and non-Tribal fisheries and function as the marked stock group used for management as in indicator stock in the PST salmon harvest agreement with Canada. Fisheries outside Bellingham Bay, and the Nooksack, Samish, and Whatcom River are not directed at salmon produced by the twelve salmon hatchery programs. Those salmon-directed fisheries would occur regardless of whether the Proposed Action continues, and are therefore not caused by the Proposed Action. Therefore, only those fisheries for salmon in Bellingham Bay, the Nooksack, Samish, and Whatcom River basins are caused by the Proposed Action.

The fishing seasons and regulations developed by the Tribes and State of Washington specifically to harvest salmon produced by the programs have previously been reviewed under the ESA, and NMFS' has exempted 'take' from those fisheries, e.g., (NMFS 2023; 2024b). Fisheries existing outside of the terminal tributary areas, those in Puget Sound and the Pacific Ocean, have previously been evaluated in Biological Opinions (NMFS 2005a; 2024b). The effects of these fisheries are described and incorporated in the environmental baseline section (Section 2.4).

1.4. Proposed Action for Nooksack-Samish salmon hatchery programs

The facilities discussed in this Opinion will be collectively referred to as operating in the "Nooksack-Samish River basins" although some facilities are located outside this area. Within the Nooksack River basin, the Skookum Creek Hatchery is located at RM 14.3 of the South Fork Nooksack River and Kendall Creek Hatchery is located on Kendall Creek, a tributary to the NF Nooksack River at RM 46. Lummi Bay Hatchery is located in Lummi Bay and releases salmon into the nearshore marine waters of Lummi Bay located in the southern Strait of Georgia. Within the Samish River basin, Samish Hatchery is located at River Mile (RM) 1 of Friday Creek, a tributary to the Samish River at RM 10.5. Outside of the Nooksack-Samish River basins, Whatcom Creek Hatchery is located at RM 0.5 of Whatcom Creek which flows directly into Bellingham Bay. Glenwood Springs Hatchery is located on the eastern shore of Eastsound on Orcas Island and releases Chinook salmon into the marine waters surrounding the San Juan Islands.

1.4.1. Proposed salmon hatchery broodstock collection and mating protocol

Nine of the proposed hatchery programs collect adult salmon for broodstock at their respective facility on-station. Lummi Bay Chinook and coho salmon programs and the Whatcom Creek

Chinook program receive fertilized eggs or juveniles from broodstock collections conducted at other facilities within the Nooksack-Samish River basin. A description of broodstock collection activities for all programs is provided in Table 2.

Table 2. Description of Nooksack-Samish Chinook salmon broodstock collection and mating protocols[*].

Program	Collection Location	Collection Duration	Collection Method	Adults Collected	Broodstock Needed	Mating Protocol	Natural Origin Broodstock	Egg Take Goal
Skookum Creek Hatchery Chinook Salmon Program	Skookum Creek Hatchery	July-October	Volunteers to Hatchery Pond	10,000	1,000	1 X 1 Crosses	Sliding scale/Up to 700	2,200,000
North/Middle Fork Nooksack Native Spring Chinook Salmon Restoration Program	Kendall Creek Hatchery	May-Sept 7	Volunteers to Hatchery Trap	10,000	2,166 (1,140 for Lummi Bay)	5 X 5 Matrix	Escapement dependent	5,400,000
Samish River Hatchery Fall Chinook Salmon	Samish River Hatchery	September-October	Volunteers to Hatchery Weir and Trap	30,000	4,320 adults (300 for Whatcom)	5 X 5 Matrix	None, Segregated program	7,000,000 + 600,000 for Whatcom
Glenwood Springs Hatchery Fall Chinook Salmon	Glenwood Springs Hatchery, Orcas Island	September-October	Volunteers to Hatchery Ladder	2,200	600	4 X 4 Matrix	None, Segregated program	1,000,000
Skookum Creek Hatchery Coho Salmon Program	Skookum Creek Hatchery	September-December	Volunteers to Hatchery Pond	30,000	4,800	10 X 10 Matrix w/ pooled eggs	As many as volunteer	1,300,000 + 2,300,000 for Lummi Bay
Kendall Creek Hatchery Coho Salmon Program	Kendall Creek Hatchery	October-January	Volunteers to Hatchery Trap	15,000	550	5 X 5 Matrix w/ pooled eggs	10% minimum escapement dependent	575,000
Kendall Creek Hatchery Nooksack Fall Chum Salmon Program	Kendall Creek Hatchery	November - January	Volunteers to Hatchery Trap, In-River with weir and seine	30,000	4,500	5 X 5 Matrix w/ pooled eggs	Escapement dependent	6,000,000
Lummi Bay Hatchery Chum Salmon Program	Lummi Bay Hatchery	October-November	Volunteers to Hatcheries	30,000	8,800	10 X 10 Matrix w/ pooled eggs	None, Segregated program	12,000,000
Whatcom Creek Hatchery Chum Salmon Program	Whatcom Creek Hatchery	October 1-December 15	Volunteers to Hatchery	30,000	4,400	Matrix spawning	None, Segregated program	2,600,000

[*] Broodstock are not collected as part of Lummi Bay Chinook and coho salmon programs or the Whatcom Creek Chinook program. These programs receive fertilized eggs or juveniles from broodstock collections conducted at Kendall Creek and Samish Hatcheries, respectively.

To ensure that collection of adult natural-origin SF Chinook salmon as broodstock will not result in negative demographic effects to the natural-origin population, the Skookum Creek Hatchery Chinook salmon program will use a sliding scale to determine broodstock integration rates based on the estimated in-season abundance of natural-origin spawners in the SF Nooksack as shown in Table 3. If the abundance of natural-origin SF Chinook salmon is projected to exceed the critical escapement threshold of 200 natural spawners (Table 11), the integration of natural-origin broodstock may occur. However, natural-origin adults will not be collected for brood if there is a possibility of reducing natural-origin abundance to a level that results in the critical escapement threshold not being met. Returning hatchery-origin adults are selected for broodstock if they are marked with a coded-wire tag (CWT) and the adipose fin is intact. The SF Nooksack River hatchery Chinook salmon program has recently been the only program releasing CWT-only juveniles in the Nooksack River and selecting these as broodstock minimizes the risk of inadvertent incorporation of NF Nooksack River Chinook salmon or out-of-basin Chinook salmon adults into the program. As brood and egg collection targets continue to be reached, the reliance on CWTs will likely gradually decrease as the primary method to identify returning adults and a transition to identification using adipose marks, potentially in conjunction with thermal marks, will occur. All hatchery-origin SF Chinook salmon will be thermally otolith marked as an additional method of confirming stock and origin identity when necessary.

SF Nooksack adults may escape to the NF Nooksack and Kendall Creek Hatchery during years when low flows or other adverse environmental conditions result in unfavorable habitat conditions in the SF Nooksack River. Adult Skookum Creek hatchery Chinook salmon escaping to the NF or Middle Fork (MF) Nooksack Rivers can be accurately identified due to the migration and spawn timing differences between NF and SF Chinook salmon, as well as differences between the markings the programs use for identification (adipose clips, otoliths, and CWTs). Adult Skookum Creek hatchery Chinook salmon escaping to Kendall Creek Hatchery may be collected and transferred to Skookum Creek Hatchery for use as broodstock. If adverse environmental conditions threaten the survival of returning adult Nooksack Chinook salmon, co-managers may collect adults from the SF Nooksack River and bring them into the hatchery as well as move adults not needed for broodstock to better upstream habitats.

Adult Chinook salmon may be collected from the SF Nooksack River if escapement to Skookum Creek Hatchery is projected to be insufficient to produce at least 500,000 eggs. In-river collection will only occur under these circumstances if sufficient adults are observed in the river to support the collection effort. The ancestry of adult Chinook salmon will be confirmed using genetic methods or by examining marks and tags before being used as broodstock. In the event that poor marine survival, degraded environmental conditions, or other unforeseen circumstances that may compromise the program result in insufficient adult returns to support the Skookum Creek program, juvenile Chinook salmon will be collected from the SF Nooksack River and used to reinitiate the captive broodstock program. The ancestry of juveniles retained for captive broodstock will be confirmed using genetic methods.

Table 3. Sliding scale of natural-origin broodstock integration for the Skookum Creek and Kendall Hatchery Chinook salmon programs based on estimated abundance of natural-origin Chinook salmon.

Estimated Natural-Origin Spawner Abundance	Percentage of Natural-Origin Adult Broodstock	Maximum Number of Natural-Origin Broodstock Removed	Resulting Natural-Origin Escapement
0–249	NA	5	45
250–300	≤ 20%	50	200
301–499	≤ 25%	125	240
500–649	≤30%	195	350
650–800	≤ 35%	280	422
801–1800	≤40%	720	481

Up to 2,166 adult NF Nooksack Chinook salmon will be collected annually at Kendall Creek hatchery to meet the current release goals (Table 2). Adult Chinook salmon collected at Kendall Creek hatchery produce eyed eggs and juveniles provided to the Lummi Bay Spring Chinook hatchery program. Although natural-origin NF Nooksack spring Chinook salmon are retained for broodstock, low numbers of natural-origin NF spring Chinook have returned to the hatchery. On average over the most recent three years (2021–2023), 3.11% of adults spawned were natural-origin. Fish not needed for hatchery broodstock are returned quickly and safely to the river. Broodstock may be collected in-river if natural escapement increases to the point natural-origin recruits (NORs) can be removed without impacting the population (Table 3). Fall Chinook salmon are not currently released in the Nooksack watershed. However, as a precautionary measure, a cut-off date of September 16 for broodstock collection at Kendall Creek Hatchery avoids the inadvertent inclusion of Fall Chinook salmon in the broodstock.

Adult Chinook salmon collected at Samish Hatchery are used to produce the juveniles released on-station, as well as the juvenile Chinook salmon released for the Whatcom Creek Hatchery Chinook salmon program. Program adults returning to the Whatcom Creek Hatchery may be used for broodstock if needed due to shortfalls of adults returning to other facilities propagating fall Chinook salmon including Samish and Glenwood Springs Hatcheries. Since 2012, all eggs collected at Samish Hatchery are transported, fertilized, incubated to the eyed stage at Kendall Creek Hatchery as pathogen-free well water is available year-round at constant temperature of 47°F. A portion or all eggs may be fertilized and incubated at Samish Hatchery. Unclipped adult Chinook salmon, steelhead, and all non-target salmon species volunteering to Samish Hatchery are passed up above the weir.

The Glenwood Springs fall Chinook salmon program was initiated with fall Chinook salmon collected at Samish and Kendall Creek hatcheries. The program now relies on returning hatchery-origin adults for broodstock on-site. When needed, additional eggs will also be collected for Glenwood Springs Hatchery fall Chinook program and other facilities requiring fall Chinook salmon egg supplementation. In years when Chinook salmon do not return to Glenwood Springs Hatchery in sufficient numbers, adult Chinook salmon may be seined from the nearby terminal marine area waters. This method has not been used to date, rather, egg transfers have been used to supplement shortages. In the event of broodstock shortfalls, eggs may be provided from Samish Hatchery or other appropriate stocks as agreed to by the co-managers. As the San Juan Islands do not have suitable Chinook salmon spawning habitat, natural-origin fish are not expected to volunteer to Glenwood Springs hatchery. However, any unmarked Chinook salmon that are encountered will be returned to the nearby saltwater as soon as possible.

Adult Chinook salmon will not be collected for broodstock at Lummi Bay Hatchery. The 570 adult pairs of Chinook salmon required for this program will be collected at Kendall Creek Hatchery on an annual basis in addition to the Kendall Creek Hatchery spring Chinook program's broodstock collection requirements. Current adult returns of hatchery Chinook salmon to the Kendall Creek Hatchery limit the Lummi Nation's ability to secure enough broodstock to reach the juvenile release target. However, it is anticipated that as the program matures, additional adults will be returning to the hatchery and broodstock and juvenile release goals are more likely to be met. Until the number of adults returning to Kendall Creek Hatchery increases, a minimum of 165 pairs of adult spring Chinook are required to meet the minimum release goal of 500,000 sub-yearling smolts from Lummi Bay Hatchery. The Lummi Bay Chinook hatchery program is a genetically linked stepping stone program with broodstock originating from the integrated Kendall Creek Hatchery broodstock. Natural-origin Chinook salmon volunteering to Kendall Creek Hatchery will not be prioritized as broodstock for juveniles destined for the Lummi Bay program. Hatchery-origin Chinook salmon captured at Lummi Bay hatchery may be provided to the Lummi community.

A minimum of 2,400 female and 2,400 male coho salmon will be collected at Skookum Creek Hatchery to produce 3.6 million unfertilized eggs annually for the Lummi Bay Hatchery coho salmon program, the Skookum Creek Hatchery coho salmon program, and the Skookum coho salmon research program. Skookum Creek and Lummi Bay coho salmon programs rely mostly on hatchery-origin fish for broodstock. However, natural-origin fish that recruit to the brood pond at Skookum Creek Hatchery will be included in the program and have comprised 1–5% of the brood spawned in past collection years. In an effort to maintain effective population size and minimize any genetic divergence between brood years, up to 10% of the males selected for brood will be comprised of age-2 jacks. If needed, natural-origin coho salmon broodstock will be collected in-river using weirs or seines. In-river collection is not expected to result in any take of ESA-listed Chinook or steelhead as coho salmon brood collection will occur after all adult Chinook salmon have finished spawning (approximately October 31) and before the earliest returning adult winter steelhead are known to enter the South Fork Nooksack River (approximately February 1). In-river brood collection will not occur in the South Fork Nooksack River mainstem where summer steelhead adults are typically expected to be encountered (i.e. above RM 25.0) and will not occur in South Fork Nooksack River tributaries that adult summer steelhead are anticipated to occupy. Coho salmon broodstock will be collected in the mainstem SF from river mile 0.0 to 25.0 using hook-and-line or by using weirs or seine nets in key tributaries. These tributaries include Edfro, Cavanaugh, Fobes, Plumbago, Deer, and Roaring Creek and unnamed tributaries at river mile 20.3, 21.3, and 22.2. Regardless of location or capture method, broodstocking efforts will occur between November 1 and January 31. In the event summer steelhead are encountered during in-river broodstock collection, encounters will be documented and broodstock efforts will be relocated to an area where adult steelhead are not expected to be encountered. The first coho salmon egg takes at Skookum Creek Hatchery will be designated for the Lummi Bay program to reduce a gradual shift towards earlier spawn time.

Natural-origin coho salmon adults displaying a relatively later spawn time may be captured from the SF Nooksack and/or SF Nooksack tributaries using weirs, seine nets, or hook and line.

Coho salmon collected in excess of the Kendall Creek Hatchery's broodstock needs, regardless of origin, will be passed upstream of the Kendall Creek Hatchery weir to spawn naturally. To maintain the natural population's run timing, hatchery-origin fish will not be passed upstream or used for broodstock until natural-origin fish begin returning to the hatchery. Hatchery-origin fish returning before the natural run is present may be surplused if sufficient numbers of broodstock are available. The broodstock selection timing will be flexible and may vary from year to year to resemble natural run timing.

Gametes or eyed eggs for the Lummi Bay chum salmon program are provided by the Kendall Creek Hatchery or Whatcom Creek Hatchery programs. As sufficient numbers of adults return to Lummi Bay Hatchery, the program will transition to capturing a majority of required broodstock at Lummi Bay Hatchery. However, it is anticipated that obtaining gametes or eyed eggs for the Lummi Bay Hatchery program from Kendall Creek Hatchery and/or Whatcom Creek Hatchery will be a long-term requirement to ensure that the program continually meets the release goal. Broodstock collected from Lummi Bay Hatchery and Whatcom Creek Hatchery will be comprised entirely of hatchery-origin adults. Adult chum salmon collected as part of the Kendall Creek Fall chum salmon program may be used to supplement fish or egg shortages at either Whatcom Creek or Lummi Bay chum salmon programs once Kendall Creek program objectives are met. Because the Kendall Creek Hatchery chum program is integrated, these juveniles that are the offspring of natural-origin brood may be included. Lummi Bay and Whatcom Creek Hatcheries may transition away from propagating Nooksack River chum salmon and instead propagate chum salmon originating from naturalized populations in independent streams in Bellingham and Samish Bays.

Up to 4,400 adult chum salmon will be collected at Whatcom Creek Hatchery. Up to 2,700 of these adults are needed to meet the 2.6 million egg take goal for the Whatcom Creek chum salmon program, including 100,000 eyed eggs that are transferred to the Nooksack/Samish Regional Enhancement Groups. Up to 1,700 adult chum salmon are collected at Whatcom Creek Hatchery to provide 1.5 million eggs annually to support the Lummi Indian Nation chum salmon program operated at Lummi Bay Hatchery. Whatcom Creek chum abundance of returning adults have been annually variable and in low return years, eggs shortages are supplemented with eggs collected at Kendall Creek Hatchery. If the abundance of the native Nooksack chum salmon population is not sufficient to support tribal fishery goals, the co-managers may agree to propagation of alternative in- or out-of-basin chum salmon stocks that are not expected to affect ESA-listed species differently than the native Nooksack chum salmon stock. Broodstock would be collected from the Samish River, the Samish Hatchery broodstock pond, or independent tributaries including Chuckanut, Oyster, Colony, and Whitehall. Chum salmon produced using these alternative stocks could be propagated at and released from Whatcom Creek and Lummi Bay Hatcheries.

Pink salmon juveniles will be reared at Skookum Creek Hatchery to produce fry that will be released in order to improve outmigration calibration trials (Lummi Nation et al. 2022). Twenty pairs of adult pink salmon will be collected opportunistically from pink salmon adults that volunteer to Skookum Creek and Kendall Creek hatcheries during periods when broodstock are being collected for the other salmon programs. Juvenile pink salmon will be reared at Skookum Creek Hatchery or Sandy Point Incubation Facility.

Hatchery-origin Chinook salmon adults collected at Kendall Creek Hatchery and Skookum Creek Hatchery in excess of broodstock needs for that program are lethally surplused and used for nutrient enhancement within the Nooksack River basin, provided to fish buyers, and distributed to tribal members of Lummi Nation and Nooksack Tribe of Indians when requested. Samish and Whatcom Hatcheries sell all carcasses to a fish buyer. Whatcom Creek chum salmon collected in excess of broodstock needs are donated to SeaShare food bank, disposed of by a contracted fish buyer, or distributed to the tribal members when requested. Egg sales from surplus Chinook and coho salmon to commercial buyers is an important source of revenue for Skookum Creek Hatchery. Surplus adult coho salmon may be used for nutrient enhancement within the Nooksack River basin after culling. Carcasses may also be sold or donated for animal feed or sold or donated to tribal crab fishers for bait.

1.4.1.1. **Proposed salmon incubation, rearing, and release protocols**

Table 4. Proposed release goals and protocols for the Nooksack-Samish River basin salmon hatchery programs.

Program	Release Duration	Release Location	Current Release Goal	Size and Life Stage at Release	Acclimation; Release Strategy	Mark
Skookum Creek Hatchery Chinook Salmon Program	May–June	Skookum Creek Hatchery	2,000,000[a]	Sub-yearling smolt 50-85 fpp	Volitional Release from Hatchery	Minimum 650,000 CWT-Only and 200,000 AD+CWT 100% Otolith Mark
	April–May	Upper South Fork Nooksack	500,000	Sub-yearling smolt 50-85 fpp	Direct plant	100% AD Clip and 50,000 AD+CWT 100% Otolith Mark
North/Middle Fork Nooksack Native Spring Chinook Salmon Restoration Program	April–May	Kendall Creek Hatchery	900,000 increasing to 1,400,000 in ten years	Sub-yearling smolt 80-100 fpp	Volitional Followed by Forced Release from Hatchery, NF Acclimation Sites, and McKinnon Pond; Direct plant in MF	100% AD Clip and Otolith Marked; 200,000 also CWT
		NF Nooksack	800,000			100% AD Clip and Otolith Marked 50,000 CWT per site
		MF Nooksack	500,000			100% AD Clip and Otolith Marked 50,000 CWT per site
Samish River Hatchery Fall Chinook Salmon	May-June	Samish holding pond into Samish River	6,000,000	Sub-yearling smolt 80fpp	Acclimated to water source; Volitional Release from hatchery	5,600,000 AD clip 200,000 AD+ CWT 200,000 CWT
		Samish Hatchery into Friday Creek				
Whatcom Creek Hatchery Fall Chinook Salmon	April–May	Whatcom Creek	500,000	Sub-yearling smolt 80 fpp	Acclimated to water source, Forced release during high tide	450,000 AD clip Up to 50,000 AD+CWT

Program	**Release Duration**	**Release Location**	**Current Release Goal**	**Size and Life Stage at Release**	**Acclimation; Release Strategy**	**Mark**
Lummi Bay Chinook Salmon	April–May	Lummi Bay Hatchery	500,000 increasing to 2,000,000	Sub-yearling smolt 40-90 fpp	Acclimated to sea pond water, forced release into seawater	100% AD clip and Otolith including ≥50,000 AD+CWT
Glenwood Springs Fall Chinook Salmon	May	Eastsound, Orcas Island	800,000	Sub-yearling smolt 80 fpp	Volitional Release from Hatchery into seawater	700,000 AD 100,000 AD+CWT
Skookum Creek Hatchery Coho Salmon Program	April–June	Skookum Creek Hatchery	1,000,000 + 200,000 for research	Yearling smolt 15-30 fpp; Experimental group 15-40 fpp	Acclimated to water source; Volitional release from Skookum hatchery	100% AD Clip 50,000 AD + CWT
Kendall Creek Hatchery Coho Salmon Program	April–May	Kendall Creek Hatchery	500,000	Yearling smolt 17 fpp	On-station release; forced release	455,000 AD Clip 45,000 AD + CWT
Lummi Bay Hatchery Coho Salmon Program	April–May	Lummi Bay Hatchery, Lummi Sea Pond	2,000,000	Yearling smolt 15-30 fpp	Acclimated to Sea Pond water. Forced release from net-pen, volitional movement through tide-gates	100% AD Clip ≥50,000 AD+CWT
Kendall Creek Hatchery Nooksack Fall Chum Salmon Program	April–May	Kendall Creek Hatchery	5,000,000	Fed Fry 400-1200 fpp	On-station release; volitional or forced release	100% Otolith marked
Lummi Bay Hatchery Chum Salmon Program	March–May	Lummi Bay Hatchery	10,000,000	Fed Fry 350-550 fpp	Six-week acclimation to salt water	May be otolith marked after marking system installed
	March–April	Jordan Creek; Jordan Creek RSI	250,000	Fed Fry 350-900 fpp or Eyed Egg	Forced or volition release	
Whatcom Creek Hatchery Chum Salmon Program	April-May	Whatcom Creek	2,000,000	Fed Fry 800 fpp	On-station release, forced during high tide	100% Otolith marked

[a] 1,500,000 if the full Upper South Fork off-station release group of 500,000 pre-smolts is realized.
[b] Dependent on future funding.

While the proposed release level for each program is given in Table 4, our analysis was performed at a 10% increase in the production level to allow a buffer against variability in within-hatchery survival; an overage of 10% is anticipated to be an infrequent occurrence with a five year running average of the total number of salmon released per program not to exceed 5% of the release target for that program.

All juvenile Chinook salmon released through the programs will be marked, tagged, and/or adipose fin clipped to allow for their differentiation from natural-origin salmon after their release as juveniles from the hatcheries and when the fish return as adults to Nooksack-Samish River basin marine and freshwater areas. At this time, the majority of juvenile Chinook salmon released from Skookum Creek Hatchery receive a CWT. As the program develops and returns increase, all juveniles will continue to receive an identifying mark but the proportion receiving a CWT may decrease. If juveniles cannot be tagged by the automarking trailer they will receive an AD clip as well as an otolith mark. At least 650,000 of the juveniles released on-station from Skookum Creek Hatchery will be marked with a CWT with adipose fin intact.

Juvenile Chinook salmon from Kendall Creek Hatchery that are released off-station may be released at McKinnon Pond, located on a tributary to the MF Nooksack River at RM 4.75, upstream of the former MF Diversion Dam site located at RM 7.2 up to the confluence with Warm Creek at RM 12.8, at RM 0.2 of Clearwater Creek, in Glacier, Cornell, Canyon, and Thompson Creeks in the NF Nooksack, or other sites in the NF Nooksack and North Fork/Middle Fork (NF/MF) tributaries agreed to by the co-managers in order to release fish at river locations conducive to increased survival and proximity to suitable spawning habitat for returning adults. Temporary acclimation tanks may be used to facilitate releases of juvenile Chinook salmon on the NF Nooksack River including Kidney Creek and Excelsior. The acclimation tanks would be installed the first week of April and removed the last week of May. Staff will monitor the juveniles and release them when they are in optimal health and condition (Davies 2023).

Kendall Creek Hatchery Coho salmon are forced released in April-May, during high spring runoff to foster rapid migration and minimize freshwater residence. All coho salmon rearing up to the point of transfer to Lummi Bay Hatchery is done at Kendall Creek Hatchery. In order to meet the maximum release objective for the Lummi Bay Hatchery coho salmon program, it is possible that a portion of the Lummi Bay release group may be reared entirely at Skookum Creek Hatchery up to the point of transfer to Lummi Bay. Up to 25,000 eyed coho salmon eggs may be provided to local salmon enhancement groups or schools as part of the “salmon in the classroom” curriculum. Juvenile coho salmon may be released in small numbers in area waters as part of these educational programs.

An additional 250,000 chum salmon fry will be released or hatched from remote site incubators within Jordan Creek (WRIA 01.0107), an independent tributary that flows into Lummi Bay. The chum salmon releases into Jordan Creek are associated with an educational salmon reintroduction program with Lummi Nation schools while habitat in this creek is reconnected and restored.

Reporting and control of specific fish pathogens is conducted in accordance with the Salmonid Disease Control Policy of the Fisheries Co-managers of Washington State (WDFW and NWIFC 1998; NWIFC and WDFW 2006).

1.4.2. Proposed research, monitoring, and evaluation

The twelve HGMPs include research, monitoring, and evaluation (RM&E) actions designed to identify the performance of the programs in meeting objectives to augment fisheries, limit effects to listed salmon and steelhead populations, and increase abundance and productivity of native salmon in target populations. Monitoring the harvest benefits of the programs from returning adult hatchery-origin fish is an important objective (e.g., smolt-to-adult survival rate and fishery contribution level monitoring). Contribution rates of hatchery-origin Chinook, coho, and chum salmon to regional fisheries will be monitored annually.

All of the Nooksack-Samish River basin hatchery programs include extensive monitoring, evaluation, and adaptive management programs. These include monitoring hatchery management strategies, harvest fisheries, and population productivity through tracking Viable Salmonid Population (VSP) metrics (McElhany et al. 2000; SSPS 2005; NMFS 2006a). These monitoring programs are designed to maximize understanding of population status and trends while minimizing incidental effects on natural-origin fish populations. VSP parameters will form the basis for RM&E priorities, though the co-managers will adapt priorities and objectives as necessary. The co-managers will use the data and information gathered from RM&E activities to inform and advise adaptive management of hatchery programs to meet HGMP performance criteria.

Table 5. Research, monitoring, and evaluation associated with the hatchery programs and any existing ESA coverage.

Objective	Activity	Associated Program	ESA Coverage
Limit effects to listed salmon and steelhead populations. Increase abundance and productivity of native salmon populations where appropriate.	Monitor adult collection, numbers, origins, sex, adipose fin clip and CWT status and record fork length, and collect scales, otoliths, tissues for genetic analysis and record other demographic data from select groups of representative fish at weirs, traps, and hatchery facilities.	All	This Opinion
Determine juvenile productivity and life history of natural- and hatchery-origin fish.	Operate rotary screw traps to estimate the abundance, timing, and age composition of hatchery- and naturally-produced migrants.	All	This Opinion Tribal 4(d) Permit
Determine if harvest objectives are being met. Compare life history characteristics of natural- and hatchery-origin fish.	Monitor hatchery- and natural-origin fish captured in freshwater, estuarine, and marine areas to collect basic life history information (i.e., length, maturity, migration status, marks/tags, sex, age and growth via scale samples and/or otoliths, genetic identity, and condition)	All	This Opinion Tribal 4(d) Permit
Monitor genetic diversity	Genetic sampling	Chinook salmon programs	This Opinion

Objective	Activity	Associated Program	ESA Coverage
Monitor life history characteristics of returning hatchery-origin fish.	Sample terminal area fisheries, spawning grounds, and hatcheries for CWTs, otoliths, scales, tissues for DNA analysis, demographic and morphometric data	All	This Opinion
Ensure performance standards for survival of life stages within the hatchery are being met. Ensure release goals are being met. Ensure health monitoring protocols are being followed.	Within hatchery monitoring of fish health and survival	All	This Opinion

Program Chinook salmon returning to hatchery facilities are annually monitored and enumerated as they can be identified by origin through the presence of adipose fin clips, otolith marks, and CWTs. Additionally, fish sex and run timing are monitored and age is determined based on CWT, scales, or otolith markings. Continued adipose fin clipping, coded-wire tagging and otolith marking of hatchery fish will allow adults to be identified by origin when encountered on spawning grounds, in fisheries, and at the hatchery. Because Skookum Creek and Kendall Creek operate integrated Chinook salmon programs, adults are intended to escape to natural spawning areas and increase the spawning abundance of the two Nooksack populations. Marking strategies will allow for monitoring of the temporal and spatial distribution of hatchery-origin Nooksack Chinook salmon adults returning to natural spawning areas to boost abundance and productivity.

Specific M&E actions for the twelve HGMPs affecting juvenile salmon are described in sections 1.10 and 11.0 of each respective HGMP. Information collected from juvenile sampling is used to inform and advise implementation of the proposed salmon hatchery programs. Juvenile salmon sampling occurring outside of the hatchery locations has been previously consulted on through a separate ESA consultation process (NMFS 2022i) and will now be evaluated through this Opinion. The co-managers propose to continue to monitor interactions between juvenile hatchery- and natural-origin salmon in freshwater, estuarine, and marine areas within the region to evaluate and manage program ecological effects. Where possible, continued juvenile outmigrant trapping by the co-managers is also proposed, using rotary screw traps in the Nooksack basin, seines and fyke nets in the estuary, and beach seines in the Nooksack basin and nearshore marine and estuarine areas, to provide important information on the co-occurrence, out-migration timing, abundance and sizes, growth indices and diets of hatchery-origin fish, ESA-listed natural-origin Chinook salmon and steelhead, and non-listed coho, chum, and pink salmon. Overall, the co-managers expect the maximum of 30,000 juvenile Chinook salmon and a maximum of 16,000 juvenile *O. mykiss* would be collected basin-wide. These juveniles would be released unharmed, the co-managers expect incidental mortality would be low and not exceed 200 juveniles annually (Lummi Nation 2024d).

The operation of a five-foot rotary smolt trap in the SF Nooksack River sub-basin will allow for monitoring and evaluation of juvenile Chinook salmon productivity, abundance, distribution, and timing in response to the hatchery supplementation activities previously described. Beach seines (2m by 9m, 1/8" braided mesh) will also be used to collect and sample juvenile salmonids. Seining events are expected to occur in all portions of the SF Nooksack River sub-basin accessible to anadromous salmonids. Non-lethal biological data collection from natural and hatchery-origin fish captured at the smolt trap and in beach seine collections will include fork length, weight, and genetic tissue samples. Passive Integrated Transponder (PIT)-tags will be inserted into natural- and hatchery-origin Chinook salmon juveniles with fork lengths ≥ 60mm to monitor freshwater survival, smolt-to-adult survival, adult run timing, and estimate juvenile abundance. The annual objective for PIT-tag deployment is 1,000 tags minimum (maximum 4,000) for natural-origin juveniles and ≤3,000 tags for unmarked (coded-wire tagged and adipose intact) hatchery-origin juveniles. Unmarked hatchery-origin Chinook released from Skookum Creek Hatchery are expected to be the most abundant ESA-listed juvenile salmonids encountered at the SF rotary smolt trap and during beach seining (Table 6). However, because collecting unmarked hatchery-origin outmigrants is not a primary monitoring goal, the operation of the rotary smolt trap may be temporarily suspended at the time of smolt release from Skookum Creek Hatchery to avoid unnecessary capture of unmarked hatchery-origin juveniles. Similarly, beach seine collections may be suspended in the SF Nooksack below the Skookum Creek confluence immediately after release.

To characterize the native SF Nooksack steelhead populations, biological samples may be collected from natural-origin juvenile winter and summer steelhead encountered at the rotary screw trap and during beach seining. Biological sampling of steelhead will include fork length, weight, a tissue sample for genetic analyses, and a subsample of encounters may include the insertion of a PIT-tag to monitor adult and juvenile migration timing and potentially estimate abundance and productivity. Details of the estimated numbers of juvenile salmon and steelhead encountered at the rotary screw trap, tagging objectives, and estimated mortality is shown in Table 6.

Table 6. Estimated annual encounters and mortality-related take of ESA-listed juvenile Chinook salmon and steelhead at the SF Nooksack River rotary screw trap and during beach seine collections.

Listed Species Affected	Total Encounters	Minimum PIT-Tag Objective	Maximum PIT-Tag Projection	Incidental Mortality
Chinook Salmon	30,000	1,000	4,000	600
Steelhead	16,000	Not Specified	2,000	320

Rotary smolt trap operation in the SF Nooksack River basin is expected to occur annually from March 1 to December 31 as river conditions allow. The trap will not operate when water temperatures exceed 66°F (19°C) to avoid lethal tagging temperatures of 63°F (17°C). These water temperatures generally occur in the SF Nooksack River basin between July 1 and the middle of September. The majority of juvenile Chinook salmon will likely be captured from May 1 to June 30 but may be encountered during any month of operation. Juvenile steelhead are expected to be encountered during any month of trap operation. The trap will be located between RM 1 and 10 of the SF Nooksack River but may be relocated to other areas of the South Fork as necessary. The trap will be checked at least once every 24-hours, with the frequency of trap checks increasing during periods of higher catches.

Beach seine collections in the SF Nooksack will generally occur in reaches accessible to anadromous salmon and steelhead from March 1 to December 31 annually. Seining will not occur if water temperature exceeds 66°F (19°C) and PIT-tagging will not occur above 63°F (17°C). Juvenile Chinook salmon and juvenile steelhead are expected to be encountered during any month of beach seine collection events. Due to the mobile nature of beach seine collection, it is possible that water temperatures will be below 63°F (17°C) in upper portions of the sub-basin during periods that water temperature exceeds 63°F (17°C) at the rotary smolt trap location.

Data collected from monitoring in the SF Nooksack River allows for evaluating migration timing characteristics of natural- and hatchery-origin juveniles. Monitoring juvenile salmon and steelhead may also allow for an estimation of the number and proportion of hatchery-origin juveniles that do not migrate in the year of release and instead migrate the following year. To understand the migrational characteristics and the frequency of subyearlings residualizing, up to 6,000 hatchery-origin Chinook that are not externally marked (CWT-only) may be PIT-tagged on an annual basis prior to release from Skookum Creek Hatchery. Expected incidental mortality may reach up to 10%. Both on-station and off-station release groups will be PIT-tagged, and the information collected from tag detections will be critical for evaluating the off-station release group survival and migration timing.

The size, number, date, and type of release of juvenile hatchery salmonids are monitored annually at the lower Nooksack smolt trap located in the Nooksack River at RM 4.5. Standard, non-lethal biological data including fork length, mark/tag status, and genetic tissue are collected for juvenile Chinook salmon and steelhead at the lower Nooksack smolt trap.

Small numbers of juvenile salmonids will be released to calibrate the smolts traps and beach seine efficiencies as shown in Table 7 (Lummi Nation et al. 2022). Releases of smolts to calibrate the smolt traps will take place two weeks before juveniles are scheduled to be released from Skookum Creek or Kendall Creek hatcheries. Smolts released to calibrate the trap in the lower mainstem Nooksack River will be released up to one mile above the trap. Juvenile salmon released to calibrate the SF Nooksack trap will be released from Skookum Creek Hatchery or released into the river between the hatchery outlet and the smolt trap. The juvenile salmon released to calibrate the smolt traps are included in the total release numbers of Chinook, coho, and chum salmon described in Table 4. Pink salmon fry will be released unfed or after a six-week feeding period to represent natural-origin pink salmon fry.

The co-managers have secured funding for a research project evaluating Chinook salmon egg to fry survival in all three forks of the Nooksack River basin. Specifically, artificial Chinook salmon redds will be constructed by hand using fertilized eggs from hatchery-origin Chinook salmon that are excess to egg take goals at Skookum Creek Hatchery. These eggs will be deposited into egg boxes placed within the Nooksack River so they experience freshwater environmental conditions and monitored throughout the incubation and emergence life stages. Up to sixteen sites will be selected from accessible reaches in the Nooksack River and three artificial redd boxes will be placed at each site in September or October. Each artificial redd box will contain approximately 300 fertilized eggs. Factors impacting egg to fry survival will be monitored including redd scour, temperature, discharge, and fine sediment infiltration. Any juveniles produced as part of this study will be lethally collected and enumerated. Because this project aims to evaluate impacts to naturally constructed redds, most artificial redds will be constructed in known Chinook salmon spawning areas of the main channels of all three forks as well as their tributaries. Artificial redds will also be constructed in areas where habitat restoration has been completed or is planned. Up to fifty artificial redds are proposed for construction annually over a 3 to 7-year period. A minimum of three consecutive years are likely needed to allow for an adequate evaluation of egg-fry survival rates to account for interannual variability. If funding allows, up to 4 additional years of the project are proposed to allow for the greatest representation of interannual environmental variation, demographic variation of spawning Chinook, and geomorphic changes to river channels. The co-managers will prevent any disturbance to active, naturally-constructed redds while constructing artificial redds, monitoring the project, or walking through spawning areas.

Table 7. Description of juvenile salmon released in the Nooksack River basin to calibrate the Mainstem and South Fork Nooksack River smolt traps. The mainstem Nooksack trap is located at RM 4.5 of the Nooksack River. AD = Adipose fin clip, CWT = Coded Wire Tag

Species/stock released	Trap Calibrated	Number released	Mark
Kendall Creek NF Nooksack Spring Chinook salmon	Mainstem Nooksack and beach seine	6,000	AD or AD+CWT Temporary epidermal dye
Skookum Creek SF Nooksack Spring Chinook salmon	Mainstem Nooksack and Beach seine	6,000	CWT-only or AD+CWT Temporary epidermal dye
Skookum Creek Nooksack River Fall coho salmon	Mainstem Nooksack and Beach seine	1,500	AD or AD+CWT
Kendall Creek Nooksack River Fall coho salmon	Mainstem Nooksack and Beach seine	1,500	AD or AD+CWT
Kendall Creek Nooksack Fall chum salmon	Mainstem Nooksack and Beach seine	6,000	Otolith marked Temporary epidermal dye
Skookum Creek SF Nooksack Spring Chinook salmon	SF Nooksack and Beach seine	1,500	AD or CWT-only AD+CWT Temporary epidermal dye
Nooksack Pink salmon	SF Nooksack and Beach seine	10,000	Temporary epidermal dye
Nooksack Pink salmon	Mainstem Nooksack and Beach seine	15,000	Temporary epidermal dye

Specific actions described in the HGMPs include monitoring of Chinook salmon natural escapement each year in the Nooksack River and the Samish River, and may include Whatcom Creek and independent WRIA 1 tributaries, including Dakota, California, Chuckanut, Padden, Squalicum, and Oyster Creeks spawning areas to estimate the number of ad-clipped, CWT tagged, and/or thermally-marked fish. Foot and/or boat spawning ground surveys would be conducted to estimate number of redds, live fish counts, and sample Chinook salmon carcasses for sex, fork length, scales, otoliths, adipose-fin clips, CWTs, and tissues for genetic analysis. Spawning ground surveys may also include monitoring and biological sampling of adult coho, chum, and pink salmon escapement each year, which may lead to encounters with ESA-listed Chinook salmon and steelhead. Annual adult Chinook, coho, and chum salmon escapement monitoring in the Nooksack River watershed, conducted to assess the performance and effects of the hatchery programs, include stream surveys and biological sampling that may lead to encounters with ESA-listed Chinook salmon, and steelhead. Effects would potentially include encountering naturally-spawning fish during the course of spawning ground surveys and biological sampling of carcasses.

All fish released through the hatchery programs are marked internally and/or externally, with the possible exception of chum released from Lummi Bay. Returning adults are annually sampled for the adipose fin-clip and CWT presence and absence in all commercial, recreational, ceremonial and subsistence fisheries to estimate fisheries contributions. Number and codes of CWTs recovered in fisheries are annually reported to Regional Mark Information System (RMIS; https://www.rmpc.org/) database and available through their web site. Details of harvest monitoring methods are presented in Puget Sound Chinook Comprehensive Harvest Management Plan (PSIT and WDFW 2022) and Puget Sound Commercial Salmon Fishery Sampling Manual (WDFW and NWIFC 2022). Lummi Natural Resources will conduct biological sampling in the Management Area 7D[2] fishery for otoliths and CWTs to allow robust statistical analysis of the total spring Chinook salmon catch by origin. Pre-terminal all citizens mark-selective fisheries will be sampled for CWTs to estimate stock compositions and the total CWTs in each fishery. All CWT recoveries in all fisheries, spawning grounds, and at the hatchery will be expanded to evaluate the success of the hatchery programs.

The co-Managers will monitor Chinook salmon escapement in the NF, MF, and SF Nooksack River sub-basins to estimate the number of tagged, untagged and marked fish present on Chinook salmon spawning grounds. Through extensive annual spawning ground surveys (Table 8), and carcass sampling, the co-managers will monitor Chinook salmon spawners and estimate the number and origin of fish escaping into the NF, MF, and SF sub-basins. This information will allow managers to understand the contribution of each stock, and their origin and release location. Hatchery-origin fish are identified based on adipose fin clip marks, otolith marks, and/or CWT presence. As of 2008, tissue samples for genetic analysis are collected from all carcasses with the exception of those encountered in the Kendall Creek Slough to determine stock assignments to one of the three Nooksack baseline stocks using probability estimates: SF early returning Chinook, NF early returning Chinook, or Samish/Nooksack fall Chinook. Continuing the comprehensive genetic analysis using DNA collected from Chinook salmon spawners may be evaluated in the future. The removal of MF Nooksack Dam in the summer of 2020 opened 16-miles of habitat for salmon and steelhead. The monitoring plan for this area is under development by co-managers and is likely to be adaptively modified as information comes available.

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[2] Area 7D are those waters of Puget Sound easterly of a line projected 154 degrees true from Sandy Point Light No. 2 (48 degrees, 47.2 minutes north latitude, 122 degrees, 42.7 minutes west longitude as per U.S. Coast Guard Light List No. 19880) to the landfall on Gooseberry Point and south of a line projected true east from Sandy Point Light No. 2 to the landfall on Sandy Point.

Table 8. Monitoring location and timing of Nooksack River basin habitats and spawning grounds. The timing and location of surveys may be adjusted annually based on fish presence.

Nooksack River	Location	Time*
North Fork	RM 40.6-65.0	Early-July – mid-October
	All Chinook salmon index tributaries and side channels as needed	
South Fork	RM 20.7-30.5 and Chinook salmon tributaries to this stretch	Mid-August – mid-October
Middle Fork	RM 0.0-17.4	Mid-July – September
	All Chinook salmon tributaries	
South Fork	RM 12.2-20.7 and Chinook salmon tributaries to this stretch	Mid-August – mid-October
South Fork	RM 0.0-12.2 and Hutchinson Creek	
North Fork	Chinook salmon tributaries and side channels	Mid-July – early September

Monitoring activities are limited in Whatcom Creek. In some years, juvenile outmigration is monitored from early March through mid-June in Cemetery Creek, a tributary to Whatcom Creek. Infrequent adult monitoring also takes place as WDFW and other agencies occasionally surveys Whatcom Creek between RM 1.2 and 1.9 for steelhead presence. For example, the complete spawning season survey performed in 2011 resulted in observation of a total of 4 redds.

WDFW and Northwest Indian Fish Commission (NWIFC) Fish Health Veterinarians and Specialists inspect adult broodstock annually for pathogens and monitor juvenile fish to assess health and detect potential disease problems. Broodstock are examined for pathogens at the time of spawning. As necessary, Fish Health Veterinarians recommend remedial or preventative measures to prevent or treat disease with administration of therapeutic and prophylactic treatments. A fish health database is maintained to identify trends in fish health and disease and to implement fish health management plans based on findings. Juvenile fish may be released at times other than those identified in Table 4 at the recommendation of Fish Health Veterinarians to stop the spread of disease.

1.5. Facilities

1.5.1. Skookum Creek Hatchery Intake Structure Upgrade

The Skookum Creek Hatchery intake structure in Skookum Creek is screened to prevent fish from entering into the facility however the screening does not meet current NMFS criteria (NMFS 2022c). The ACOE is proposing to permit under Section 404 of the Clean Water Act (CWA) improvements at the Skookum Creek fish hatchery to upgrade the water intake infrastructure at the Skookum Creek Fish Hatchery by installing a new intake structure, replacing a section of the intake pipe, repurposing the old intake structure, and elevating an existing road section. This work would be done consistent with WDFW Hydraulic Project Approval (HPA) work windows, during periods when migrating juvenile and adult salmonids are least likely to be present and flows are at the lowest point of the year (July 1 through September 15). The project will be completed during the 2024 in-water work window unless work is postponed if available funding is insufficient.

The Proposed Action for updating the intake structure at Skookum Creek Hatchery includes:

1. Replacing existing intake structure with a trashrack system. The existing fish screens will be replaced with a new trashrack system, and a new air-burst system will be installed to mobilize debris and encourage it to continue to move downstream to the sluice gate and overflow weir. The existing water supply pipeline will be replaced with a 36-inch advanced drainage system (ADS) (polyethylene) smooth walled corrugated pipe and the intake floor will be steepened somewhat and chamfered slightly to connect to the invert elevation of the new pipeline. A permanent sediment sluice pipe will be installed by expanding an existing opening on the west wall and extend downstream approximately 6 feet. Intake modifications will be performed primarily by small excavators, tracked small dump vehicles, concrete pumps, and manual labor, accessed from the existing roadway. All of this work will occur within the existing footprint of the intake structure under dewatered and isolated conditions.

2. Installing a new fish screen structure. A new replacement off-channel fish screen structure approximately 26 feet long and 11 feet wide is proposed further downstream along the access road/pipeline alignment. The new off-channel fish screen structure will be a rectangular concrete structure embedded approximately 11 to 13 feet below the final ground surface within the access road and out of the 100-year floodplain. The structure will be placed on one side of the access road and sufficient space will be provided to maintain vehicular access between the screen structure and the hill slope. Two pipes will exit the structure and be routed below the ordinary high-water mark (OHWM). Approximately 30 cubic yards of sub-angular rock material will be placed along the bank adjacent to the new fish screen structure to protect the fish bypass and sediment sluice pipes, as well as the toe of the screen structure from rock and wood debris transported by Skookum Creek during flood flows. Additional pipe valve vaults will be installed adjacent to the structure, and an above ground electrical control box will be constructed nearby. Ground excavation will be completed using a small excavator. The structure will be cast-in-place concrete. The new water supply pipeline will be connected to the fish screen structure. Approximately 13 cubic yards of material will be excavated to create an outfall pool for the fish screen return pipe to provide refuge and energy dissipation for the water and fish. The configuration will also allow fish are be returned below the low-water level of Skookum Creek, ensuring connection of the outfall pool with the main stream flow under all flow conditions. Construction at the fish screen return pipe area is expected to last approximately 14 days. It is expected that the in-water work area would be isolated with a coffer dam and pumps would be used to dewater similar to the method described for the intake area bolder weir construction. The coffer dam would not span the channel. The new fish screen system will meet NMFS passage and fish screen criteria.

3. Installing a new section of the water supply pipe. In the current condition, water is conveyed to the hatchery water tower from the intake via approximately 550 feet of 36-inch diameter corrugated aluminum pipe (encased in concrete) and 460 feet of 36-inch diameter fiberglass pipe. The existing pipeline has been in service for over 50 years. Approximately 350-feet of new 36-inch diameter high-density polyethylene (HDPE) pipe will be installed between the intake and new screen structure. The new pipe will be installed adjacent to, and on the landward side of the existing pipe. Some rock excavation may be required for the trench but will be minimized by raising the grade of the pipe. At the screen structure, a wye will be installed with one branch connecting into the screen structure and the other branch connecting into a vault downstream of the screen structure to function as a bypass during screen maintenance. The existing pipe will be abandoned for normal operations just upstream of the new screen structure. Downstream of the fish screens the existing pipe is in good condition and will continue to be used to convey flow to the hatchery. This work is entirely above the OHWM.

4. Elevating the access road. The access road between the intake and 40 feet downstream of the screen structure will be raised between two to six feet to accommodate installation of, and provide sufficient cover for, the new water supply pipeline. The existing concrete retaining wall will be raised using ecology blocks to allow this without extending fill below the OHWM. After installation of the new water pipe and subsequent backfilling and compaction of pipe bedding material, the existing concrete slabs will be placed back on top of the access road. The portion of the access road between the new fish screen structure and Saxon Road not covered by the existing concrete slabs will be resurfaced with 4-inches of gravel. This work is entirely above the OHWM, but includes some wetland fill with impacts described below.

    1. Repurposing the existing fish screen structure. The existing intake structure will be mostly retained with major modifications limited to the interior components. The intake bulkhead assembly and sediment sluice gate assembly will be removed and replaced. The north intake wall against the valley slope will be reinforced with rock anchor bolts into the hill slope to provide long-term stability. The interior timber wall will be removed and replaced with a concrete wall to serve as the new exterior wall. A section of the intake floor will be re-sloped to a steeper grade to improve sediment transport and removal within the intake structure. The steel grating at the top of the structure will be replaced with structural steel lids to protect the internal components from rockfall hazards, reduce icing, and prevent large flood sediment ingestion while maintaining easy access both above and into the structure. A parapet wall will replace the existing handrail to minimize inundation of the intake structure deck, improving maintenance accessibility and large flood sediment ingestion. The existing fish screens will be replaced with new a trashrack, and a new air-burst system will be installed to minimize maintenance and improve operational efficiency by periodically mobilizing debris such that it can be moved downstream and out of the intake structure via the sediment sluicing gate or proposed overflow weir. The existing water supply pipeline will be replaced with a 36-inch HDPE pipe and the intake floor will be chamfered slightly to the invert elevation of the new pipeline. A permanent

sediment sluice pipe will extend downstream approximately 6 feet from the intake and will be connected by expanding an existing opening on the west wall. The existing concrete exterior wall along the riverward side of the existing interior timber wall will be demolished.

2. Construction of a boulder weir. The channel modifications would be completed as part of the intake modifications and would include construction of a boulder weir to provide a reliable water supply to the Skookum Creek Hatchery. The boulder weir will mimic similar natural features in the stream. It will span the low-flow channel and the boulders will be placed to produce a depth of approximately 1.5 feet at the inflow to the intake structure during low flow conditions. This is the minimum depth required to meet the hatchery's water demand at low baseflows. This work will require a full stream diversion. Anchor boulders will be secured to the channel bottom with a steel rod embedded into the stream bottom a minimum of 10 feet. Bridging boulders will not be anchored. Construction access within the OHWM will be provided via a temporary gravel/cobble access ramp constructed using clean gravel of a size typically used for salmon and steelhead spawning. The streamside of the ramp will be contained in temporary geotextile wraps to minimize the fill footprint and ease removal.

Construction dewatering at the intake to install the boulder weir is expected to occur in June or July and last approximately 20 days. Work area isolation will be accomplished by diverting flow around the work area and through the existing intake structure. Water diverted into the intake will be returned back into the channel through the existing or proposed sediment sluice openings. The anticipated total length of channel isolation / dewatering is approximately 100 linear feet, primarily a steep boulder cascade. A sandbag coffer dam will be used at the upstream end of the project area to direct water into the intake structure. Pumping may be required to dewater pools such that instream structure subgrade elevations can be reached. Additionally, a sump will be excavated at the downstream end of the work area to capture storm runoff or groundwater inputs. Construction water will either be pumped to a filter bag located along the top of bank downstream of the work area and allowed to infiltrate into the ground, or discharged into the existing water supply pipeline and treated at the existing sediment decanting pond adjacent to the main hatchery building. Upon the completion of in-channel modifications, the flow diversion dam will be removed to reintroduce flow to the river channel in a controlled manner. The temporary bypass pump will be equipped with a NOAA-compliant intake screen to exclude fish from the diversion.

Fish salvage operations will be conducted during temporary bypass activation and deactivation, and following any unusual high-water overflow events that might overtop diversion facilities during construction. Fish salvage will be performed under conditions specified by NMFS and WDFW during the stream dewatering operation. Fish will be encouraged to move downstream by volitional movement during the progressive dewatering activities starting upstream and ending at the downstream end of the reach. Fish salvage operations will be performed by qualified biologists using electrofishing and hand dipnets. Any captured fish will be quickly transported downstream in aerated containers as captured and released back to the river. Fish removed and relocated will be enumerated by species, size class and condition.

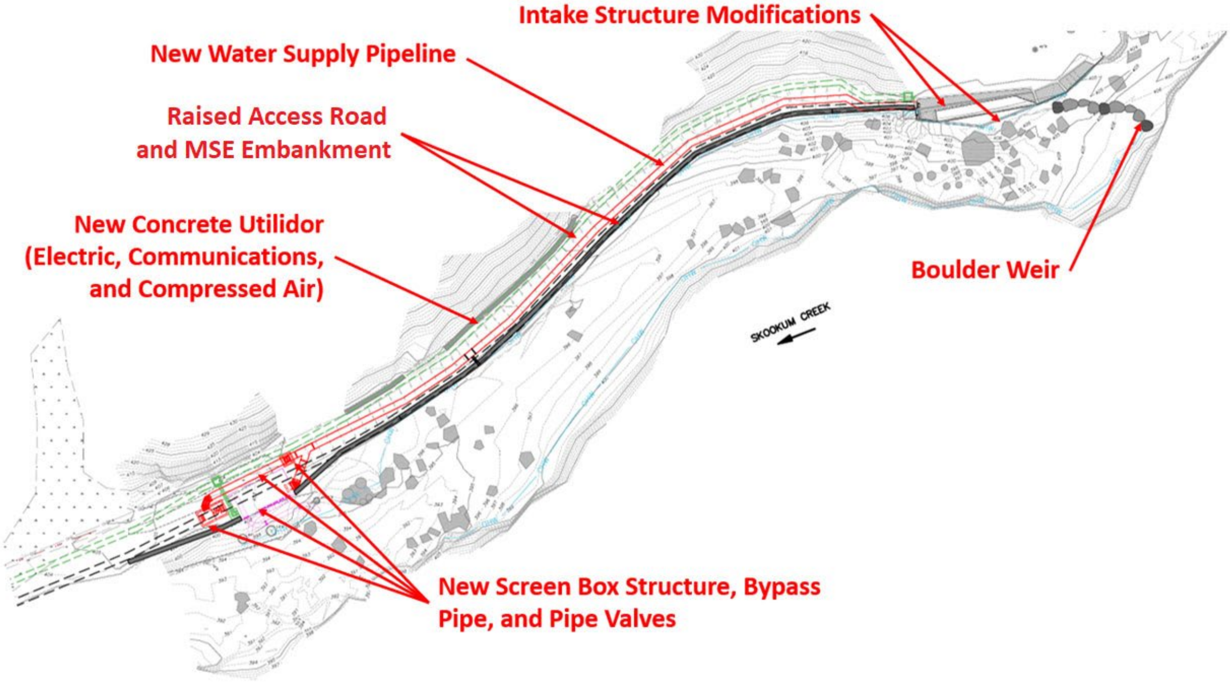

Figure 1. Site plan of the Skookum Creek Hatchery indicating locations of proposed project features.

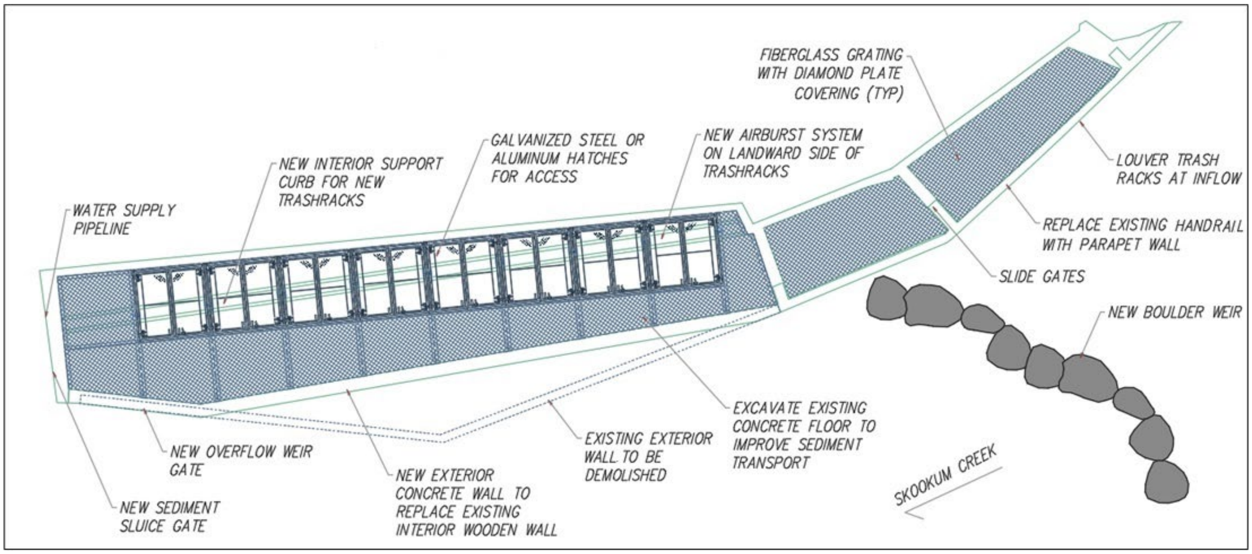

Figure 2. Proposed modification of the Skookum Creek Hatchery intake structure.

Best Management Practices
Best management practices (BMPs) are proposed for all project repair sites and include:

Staging Areas
- Staging areas will be the minimum size necessary to practically conduct the work.
- Staging area limits will be clearly marked on the ground prior to construction.
- Staging areas will be chosen to minimize disturbance to perennial vegetation (based on logistical constraints).

Pollution Control Measures
Prior to initiating construction, a Stormwater Pollution Prevention Plan for construction activities will be prepared and implemented by the contractor to prevent construction-related pollution from reaching flowing waters or contaminating upland areas. This plan will include the following:
- Practices will be identified to prevent pollution from equipment and material storage sites, fueling operations and staging areas.
- Sanitary facilities such as chemical toilets will be located at least 150 feet from water bodies to prevent contamination of surface or subsurface water.
- All poured concrete will be completed in isolated, dewatered or dry areas with containment methods in place. Concrete will be completely cured before contact with flowing water is allowed.
- A spill containment and control plan will be prepared that includes notification procedures, specific clean-up and disposal instructions, quick response containment and clean up materials that will be available on the site, proposed methods for disposal of spilled materials, and employee training for spill containment.
- Spill containment kits will be stored at each work site and the construction crews will be trained in proper use.
- A spill response plan will describe the chain of command, incident response procedures, agency notification protocols, and disposal protocols following all applicable local, state, and Federal regulations.
- If a spill of chemical pollutants such as fuel or hydraulic fluid should occur, the plan will require that the contractor attempt to contain the spilled material. The following procedures will be followed:
    - Notify the project inspector immediately.
    - For spillage on land, construct earthen berms or use other suitable barricade material of sufficient size to contain the spill and keep it from spreading.
    - For spillage on water, attempt to isolate and contain the spilled material. Commercial booms or other suitable materials shall be kept on site during construction to contain fuel and oil spills on water.

Equipment Maintenance and Refueling
- Prior to mobilizing to the project site, all equipment will be washed to minimize the introduction of foreign materials and fluids. All equipment will be free of oil, hydraulic fluid, and diesel fuel leaks.
- Vehicle staging, cleaning, maintenance, refueling, and fuel storage must take place in a designated area at least 150 feet from any stream or wetland.

- All vehicles operated within 150 feet of any stream or wetland must be inspected daily for fluid leaks before leaving the vehicle staging area. Any leaks detected must be repaired in the vehicle staging area before the vehicle resumes operation. Inspections must be documented in a record that is available for review on request.
- All equipment operated instream must be cleaned before beginning operations below the bankfull elevation to remove all external oil, grease and dirt.
- All equipment operating in or near the water will have hydraulic fluid replaced with biodegradable, vegetable-based hydraulic fluid.
- All other power equipment within 150 feet of the water will be inspected daily for fluid leaks and repaired. The contractor must prepare daily inspection reports.
- If a fluid leak does occur, the project inspector shall be notified immediately, and all work ceased at that specific location until the leak has been rectified. At all times during construction, fluid spill containment equipment will be present on-site and ready for deployment should an accidental spill occur.
- Stationary power equipment (e.g., generators) operated within 150 feet of any stream, water body or wetland must be diapered to prevent leaks, and fuel spill containment enclosures will be used.
- All fuel and lubricants will be stored in containers and areas that conform to applicable local, state and Federal regulations.
- If a spill of fuel or hydraulic fluid occurs, the contractor will immediately attempt to contain the spilled material and notify the appropriate regulatory agency following the spill response plan and all applicable local, state, Federal regulations.
- Petroleum contaminated soils resulting from contractor fueling, greasing, and cleaning, or due to fluid leaks will be removed and disposed of following all applicable local, state, and Federal regulations.
- Contractors will be required to conduct education and training for all employees working on site to describe the methods for spill prevention, spill notification, and spill response.

Erosion Control and Construction Stormwater Management

An Erosion Control Plan and a Stormwater Pollution Prevention Plan will be prepared. The plan will identify BMPs to minimize erosion and sedimentation associated with access roads, water crossings, construction sites, equipment and material storage sites, and staging areas. Measures include:

- To prevent sediment from entering stream and wetland habitats, erosion control measures will be implemented such as filter bags, sediment traps or catch basins, vegetative strips, berms, jersey barriers, fiber blankets, bonded fiber matrices, geotextiles, mulches or compost, wattles and silt fences, and covering exposed soils with plastic sheeting.
- Disturbance to riparian vegetation will be the minimum necessary to achieve construction objectives so as to minimize habitat alteration and the effects of erosion and sedimentation.
- During construction, all erosion controls will be examined daily by the project inspector to ensure they are working adequately.
- If inspection shows that the erosion controls are ineffective, work crews will be mobilized immediately to make repairs, install replacements, or install additional controls as necessary.
- Sediment will be removed from control devices once it has reached 1/3 of the exposed

height of the control.

- Measures will be implemented to prevent stockpile erosion during rain events or when the stockpile site is not moved or reshaped for more than 48 hours. These may include surrounding piles with compost berms, covering piles with impervious materials or other equally effective methods.
- Measures will be implemented to prevent construction vehicles from tracking sediment offsite or onto roadways where it may wash into storm drains, waterways, or wetlands; including gravel access pads, wheel wash stations, or other equally effective methods.

In-water Work, Dewatering and Water Treatment

- Isolation methods will remain in place for the duration of work. After the work in the specific area is complete, these measures will be removed to introduce free flowing water into the area in a controlled manner. Introduced flow rates shall be managed to maintain low velocities to minimize turbidity.
- Any pumps used to dewater areas potentially used by fish will be screened to prevent fish entrainment. Pump screens will meet National Marine Fisheries Service salmonid fry criteria.
- As work areas are dewatered, fish will be removed by hand dipnet and/or electrofishing. Use of electrofishing for fish salvage would comply with NMFS electrofishing guidelines (NMFS 2000). Fish will be transported safely downstream of the work zone in covered aerated containers and released as soon as possible after collection. A summary report of any fish salvage effort will be prepared that, at a minimum, includes a summary of methods, enumeration by species of fish encountered, and description of their ultimate disposition.

Restoration of Temporary Construction Impacts

Temporary construction impacts will be restored as follows:

- The staging area will be restored to pre-construction condition, or as requested by the Lummi Indian Business Council (LIBC).
- Temporary erosion control measures will remain on site and operational until the site is stabilized and permanent measures are functional, at which time the devices will be removed.
- Any temporarily disturbed bare soil areas surrounding the construction work zones will be seeded with a native grass seed mix for sediment and erosion control.
- Implement any mitigation measures for impacts to waters of the United States including wetlands, and buffers that are specified in permit(s) issued by the Army Corps of Engineers, Washington Department of Ecology, Washington Department of Fish and Wildlife, and/or Whatcom County

1.5.2. Existing infrastructure

The Kendall Creek Hatchery surface water structure does not meet the current NMFS criteria (NMFS 2022c). These intake screens are scheduled for replacement when funds become available. To collect returning hatchery adults, Kendall Creek Hatchery utilizes a permanent weir spanning the entire creek to direct all returning fish through a ladder and “V”-trap into the hatchery holding ponds, where they are sorted and kept for broodstock or released if not targeted for hatchery programs. The trap is operated annually beginning in late May or the beginning of June through at least March 15 to collect spring Chinook, chum, and winter steelhead broodstock and for the removal of hatchery-origin steelhead from the system. Screening on temporary acclimation ponds will meet the current NMFS criteria (Davies 2023).

The Samish River diversion dam was replaced with a collapsible weir in the spring of 2021. The weir is lowered allowing unimpeded fish movement when broodstock are not being collected. During broodstock collection, all fish are directed from the ladder into the holding pond, where they are sorted.

The Lummi Bay Hatchery freshwater intake structure is located on the Lummi Reservation in the tidal area of the lower Nooksack River. This intake structure is screened according to NMFS most recent standards and is located away from the main smolt migration corridor. No interactions or take with ESA-listed fish are anticipated through the operation of this water intake. Salt water is used at Lummi Bay Hatchery to condition and acclimate juvenile Chinook salmon prior to release. Salt water for conditioning and acclimating fish in rearing ponds is supplied from within the Lummi Sea Pond, an artificial impoundment within Lummi Bay that serves as the salt water source for Lummi Bay Hatchery program, with electric water pumps at volumes of up to 5.35 cubic feet per second (cfs). Eyed eggs may be incubated and hatched at an auxiliary facility at Sandy Point on the Lummi Reservation. Water delivered at approximately 0.27 cfs is provided from a well and gravity fed to the incubation facility. The incubation facility uses a 1.20 cfs partial reuse system operated with filters, pumps and ultra-violet (UV) sterilizers. The Nooksack River pump station supplying water to Lummi Bay Hatchery is in compliance with current NMFS screening criteria (NMFS 2022c). The new pump station meets current screening criteria (NMFS 2022c).

The water intake screens at Whatcom Creek Hatchery have been upgraded to bring the intake structure into compliance with current NMFS screening requirements. Due to the heavy silt loads, diatoms, and urban runoff, incubation of eggs to the eyed stage for all Whatcom Creek programs takes place at Kendall Creek Hatchery to prevent egg suffocation. To remedy issues related to diatoms, a new filtration system and water pumps have been installed at the facility and a thermal otolith marking system is expected to be operational within 1-2 years. Chum salmon broodstock are collected by volunteering to the hatchery using a fish ladder which is open from October 1 through December 15, there is no weir associated with the Whatcom Creek Hatchery.

Table 9. Water source, water withdrawal amount, NPDES and water rights permits, and screening information for facilities associated with the twelve programs presented in the Nooksack-Samish River Basin HGMPs.

Facility	Water Source	Withdrawal (cfs)	Instream Structures	Screening	Discharge Location	Water Rights Record/Cert	Permit	NPDES
Skookum Creek Hatchery	Skookum Creek	40 cfs	Water Intake; Weir	Brought into compliance Summer 2024	SF Nooksack River	Not Applicable	22899	WAG 13-0017
	Five Groundwater Wells	2.8 cfs	Not Applicable	Not Applicable		Not Applicable		
Kendall Creek Hatchery	Wells 1,2	11 cfs	Water Intake, Weir	Not in Compliance	Kendall Creek	G1-*10562C WRIS/ 10562 G1-2361c	09733	WAG 13-3007
	Wells 3, 4, 5	24.5 cfs				G2-23273C WRIS		
	Kendall Creek Surface Water	22.36 cfs				S1-CV1-1P31/ S1-00317C		
Samish Hatchery	Friday Creek (surface)	15.0 cfs	Water Intake	In Compliance with NMFS 2022 standards	Friday Creek and Samish River	S1-CV3-P1047 WRIS/ 00749	01871	WAG 13-3011
		8.13 cfs				S1-*22140C WRIS/ 11845	16877	
	Samish River (surface)	8.0 cfs	Water Intake, Collapsible Weir	In Compliance with NMFS 2022 standards		S1-*17762C WRIS/ 09937	13063	
		7.0 cfs				S1-*20468C WRIS/ 10245	15051	
		10.0 cfs				S1-24618C WRIS	-----	
Lummi Bay Hatchery	Nooksack River	2.34 cfs	On-Reservation water pump intake	In Compliance with NMFS 2022 standards	Lummi Bay	Not Applicable	Not Applicable	WAG 13-0018 WAG 13-2000
Glenwood Springs Hatchery	Unnamed Spring on Orcas Island	0.95 cfs	Water Intake	None, not fish bearing	Eastsound salt water	S1-27036C	Not Applicable	Not required
McKinnon Acclimation Pond	Stream	2.23 cfs	Water Intake	In Compliance with NMFS 2022 standards	Settling box	S1-27351	Not Applicable	Not required
Whatcom Creek Hatchery	Whatcom Creek Surface Water	5.8 cfs	Water intake	In Compliance with NMFS 2022 standards	Whatcom Creek	S1-28591C	Not Applicable	Not required

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 to 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.

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 also relies on the regulatory 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 designation(s) of critical habitat for Puget Sound Chinook salmon and steelhead uses the term primary constituent element (PCE) or essential features. The 2016 final rule (81 FR 7414; February 11, 2016) that revised the 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 or essential feature, as appropriate for the specific critical habitat.

The ESA Section 7 implementing regulations define effects of the action using the term "consequences" (50 CFR 402.02). As explained in the preamble to the final rule revising the definition and adding this term (84 FR 44976, 44977; August 27, 2019), that revision does not change the scope of our analysis, and in this Opinion, we use the terms "effects" and "consequences" interchangeably.

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 species and their critical habitat using an exposure–response approach.
- 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.

We use the following approach to determine whether a Proposed Action is likely to jeopardize listed species or destroy or adversely modify critical habitat.

Range-wide status of the species and critical habitat

This section describes the status of species and critical habitat that are the subject of this Opinion. The status review starts with a description of the general life history characteristics and the population structure of the ESU/DPS, including the strata or major population groups (MPG) where they occur. NMFS has developed specific guidance for analyzing the status of salmon and steelhead populations in a VSP paper (McElhany et al. 2000). The VSP approach considers four attributes, the abundance, productivity, spatial structure, and diversity of each population (natural-origin fish only), as part of the overall review of a species' status. For salmon and steelhead protected under the ESA, the VSP criteria therefore encompass the species' "reproduction, numbers, or distribution" (50 CFR 402.02). In describing the range-wide status of listed species, NMFS reviews available information on the VSP parameters including abundance, productivity trends (information on trends, supplements the assessment of abundance and productivity parameters), spatial structure and diversity. We also summarize available estimates of extinction risk that are used to characterize the viability of the populations and ESU/DPS, and the limiting factors and threats. To source this information, NMFS relies on viability assessments and criteria in technical recovery team documents, ESA Status Review updates, and recovery plans. We determine the status of critical habitat by examining its PBFs. Status of the species and critical habitat are discussed in Section 2.2.

Action area

The "action area" means all areas to be affected directly or indirectly by the Proposed Action, in which the effects of the action can be meaningfully detected, measured, and evaluated (50 CFR 402.02). The action area is discussed in Section 2.3 of this Opinion.

Describing the environmental baseline

The environmental baseline includes the past and present impacts of Federal, state, or private actions and other human activities in the action area on ESA-listed species. It includes the anticipated impacts of proposed Federal projects that have already undergone formal or early section 7 consultation and the impacts of state or private actions that are contemporaneous with the consultation in process. The environmental baseline is discussed in Section 2.4 of this Opinion.

Cumulative effects

Cumulative effects, as defined in NMFS' implementing regulations (50 CFR 402.02), are the effects of future state or private activities, not involving Federal activities, that are reasonably certain to occur within the action area. Future Federal actions that are unrelated to the Proposed Action are not considered because they require separate Section 7 consultation. Cumulative effects are considered in Section 2.6 of this Opinion.

Integration and synthesis

Integration and synthesis occurs in Section 2.7 of this Opinion. In this step, NMFS adds the effects of the Proposed Action (Section 2.5.2) to the status of ESA protected populations in the Action Area under the environmental baseline (Section 2.4) and to cumulative effects (Section 2.6). Impacts on individuals within the affected populations are analyzed to determine their effects on the VSP parameters for the affected populations. These impacts are combined with the overall status of the MPG to determine the effects on the ESA-listed species (ESU/DPS), which will be used to formulate the agency's Opinion as to whether the hatchery action is likely to: (1)

result in appreciable reductions in the likelihood of both survival and recovery of the species in the wild by reducing its numbers, reproduction, or distribution; or (2) reduce the value of designated or proposed critical habitat.

Jeopardy and adverse modification

Based on the Integration and Synthesis analysis in Section 2.7, the Opinion determines whether the Proposed Action is likely to jeopardize ESA protected species or destroy or adversely modify designated critical habitat in Section 2.9.2.

Reasonable and prudent alternative(s) to the Proposed Action

If NMFS determines that the action under consultation is likely to jeopardize the continued existence of listed species or destroy or adversely modify designated critical habitat, NMFS must identify an RPA or RPAs to the Proposed Action.

Other species in action area

NMFS has determined the Proposed Action is not likely to adversely affect some listed salmon ESUs and steelhead DPSs or their critical habitat. Our concurrence is documented in the "Not Likely to Adversely Affect" Determinations Section (2.11). NMFS has previously considered whether hatchery releases of salmon and steelhead in Puget Sound would affect other ESA-listed species under NMFS regulatory purview, including Pacific eulachon, green sturgeon, southern resident killer whales, bocaccio, and rockfish, and has determined that Puget Sound hatchery releases are not likely to have a meaningful or measurable effect on these species. As this has been evaluated through a separate NMFS ESA consultation (NMFS 2020), these species will not be addressed further in this Opinion.

The ESA-listed threatened Coastal-Puget Sound bull trout (*Salvelinus confluentus*) DPS is administered by the USFWS. Effects on bull trout associated with the NMFS 4(d) rule determination for the proposed hatchery salmon programs will be addressed through a separate ESA Section 7 consultation with USFWS.

In addition, NMFS has considered whether the Proposed Action would affect other ESA-listed species under NMFS regulatory purview, including Pacific eulachon, southern resident killer whales, or rockfish, and has determined that the Proposed Action is not likely to have a meaningful or measurable effect on any additional species based on the very small proportion of Nooksack-Samish hatchery-origin salmon produced by the Proposed Action in the Salish Sea and Pacific Ocean areas where these ESA-listed species occur. The effects of all hatchery releases that provide prey for ESA-listed Southern Resident Killer Whale (SRKW) originating from Puget Sound hatcheries that are described in the Proposed Action, have been evaluated through a separate NMFS ESA consultation (NMFS 2020). Based on this, these species will not be addressed further in this Opinion.

In analyzing the effects of the Proposed Actions on threatened Puget Sound Chinook salmon and steelhead natural populations, NMFS considers its classification of each population and the role of the population in recovery of the ESU. Under the Population Recovery Approach (PRA)

(NMFS 2010), each natural population is assigned to a tier designation based on life history, production and habitat indicators, and the Puget Sound Recovery Plan biological delisting criteria (Figure 3). NMFS applies the PRA in ESA consultations for actions affecting ESA-listed Chinook salmon in Puget Sound (e.g., (NMFS 2011c; 2015d)). Although recognizing prioritization of the 22 Puget Sound Chinook Salmon ESU populations is valuable, NMFS understands that there are non-scientific factors (e.g., the importance of a salmon or steelhead population to tribal culture and economics) that are important considerations in salmon and steelhead recovery.

Under the PRA, Tier 1 populations are of primary importance for preservation, restoration, and ESU recovery. Tier 2 populations play a secondary role in recovery of the ESU and Tier 3 populations play a tertiary role. When NMFS analyzes Proposed Actions, it evaluates impacts at the individual population scale for their effects on the viability of the ESU. Impacts on Tier 1 populations would be more likely to affect the viability of the ESU as a whole than similar impacts on Tier 2 or 3 populations, because of the primary importance of Tier 1 populations to overall ESU viability. Both the SF and NF Nooksack Chinook salmon populations are classified through the approach as Tier 1 populations (NMFS 2010). The classification for these two Chinook salmon populations that may be affected by the Proposed Actions are considered in NMFS' analysis with other factors (Section 2.6) to derive conclusions regarding the Nooksack-Samish salmon hatcheries-related effects on the Puget Sound Chinook Salmon ESU.

2.2. Range-wide Status of the Species and Critical Habitat

This Opinion examines the status of each species that is likely to 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" for the jeopardy analysis. The Opinion also examines the condition of designated critical habitat, evaluates the conservation value of the various watersheds and coastal and marine environments that make up the designated critical habitat, and discusses the function of the PBFs that are essential for the species' conservation.

Table 10. Federal Register notices for the final rules that list species, designate critical habitat, or apply protective regulations to ESA-listed species considered in this consultation that are likely to be adversely affected.

Species	Listing Status	Critical Habitat	Protective Regulation
Chinook salmon (*O. tshawytscha*)			
Puget Sound	Threatened, March 24, 1999; 64 FR 14508	Sept 2, 2005; 70 FR 52630	June 28, 2005; 70 FR 37160
Steelhead (*O. mykiss*)			
Puget Sound	Threatened, May 11, 2007; 72 FR 26722	February 24, 2016; 81 FR 9252	September 25, 2008; 73 FR 55451

"Species" Definition: The ESA of 1973, as amended, 16 U.S.C. 1531 *et seq.* defines "species" to include any "distinct population segment (DPS) of any species of vertebrate fish or wildlife which interbreeds when mature." To identify DPSs of salmon species, NMFS follows the "Policy on Applying the Definition of Species under the ESA to Pacific Salmon" (56 FR 58612, November 20, 1991). Under this policy, a group of Pacific salmon is considered a DPS and hence a "species" under the ESA if it represents an evolutionarily significant unit (ESU) of the biological species. The group must satisfy two criteria to be considered an ESU: (1) It must be substantially reproductively isolated from other con-specific population units; and (2) It must represent an important component in the evolutionary legacy of the species. To identify DPSs of steelhead, NMFS applies the joint FWS-NMFS DPS policy (61 FR 4722, February 7, 1996). Under this policy, a DPS of steelhead must be discrete from other populations, and it must be significant to its taxon.

2.2.1. Status of Listed Species

For Pacific salmon and steelhead, NMFS commonly uses four parameters to assess the viability of the populations that, together, constitute the species: abundance, productivity, spatial structure, and diversity (McElhany et al. 2000). These VSP criteria therefore 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. These parameters or attributes are substantially influenced by habitat and other environmental conditions.

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

"Productivity," as applied to viability factors, refers to the entire life cycle; i.e., the number of naturally spawning adults (i.e., progeny) produced per naturally spawning parental pair. 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.

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

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

In describing the range-wide status of listed species, we rely on viability assessments and criteria in NMFS Technical Recovery Team (TRT) documents and NMFS recovery plans, when available, that describe VSP parameters at the population, MPG, and species scales (i.e., salmon ESUs and steelhead DPSs). For species with multiple populations, once the biological status of a species' populations and MPGs have been determined, NMFS assesses the status of the entire species. 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 meta-populations (McElhany et al. 2000).

2.2.1.1. **Life History and Status of the Puget Sound Chinook Salmon ESU**

The Puget Sound Chinook ESU was listed as a threatened species in 1999. Its threatened status was reaffirmed June 28, 2005 (70 FR 37160), and again on April 14, 2014 (79 FR 20802). Chinook salmon, *Oncorhynchus tshawytscha,* exhibit a wide variety of life history patterns that include: variation in age at seaward migration; length of freshwater, estuarine, and oceanic residence; ocean distribution; ocean migratory patterns; and age and season of spawning migration. Two distinct races of Chinook salmon are generally recognized: "stream-type" and "ocean-type" (Healey 1991; Myers et al. 1998). Ocean-type Chinook salmon reside in coastal ocean waters for three to four years, tending to not range very far northward in the Pacific Ocean prior to returning to their natal rivers. Stream-type Chinook salmon, predominantly represented by spring-run Chinook salmon populations, spend two to three years in the ocean and exhibit extensive offshore ocean migrations. Ocean-type Chinook salmon enter freshwater later in the season upon returning to spawn than stream type fish; June through August compared to March through July (Myers et al. 1998). Ocean-type Chinook salmon use different stream areas – they primarily spawn and rear in lower elevation mainstem rivers and typically reside in fresh water for no more than three to five months compared to spring Chinook salmon, which spawn and rear high in the watershed and reside in freshwater for more than a year.

Status of the species is determined based on the abundance, productivity, spatial structure, and diversity of its constituent natural populations. Best available information indicates that the Puget Sound Chinook Salmon ESU is at high risk and is threatened with extinction (NWFSC 2015; Ford 2022). The Puget Sound Technical Recovery Team (PSTRT) determined that 22 historical natural populations currently contain Chinook salmon and grouped them into five biogeographical regions (BGRs), based on consideration of historical distribution, geographic isolation, dispersal rates, genetic data, life history information, population dynamics, and environmental and ecological diversity. Based on genetic and historical evidence reported in the literature, the TRT also determined that there were 16 additional spawning aggregations or populations in the Puget Sound Chinook Salmon ESU that are now putatively extinct (Ruckelshaus et al. 2006). The ESU encompasses all runs of Chinook salmon from rivers and streams flowing into Puget Sound, including the Strait of Juan de Fuca from the Elwha River eastward, and rivers and streams flowing into Hood Canal, South Sound, North Sound, and the Strait of Georgia in Washington. We use the term ‘‘Puget Sound’’ to refer to this collective area of the ESU. As of 2016, there are 24 artificial propagation programs producing Chinook salmon that are included as part of the listed ESU (71 FR 20802, April 14, 2014). Indices of spatial distribution and diversity have not been developed at the population level, though diversity at the ESU level is declining (NWFSC 2015; Ford 2022).

Table 11 summarizes the available information on current abundance and productivity and their trends for the Puget Sound Chinook salmon natural populations including NMFS’ critical and rebuilding thresholds and recovery plan targets for abundance and productivity (NMFS 2004a). Most Puget Sound Chinook salmon populations are well below escapement levels and productivity goals required for recovery. The most recent 5-year viability assessment (Ford 2022) indicates total abundance in the ESU over the entire time series shows that trends for individual populations are mixed. Generally, many populations experienced increases in total abundance during the years 2000–2008, and more recently in 2015–2017, but general declines during 2009–2014, and a downturn again in the two most recent years, 2017–2018. The downturn in the most recent years was likely associated with the period of anomalously warm sea surface temperatures in the northeast Pacific Ocean that developed in 2013 and continued to persist through much of 2015; this phenomenon was termed “the Blob.” Chinook salmon returning in 2017 and 2018 would have reached maturation in the ocean during these years, experiencing lower marine survival as a result of the hostile ocean conditions. Abundance across the Puget Sound ESU has generally increased since the last status review, with only 2 of the 22 populations (Cascade and North Fork Stillaguamish) showing a negative % change in the 5-year geometric mean natural-origin spawner abundances since the prior status review. Several populations (North Fork and South Fork Nooksack, Sammamish, Green, White, Puyallup, Nisqually, Skokomish, Dungeness and Elwha) are dominated by hatchery returns. Fifteen of the remaining 20 populations with positive % change in the 5-year geometric mean natural-origin spawner abundances since the prior status review have relatively low natural spawning abundances of < 1000 fish, so some of these increases represent small changes in total abundance (Ford 2022).

The Recovery Plan describes the ESU's population structure, identifies populations essential to recovery of the ESU, establishes recovery goals for most of the populations, and recommends habitat, hatchery, and harvest actions designed to contribute to the recovery of the ESU (NMFS 2006a; SSDC 2007). It adopts ESU and population level viability criteria recommended by the Puget Sound Technical Recovery Team (Ruckelshaus et al. 2002) as follows:

- All watersheds improve from current conditions, resulting in improved status for the species

- At least two to four Chinook salmon populations in each of the five biogeographical regions of Puget Sound attain a low risk status over the long-term
- At least one or more populations from major diversity groups historically present in each of the five Puget Sound regions attain a low risk status
- Tributaries to Puget Sound not identified as primary freshwater habitat for any of the 22 identified natural populations are functioning in a manner that is sufficient to support an ESU-wide recovery scenario
- Production of Chinook salmon from tributaries to Puget Sound not identified as primary freshwater habitat for any of the 22 identified populations occurs in a manner consistent with ESU recovery

NMFS further classified Puget Sound Chinook salmon populations into three tiers (Figure 3) based on its draft Population Recovery Approach (PRA) using a variety of life history, production and habitat indicators, and the Puget Sound Recovery Plan biological delisting criteria (NMFS 2010). NMFS understands that there are non-scientific factors, (e.g., the importance of a salmon or steelhead population to tribal culture and economics) that are important considerations in salmon and steelhead recovery. Tier 1 populations are of primary importance for preservation, restoration, and ESU recovery. Tier 2 populations play a secondary role in recovery of the ESU and Tier 3 populations play a tertiary role. When NMFS analyzes Proposed Actions, it evaluates impacts at the individual population scale for their effects on the viability of the ESU. Accordingly, impacts on Tier 1 populations would be more likely to affect the viability of the ESU as a whole than similar impacts on Tier 2 or 3 populations.

Trends in long-term growth rate of natural-origin escapement are generally higher than growth rate of natural-origin recruitment (i.e., abundance prior to fishing) indicating some stabilizing influence on escapement, possibly from past reductions in fishing-related mortality (Table 12). Since 1990, 13 populations show long-term growth rates that are at or above replacement for natural-origin escapement including populations in four of five regions. Currently, only five populations, in two regions, show long-term neutral to positive growth rates in natural-origin recruitment (Table 12). Additionally, most populations are consistently well below the productivity goals identified in the recovery plan (Table 11). Although long-term trends (1990 forward) vary for individual populations across the ESU, currently 20 populations exhibit a stable or increasing long-term trend in total natural escapement (Table 12). Thirteen of 22 populations show a growth rate in the 18-year geometric mean natural-origin spawner escapement that is greater than or equal to 1.00 (Table 12). Even given some of the incremental increases in natural-origin spawner abundances in the most recent five-year period, the long-term trends in both abundance and productivity, in most Puget Sound populations, are well below the levels necessary for recovery (Table 12).

Table 11. Long-term[13] estimates of escapement and productivity (recruits/spawner) for Puget Sound Chinook populations. Natural origin escapement information is provided where available. Populations at or below their critical escapement threshold are bolded. Populations exceeding their rebuilding natural-origin escapement threshold are underlined.

Region	Population	1999 to 2018 Run Year Geometric mean Escapement (Spawners)		NMFS Escapement Thresholds		Recovery Planning Abundance Target in Spawners (productivity)[2]	Average % hatchery fish in escapement 1999-2018 (min-max)[5]
		Natural[1]	Natural-Origin (Productivity[2])	Critical[3]	Rebuilding[4]		
Georgia Basin	Nooksack MU	1,798	236	400	500		
	NF Nooksack	1, 532	**180** (0.3)	*200*[6]	-	3,800 (3.4)	86 (63-97)
	SF Nooksack	266	**56** (1.9)	*200*[6]	-	2,000 (3.6)	51 (19-82)
Whidbey/Main Basin	Skagit Summer/Fall MU						
	Upper Skagit River	9,349	8,314 (2.7)	738	5,740	5,380 (3.8)	11 (2-36)
	Lower Sauk River	560	531 (3.1)	*200*[6]	371	1,400 (3.0)	5 (0-33)
	Lower Skagit River	2,090	1,845 (2.8)	281	2,131	3,900 (3.0)	9 (0-23)
	Skagit Spring MU						
	Upper Sauk River	633	624 (2.2)	130	470	750 (3.0)	1 (0-5)
	Suiattle River	379	372 (2.0)	170	223	160 (2.8)	2 (0-7)
	Upper Cascade River	289	260 (1.5)	130	148	290 (3.0)	7 (0-25)
	Stillaguamish MU						
	NF Stillaguamish R.	1,029	472 (0.9)	300	550	4,000 (3.4)	51 (25-80)
	SF Stillaguamish R.	122	**58** (1.2)	*200*[6]	300	3,600 (3.3)	48 (9-79)
	Snohomish MU						
	Skykomish River	3,193	2,212 (1.5)	400	1,491	8,700 (3.4)	28 (0-62)
	Snoqualmie River	1,449	1,182 (1.3)	400	816	5,500 (3.6)	18 (0-35)
Central/South Sound	Cedar River	924	659 (2.7)	*200*[6]	*282*[7]	2,000 (3.1)	28 (10-50)
	Sammamish River	1,073	**161** (0.5)	*200*[6]	*1,250*[6]	1,000 (3.0)	80 (36-96)
	Duwamish-Green R.	4,014	1,525 (1.4)	400	1,700	-	59 (27-79)
	White River[9]	1,859	625 (0.8)	*200*[6]	488[7]	-	59 (14-90)
	Puyallup River[10]	1,646	784 (1.2)	*200*[6]	797[7]	5,300 (2.3)	54 (19-83)
	Nisqually River	1,670	621 (1.5)	*200*[6]	1,200[8]	3,400 (3.0)	56 (17-87)
Hood Canal	Skokomish River	1,398	**282** (0.8)	452	1,160	-	71 (7-96)
	Mid-Hood Canal Rivers[11]	**187**		*200*[6]	*1,250*[6]	1,300 (3.0)	36[11] (2-87)
Strait of Juan de Fuca	Dungeness River	411	**98**(1.0)	*200*[6]	925[8]	1,200 (3.0)	72 (39-96)
	Elwha River[12]	1,231	**171**(1.02)	*200*[6]	*1,250*[6]	6,900 (4.6)	74 (31-98)

[1] Includes naturally spawning hatchery fish (estimates represent 1999-2019 geo-mean for: NF and SF Stillaguamish, Skykomish, Snoqualmie, Cedar, Duwamish-Green, White, Puyallup, and Elwha).

2 Source productivity is Abundance and Productivity Tables from NWFSC database; measured as the mean of observed recruits/observed spawners through brood year 2015, except: SF Nooksack through brood year 2013; and NF and SF Stillaguamish, Sammamish, Cedar, Duwamish-Green, Puyallup, White, Snoqualmie, Skykomish, through brood year 2016. Sammamish productivity estimate has not been revised to include Issaquah Creek. Source for Recovery Planning productivity target is the final supplement to the Puget Sound Salmon Recovery Plan (NMFS 2006a); measured as recruits/spawner associated with the number of spawners at Maximum Sustained Yield under recovered conditions.

3 Critical natural-origin escapement thresholds under current habitat and environmental conditions (McElhany et al. 2000; NMFS 2000a; NOAA Fisheries Service 2018).

4 Rebuilding natural-origin escapement thresholds under current habitat and environmental conditions (McElhany et al. 2000; NMFS 2000a; NOAA Fisheries Service 2018).

5 Estimates of the fraction of hatchery fish in natural spawning escapements are from the Abundance and Productivity Tables from NWFSC database; measured as mean and range for 1999-2018. Estimates represent hatchery fraction through 2019 for: NF and SF Stillaguamish, Skykomish, Snoqualmie, Cedar, Duwamish-Green, White, Puyallup, and Elwha)

6 Based on generic VSP guidance (McElhany et al. 2000; NMFS 2000a).

7Based on spawner-recruit assessment (PSIT and WDFW 2017).

8 Based on alternative habitat assessment.

9 Captive broodstock program for early run Chinook salmon ended in 2000; estimates of natural spawning escapement include an unknown fraction of naturally spawning

hatchery-origin fish from late- and early run hatchery programs in the White and Puyallup River basins.

10 South Prairie index area provides a more accurate trend in the escapement for the Puyallup River because it is the only area in the Puyallup River for which spawners or redds can be consistently counted (PSIT and WDFW 2010).

11 The PSTRT considers Chinook salmon spawning in the Dosewallips, Duckabush, and Hamma Hamma rivers to be subpopulations of the same historically independent population; annual counts in those three streams are variable due to inconsistent visibility during spawning ground surveys. Data on the contribution of hatchery fish is very limited; total abundance estimates primarily based on returns to the Hamma Hamma River.

12 Estimates of natural escapement do not include volitional returns to the hatchery or those hatchery or natural-origin fish gaffed or seined from spawning grounds for supplementation program broodstock collection

Table 12. Long-term trends[3] in abundance and productivity for Puget Sound Chinook salmon populations. Long-term, reliable data series for natural-origin contribution to escapement are limited in many areas.

Region	Population	Total Natural Escapement Trend[1] (1990-2018)		Natural Origin Growth Rate[2] (1990-2018)	
		NMFS		Recruitment (Recruits)	Escapement (Spawners)
Georgia Basin	NF Nooksack (early)	1.10	increasing	0.99	1.00
	SF Nooksack (early)	1.06	stable	0.96	0.96
Whidbey/Main Basin	Upper Skagit River (moderately early)	1.02	stable	1.01	1.00
	Lower Sauk River (moderately early)	1.01	stable	0.99	1.00
	Lower Skagit River (late)	1.02	stable	1.00	1.00
	Upper Sauk River (early)	1.05	increasing	0.97	1.02
	Suiattle River (very early)	1.02	stable	0.96	1.00
	Upper Cascade River (moderately early)	1.01	stable	0.96	1.00
	NF Stillaguamish R. (early)	0.99	stable	0.92	0.98
	SF Stillaguamish R (moderately early)	0.95	**declining**	0.90	0.96
	Skykomish River (late)	1.00	stable	0.99	0.99
	Snoqualmie River (late)	1.00	stable	1.00	1.00
Central/South Sound	Cedar River (late)	1.04	increasing	0.99	1.00
	Sammamish River[3] (late)	1.03	increasing	1.01	0.99
	Duwamish-Green R. (late)	0.98	stable	0.98	1.00
	White River[4] (early)	1.10	increasing	1.07	1.07
	Puyallup River (late)	0.98	**declining**	0.96	0.98
	Nisqually River (late)	1.05	increasing	0.97	1.00
Hood Canal	Skokomish River (late)	1.02	stable	0.93	0.97
	Mid-Hood Canal Rivers (late)	1.05	increasing	0.98	1.04
Strait of Juan de Fuca	Dungeness River (early)	1.05	increasing	0.96	0.98
	Elwha River (late)	1.05	increasing	0.89	0.92

[1] Total natural escapement Trend is calculated based on all spawners (i.e., including both natural origin spawners and hatchery-origin fish spawning naturally) to assess the total number of spawners passed through the fishery to the spawning ground. Directions of trends defined by statistical tests. Trends for NF and SF Stillaguamish, Skykomish, Snoqualmie, Cedar, Sammamish, Duwamish-Green, White, Puyallup, and Elwha are from 1999-2019.

[2] Median growth rate (λ) is calculated based on natural-origin production. It is calculated assuming the reproductive success of naturally spawning hatchery fish is equivalent to that of natural-origin fish (for those populations where information on the fraction of hatchery fish in natural spawning abundance is available). Source: Abundance and Productivity Tables from NWFSC database.

[3] Median growth rate estimates for Sammamish has not been revised to include escapement in Issaquah Creek.

[4] Natural spawning escapement includes an unknown % of naturally spawning hatchery-origin fish from late- and early run hatchery programs in the White/Puyallup River basin.

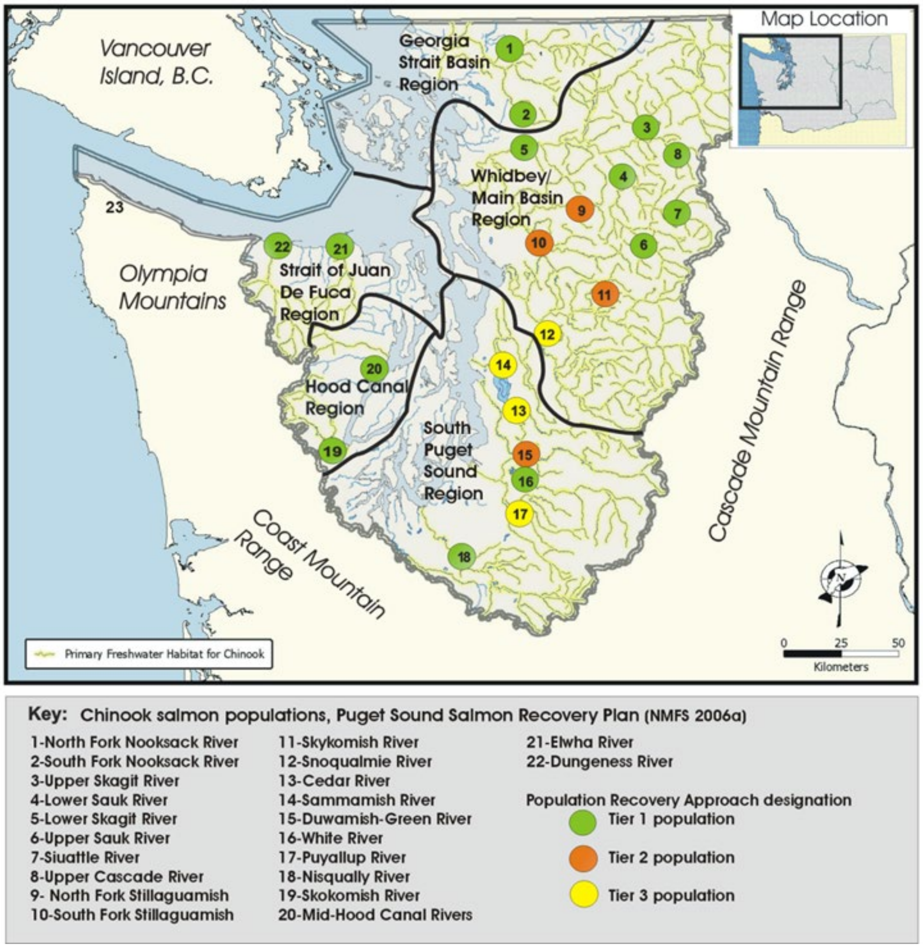

Figure 3. Populations delineated by NMFS for the Puget Sound Chinook salmon ESU and their assigned Population Recovery Approach tier status (SSDC 2007; NMFS 2010). Note: Dosewallips, Duckabush and Hamma Hamma River Chinook salmon are aggregated as the "Mid Hood Canal" population.

The limiting factors described in SSDC (2007) and NMFS (2006a) include:

- Degraded nearshore and estuarine habitat: Residential and commercial development has reduced the amount of functioning nearshore and estuarine habitat available for salmon rearing and migration. The loss of mudflats, eelgrass meadows, and macroalgae further limits salmon foraging and rearing opportunities in nearshore and estuarine areas.
- Degraded freshwater habitat: Floodplain connectivity and function, channel structure and complexity, riparian areas and large wood supply, stream substrate, and water quality have been degraded for adult spawning, embryo incubation, and rearing as a result of cumulative impacts of agriculture, forestry, and development.
- Anadromous salmonid hatchery programs: Salmon and steelhead released from Puget Sound hatcheries operated for harvest augmentation purposes can potentially pose ecological, genetic, and demographic risks to natural-origin Chinook salmon populations but can also provide benefits to viability parameters such as increased abundance and preserving genetic diversity.

- Salmon harvest management: Total fishery exploitation rates have decreased to 30% from higher rates in the 1980s as an enhanced protective measure to reduce the risk of overharvest to natural-origin Chinook salmon at low population abundances in Puget Sound.

The severity and relative contribution of these factors varies by population. The declines in fish populations in Puget Sound in the 1980s and into the 1990s may reflect broad-scale shifts in natural limiting conditions, such as increased predator abundances and decreased food resources in ocean rearing areas. These factors are discussed in more detail in the environmental baseline (Section 2.4).

Georgia Strait MPG

The Georgia Strait MPG contains two Chinook salmon populations, the SF Nooksack River population and the NF Nooksack River population which includes the MF Nooksack River (Ruckelshaus et al. 2006). Both populations need to be viable for recovery of the Puget Sound Chinook salmon ESU (NMFS 2006a). SF Nooksack Chinook salmon have a later peak spawning time than NF Nooksack Chinook salmon. It was thought that historically the Nooksack may have also had a late-returning life history (Ruckelshaus et al. 2006) but recent evidence indicates the late returning Chinook salmon were likely from the SF Nooksack population which has shown to have a longer return time and not an independent fall timed population. Evidence suggests that much of the life-history diversity represented by early-type populations or population components that existed historically in the Puget Sound Chinook ESU has been lost (Ruckelshaus et al. 2006) so protection of the remaining early-type populations like those in the Nooksack is particularly important to recovery of the ESU. Based on the most recent available information, escapement in both populations in the MPG are below their critical and rebuilding thresholds with high proportions of the escapement being composed of hatchery-origin Chinook salmon (Table 11). Both populations show a declining growth rate (Table 12). Both populations have on-going conservation hatchery programs to increase the number of natural spawners and reduce short-term extinction risk. These supportive hatchery programs are considered essential components to the recovery strategies for both populations (Entrix 2005; NMFS 2012b). Although Chinook salmon were likely present in the Samish River as they are currently, no evidence was found to support an independent Samish River Chinook salmon population (Ruckelshaus et al. 2006). In summary, populations within the Georgia Strait MPG exhibit life history components unique within the ESU and present significant challenges to ESU recovery given their critical status.

Nooksack Populations

There are two independent populations of Chinook salmon in the Nooksack River basin. These two early-returning, genetically distinct populations exhibit different migration and spawn timing from one another. The SF Nooksack early Chinook salmon generally spawn in the SF and larger SF tributaries from the confluence with the NF to the cascades at RM 30.8, although use is much lower upstream of Sylvester's Falls at RM 25 in recent decades. NF Nooksack early Chinook salmon generally spawn in the NF and MF of the Nooksack River, including tributaries, from the confluence of the South Fork at RM 36.6 up to Nooksack Falls at RM 65, and in the Middle Fork at RM 7.2. Passage to the upper Middle Fork was restored in 2020 and the co-managers are devising a monitoring plan to determine how salmon and steelhead utilize this recently opened habitat (PSIT and WDFW 2022). Data collected by co-managers indicates the two populations are not as geographically isolated as described in Ruckelshaus et al. (2006) and more segregated due to differences in spawn timing (Ford 2022).

SF Nooksack Chinook salmon have later run and spawn timing than NF Nooksack Chinook salmon. Adult Chinook salmon begin entering the Nooksack River in March and hold for an extended period before spawning. Spawning occurs in NF population beginning in late-July and continuing into early September with peak spawning in August. In recent years, 50% of all NF Nooksack population carcasses were recovered between 8/19 an 9/1 (Figure 4) whereas only 5% were collected before 8/11 and after 9/18 (Figure 5) (Haggerty 2024). The SF Nooksack population spawns from late-August through early-October with peak spawn occurring in mid- to late-September, with the median carcass recovery date approximately five weeks later than the NF population. In recent years, 50% of all SF Nooksack population carcasses were recovered between 9/27 and 10/6, again, about five weeks later than observed in the NF Nooksack population. Nooksack Chinook salmon predominantly exhibit an ocean-type life history trajectory (Myers et al. 1998), however all three outmigration life history types are observed in both Nooksack populations (PSIT and WDFW 2022). Ocean-type age 0 Chinook salmon fry outmigrate from late winter through March then rear in the river delta or pocket estuaries until they are large enough to undergo the physiological shift to salt water. Ocean-type age 0 parr rear for a few months in freshwater before outmigrating out directly to estuaries and near-shore regions with outmigration peaks in May and June. Yearlings rear over summer and overwinter in freshwater and outmigration occurs either in April through May preceding the main parr outmigration or in late fall into late winter ending in February prior to the out-migrant fry peak (PSIT and WDFW 2022). Although data is limited, age 4 adult returns are predominate in both populations (PSIT and WDFW 2022).

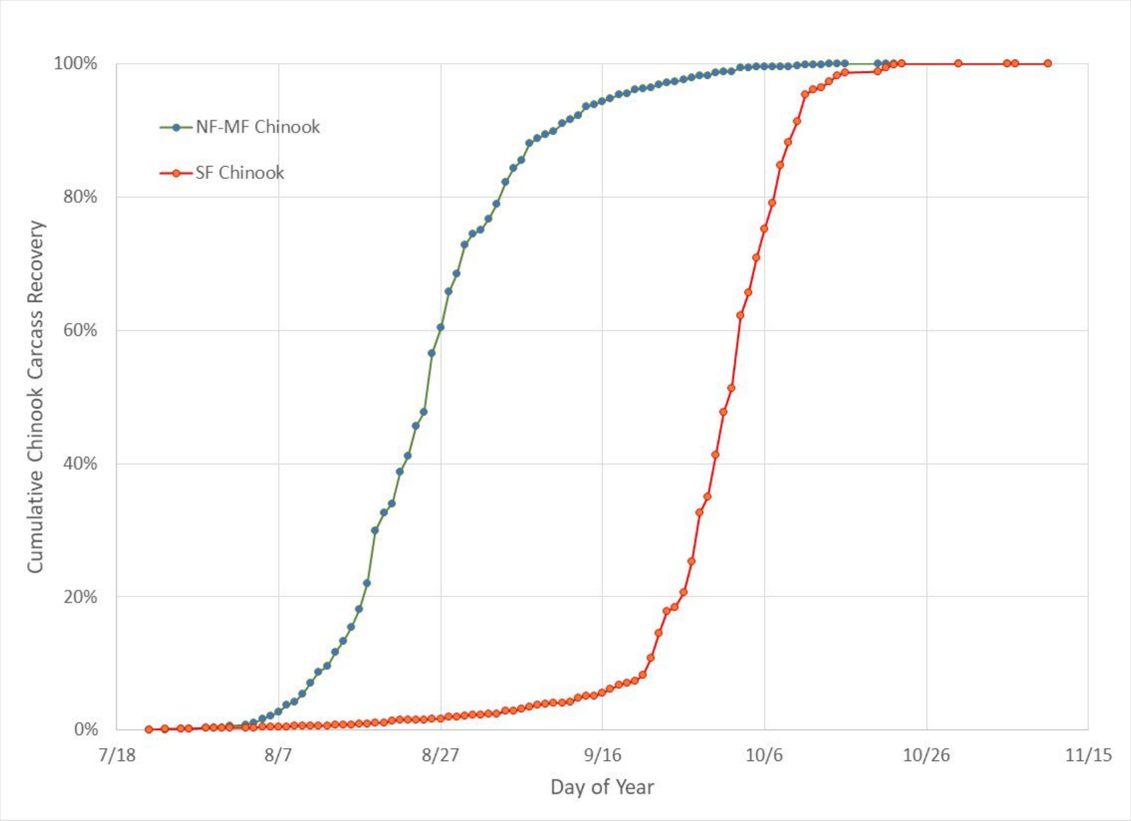

Figure 4. Cumulative adult Chinook salmon carcass recovery for the North/Middle Fork and South Fork Chinook populations based on stock assignment for return years 2016 through 2021. All known pre-spawn mortalities were removed from the carcass recovery dataset, these carcasses represent fish that spawned naturally (Haggerty 2024).

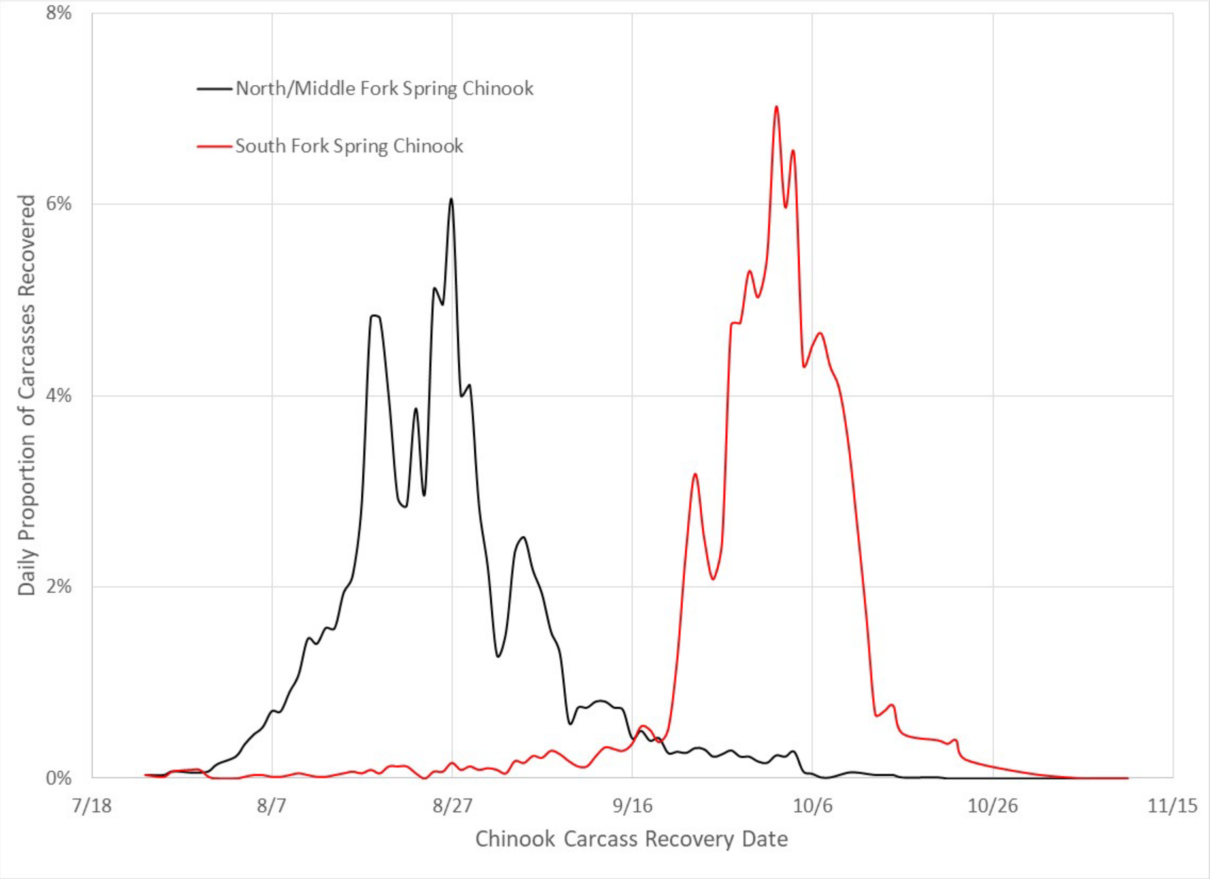

Figure 5. Smoothed daily proportion of SF Nooksack and NF/MF Nooksack Chinook salmon carcass recoveries. The transition between the populations takes place approximately on 9/16 (Haggerty 2024).

The current abundance of both NF and SF Nooksack Chinook salmon is substantially reduced from historical levels (Entrix 2005). Between 1999 and 2018, the estimated average total annual naturally spawning NF Nooksack Chinook salmon escapement was 1,532, compared to the recovery goal of 3,800 natural spawners (Table 11). During this same period, the estimated average total annual naturally spawning SF Nooksack Chinook salmon escapement was 266, compared to the recovery goal of 2,000 natural spawners (Table 11) (Ford 2022). Hatchery-origin Chinook salmon associated with the conservation hatchery programs make up a sizeable fraction of the annual naturally spawning adult abundance, averaging 86% in the NF Nooksack and 51% in the SF Nooksack (Table 11). Total naturally spawning fish escapements have fluctuated with recent increases from the conservation hatchery programs (Figure 6; Figure 7). The 5-year geometric mean of total annual naturally spawning Chinook salmon escapement is 1,553 with 137 of those being NORs in the NF Nooksack and 106 with 42 of those being NORs in the SF Nooksack. This is a 29% increase of mean total spawners from the previous 5-year period in the NF Nooksack and a 203% increase in the SF Nooksack (NMFS 2022n). The most recent NMFS status review for the ESU found that productivity trends for the Nooksack Chinook salmon populations, as measured by recruit per spawner and spawner to spawner rates, have been below replacement levels in all years since the mid-1980s (Ford 2022).

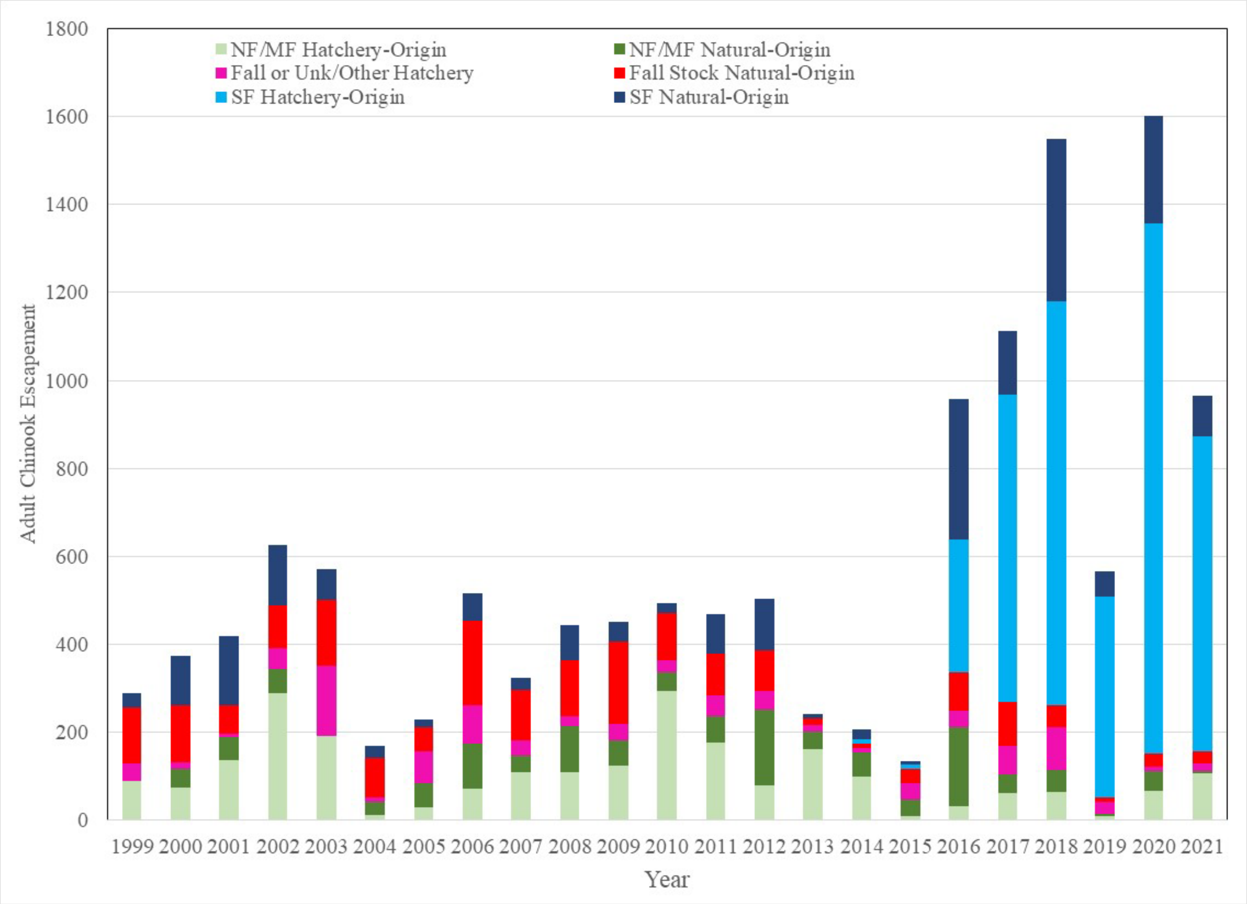

Figure 6. Estimated number of hatchery- and natural-origin Chinook salmon spawners in the SF Nooksack River by population or stock assignment (Haggerty 2024).

Figure 7. Estimated number of hatchery- and natural-origin Chinook salmon spawners in the NF Nooksack River by population or stock assignment (Haggerty 2024).

Spatial structure for the Nooksack Chinook salmon populations have been affected over time relative to historical levels. A full river spanning diversion dam located on the MF Nooksack River at RM 7.2 was constructed in 1962 (WDFW 2024c) blocking access to habitat historically used by Nooksack Chinook salmon and steelhead. The removal of the MF diversion dam in 2020 restored access to 16 miles of relatively pristine habitat for Chinook salmon and steelhead, an estimated 30% increase in habitat available for Chinook salmon and 45% increase in habitat available for steelhead in the MF Nooksack (Treaty Tribes in Western Washington 2020). Additionally, 662 culverts have been identified in the WRIA 1 area which are barriers to anadromous fish passage (Treaty Tribes in Western Washington 2020) further reducing spatial structure. Dikes, levees, and other actions to control the lower reaches of the river and tributaries have adversely affected population spatial structure, particularly through adverse impacts on side-channel habitat and increased scour of redds (Haring 1999). These actions have degraded available spawning and migration areas for adult fish, and refugia for rearing juvenile salmon. Finally, water withdrawals associated with human development have substantially reduced flows needed during the adult salmon upstream migration and spawning periods, forcing adults to construct spawning redds in channel areas that are extremely susceptible to sediment scour and aggradation.

Genetic diversity of the Nooksack Chinook salmon population has likely been substantially impacted by anthropogenic activities over the last century leading to the loss of habitat complexity in the watershed which caused declines in abundance and productivity. A captive broodstock program was initiated in 2007 using juveniles captured in the SF Nooksack River with identity confirmed by genetic analysis. This captive broodstock was intensely monitored using genetic techniques to avoid loss of genetic variation and inbreeding. This captive rearing program was terminated in 2016 as the program transitioned to reliance on returning anadromous adults (Lummi Nation 2015a; 2024d). The captive breeding and hatchery programs operating in the Nooksack Basin may have affected genetic diversity of the Nooksack River Chinook salmon populations. However, in founding the original hatchery and captive broodstock programs, the risk of within-population genetic diversity loss was reduced by selecting the indigenous Chinook salmon population for use as broodstock. Genetic management also greatly reduced the risk of genetic diversity loss that may occur due to captive breeding and hatchery rearing. As discussed previously, the disproportionate loss of early-run life history diversity represents a particularly significant loss of the evolutionary legacy of the historical Puget Sound ESU. The substantially reduced abundance of the Nooksack populations relative to historical levels represents a risk to remaining ESU diversity.

2.2.1.2. **Status of Critical Habitat for Puget Sound Chinook Salmon**

Critical habitat for Puget Sound 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 Puget Sound. The designation also includes some nearshore areas occupied by the 22 populations, because of their importance to rearing and migration for Chinook salmon and their prey. The designation includes nearshore areas extending from the extreme high water point out to a depth of 30 meters and adjacent to watersheds, but does not otherwise include offshore marine areas. Puget Sound Chinook salmon critical habitat includes estuarine areas and certain river reaches associated with the following subbasins: Strait of Georgia, Nooksack, Upper Skagit, Sauk, Lower Skagit, Stillaguamish, Skykomish, Snoqualmie, Snohomish, Lake Washington, Duwamish, Puyallup, Nisqually, Deschutes, Skokomish, Hood Canal, Kitsap, and Dungeness/Elwha (70 FR 52630).

The Puget Sound Chinook salmon ESU has 61 freshwater and 19 marine areas within its range. Of the freshwater watersheds, 41 are rated high conservation value, 12 low conservation value, and eight received a medium rating. Of the marine areas, all 19 are ranked with high conservation value from NOAA Fisheries' CHART (NMFS 2005b; 2022j). Of the stream and nearshore habitat eligible for designation, 3,865 miles are designated critical habitat while the remaining 740 miles were excluded because they are lands controlled by the military, overlap with Indian lands, or the benefits of exclusion outweighed the benefits of designation (70 FR 52630). It does not include marine or open ocean waters. Critical habitat information for Puget Sound Chinook salmon can be found online at: https://www.fisheries.noaa.gov/west-coast/endangered-species-conservation/puget-sound-chinook-salmon.
For the Puget Sound steelhead DPS, nine watersheds received a low conservation value rating, 16 received a medium rating, and 41 received a high rating to the DPS from CHART (NMFS 2015e; 2022j).

The Puget Sound recovery domain CHART determined that only a few watersheds for Chinook salmon (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 (NMFS 2005b). Most HUC5 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 13) (NMFS 2005b; 2022j).

Table 13. Puget Sound Recovery Domain habitat quality status and potential quality of HUC5 watersheds identified as supporting historically independent populations of ESA-listed Chinook salmon (CK) and chum salmon (CM) (NMFS 2005b).

Current PCE Condition	Potential PCE Condition
3 = good to excellent	3 = highly functioning, at historical potential
2 = fair to good	2 = high potential for improvement
1 = fair to poor	1 = some potential for improvement
0 = poor	0 = little or no potential for improvement

Watershed Name(s) and HUC5 Code(s)	**Listed Species**	**Current Quality**	**Restoration Potential**
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

Current PCE Condition	Potential PCE Condition
3 = good to excellent	3 = highly functioning, at historical potential
2 = fair to good	2 = high potential for improvement
1 = fair to poor	1 = some potential for improvement
0 = poor	0 = little or no potential for improvement

Watershed Name(s) and HUC$_5$ Code(s)	**Listed Species**	**Current Quality**	**Restoration Potential**
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
Strait of Juan de Fuca 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
Port Angeles Harbor (004)	CK	1	1
Watershed Name(s) and HUC$_5$ Code(s)	**Listed Species**	**Current Quality**	**Restoration Potential**
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

Current PCE Condition	Potential PCE Condition
3 = good to excellent	3 = highly functioning, at historical potential
2 = fair to good	2 = high potential for improvement
1 = fair to poor	1 = some potential for improvement
0 = poor	0 = little or no potential for improvement

Watershed Name(s) and HUC5 Code(s)	**Listed Species**	**Current Quality**	**Restoration Potential**
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
Strait of Juan de Fuca 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
Port Angeles Harbor (004)	CK	1	1

Major management activities affecting PBFs are forestry, grazing, agriculture, channel/bank modifications, road building/maintenance, urbanization, sand and gravel mining, dams, irrigation impoundments and withdrawals, river, estuary and ocean traffic, wetland loss, and forage fish/species harvest.

Landslides can occur naturally in steep, forested lands, but inappropriate land use practices likely have accelerated their frequency within designated critical habitat and increased 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 Puget Sound 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 (SSDC 2007; NMFS 2022j).

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; SSDC 2007; NMFS 2022j).

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 Puget Sound tributaries (SSDC 2007; NMFS 2022j).

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 (SSDC 2007). In urbanized Puget Sound, 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; NMFS 2022j). After years of forensic investigation, the urban runoff coho mortality syndrome has now been directly linked to motor vehicle tires, which deposit the compound 6PPD and its abiotic transformation product 6PPD-quinone onto roads. 6PPD or [(N-(1, 3-dimethylbutyl)-N'-phenyl-p-phenylenediamine] is used to preserve the elasticity of tires. 6PPD can transform in the presence of ozone (O3) to 6PPD-quinone. 6PPD-quinone is ubiquitous to roadways (Sutton 2019) and was identified by Tian et al. (2021) as the primary cause of urban runoff coho mortality syndrome described by Scholz et al. (2011). Laboratory studies have demonstrated that juvenile coho salmon, juvenile steelhead, and juvenile Chinook salmon are also susceptible to varying degrees of mortality when exposed to urban stormwater (Chow et al. 2019; French et al. 2022). Fortunately, recent literature has also shown that mortality can be prevented by infiltrating road runoff through soil media containing organic matter, which removes 6PPD-quinone and other contaminants (McIntyre et al. 2015; Spromberg et al. 2016; Fardel et al. 2020). Research and corresponding adaptive management surrounding 6PPD is rapidly evolving. Although Chinook salmon did not experience the same level of mortality as coho, tire leachate is still a concern for all salmonids. Traffic residue also contains many unregulated toxic chemicals such as pharmaceuticals, polycyclic aromatic hydrocarbons (PAHs), fire retardants, and emissions that have been linked to deformities, injury and/or death of salmonids and other fish (Trudeau 2017; Young et al. 2018; NMFS 2022j).

The nearshore marine habitat has been extensively altered and armored by industrial and residential development near the mouths of many of Puget Sound's tributaries. A railroad runs along large portions of the eastern shoreline of Puget Sound, eliminating natural cover along the shore and natural recruitment of beach sand (SSDC 2007; NMFS 2022j). 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; SSDC 2007).

NMFS has completed several Section 7 consultations on large-scale habitat projects affecting listed species in Puget Sound. Among these are the Washington State Forest Practices Habitat Conservation Plan (NMFS 2006b), and consultations on Washington State Water Quality Standards (NMFS 2008c), the National Flood Plain Insurance Program (NMFS 2008b), the Washington State Department of Transportation Preservation, Improvement and Maintenance Activities (NMFS 2013a), and the Elwha River Fish Restoration Plan (Ward et al. 2008; NMFS 2014a).

In 2012, the Puget Sound Action Plan was also developed with several Federal agencies (e.g., Environmental Protection Agency [EPA], NOAA Fisheries, the Army Corps of Engineers, Natural Resources Conservation Service [NRCS], United States Geological Survey [USGS], Federal Emergency Management Agency [FEMA], and USFWS), created the Puget Sound Federal Task Force (PSFTF). The PSFTF developed a five-year Action Plan (2017-2021) which collaborated on an enhanced approach to implement the Puget Sound Action Plan. The purpose of the Puget Sound Federal Task Force Action Plan is to contribute toward realizing a shared vision of a healthy and sustainable Puget Sound ecosystem by leveraging Federal programs across agencies and coordinating diverse programs on a specific suite of priorities.

In 2021, the PSFTF produced a progress report describing how 99 of the 127 priority Federal actions to protect and restore Puget Sound were 'implemented as described' from the 2017-2021 Action Agenda. These actions included a variety of projects including, but not limited to, improvement to fish passage, restoration of floodplains, riparian, and in-stream habitat, improvements in and monitoring of nearshore and estuary habitat, and investigating and minimizing harmful stormwater runoff (Puget Sound Federal Task Force 2021). In addition to the 2021 report, in 2022 the PSFTF completed an action plan for 2022-2026 to continue to integrate Federal activities and capabilities into implementation of the Puget Sound Action Agenda (Puget Sound Federal Task Force 2022).

While a few Puget Sound indicators of habitat function show mixed results or decline, two are improving according to the Puget Sound Partnership's 2023 State of the Sound report. These indicators, estuaries and streams and floodplains, are both important parts of salmon and steelhead critical habitat. The Puget Sound Partnership (PSP) reports that since 2006, restoration activities have improved connectivity to 3,240 acres of wetland area, equivalent to four percent of total wetland area, primarily in the Snohomish, Nisqually, Skagit, Stillaguamish, and Skokomish deltas. In addition, the PSP reports that since 2011, approximately 3,500 floodplain acres have been reconnected through restoration activities, even though this represents a small percentage of total floodplain area and more than 200,000 acres remain disconnected (Puget Sound Partnership 2023).

Dams constructed for hydropower generation, irrigation, or flood control have substantially affected Puget Sound salmon and steelhead populations in a number of river systems. Habitat utilization by Chinook salmon and steelhead in the Puget Sound area has also been historically limited by large dams and other manmade barriers in a number of drainages, including the Nooksack[4], Skagit, White, Nisqually, Skokomish, and Elwha River basins. In addition to limiting habitat accessibility, dams affect habitat quality through blocked access to spawning and rearing 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 (SSDC 2007). These actions also 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; NMFS 2022j). Such changes can have significant negative impacts on salmonids (e.g., increased water temperatures resulting in decreased disease resistance) (Spence et al. 1996; McCullough 1999).

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. Blockages by dams, water diversions, and shifts in flow regime due to hydroelectric development and flood control projects are major habitat problems in many Puget Sound tributary basins (SSDC 2007; NMFS 2022j).

However, over the past several years, modifications have occurred to existing barriers, which have reduced the number of basins with limited anadromous access to historical habitat. The completion of the Elwha and Glines Canyon dam removals occurred in 2014. The response of fish populations to this action is still being evaluated. It is clear; however, that Chinook salmon and steelhead are accessing much of this newly available habitat. Hatchery operations in the

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[4] A dam that blocked upstream passage to fish on the Middle Fork Nooksack River was removed in July of 2020.

North Fork Skokomish River are ongoing to supplement the winter steelhead population in the lower North Fork, below the Cushman dams. Passage facilities are operational at the dams that would allow access to habitat in the upper North Fork when or if steelhead are passed in the future. A new fish collection facility is operational at the Mud Mountain Dam (White River Basin). Improvements are ongoing to increase the collection efficiency and survival rates, but the facility is expected to improve adult survival and utilization of habitat above the dam. The recent removal of the diversion dam on the Middle Fork Nooksack Dam (16 July 2020) and the Pilchuck River Dam (late 2020) will provide access to important headwater salmonid spawning and rearing habitats. Similarly, the proposed modification of Howard Hanson Dam for upstream fish passage and downstream juvenile collection in the longer term (NMFS 2019b) will allow winter steelhead to return to historical habitat (Ford 2022; NMFS 2022j).

The Nooksack River watershed and associated nearshore area received high conservation value ratings (NMFS 2005b). Critical habitat is designated for Puget Sound Chinook salmon in the Nooksack River watershed action area. Within the watershed, critical habitat extends from the outlet of the Nooksack River upstream to the limits of Chinook salmon access in the SF, MF, and NF Nooksack Rivers, and their tributaries, and includes a lateral extent as defined by the ordinary high-water line (33 CFR 319.11). The entire watersheds of Samish River and Bellingham Bay are excluded from critical habitat. Tribal lands and land managed by Washington State Department of Natural Resources are also excluded from critical habitat.

2.2.1.3. **Life History and Status of the Puget Sound Steelhead DPS**

The Puget Sound steelhead DPS was listed as a threatened species under the ESA on May 11, 2007 (72 FR 26722). Subsequent status assessments of the DPS after the ESA-listing decision have found that the status of Puget Sound steelhead regarding risk of extinction has not changed substantially (81 FR 33468, May 26, 2016) (Ford et al. 2011; NMFS 2016c; Ford 2022). As mentioned above, on October 4, 2019 NMFS published a Federal Register notice (84 FR 53117), announcing NMFS' intent to initiate a new 5-year status review for 28 listed species of Pacific salmon and steelhead and requesting updated information from the public to inform the most recent five-year status review. On March 24, 2020, NMFS extended the public comment period, from the original March 27, 2020, through May 26, 2020 (85 FR 16619). The NWFSC finalized its latest viability assessment, for Pacific Northwest salmon and steelhead listed under the ESA, in January of 2022 (Ford 2022). The NMFS' WCR is currently preparing the five-year status review documents for the Puget Sound region, with anticipated completion in 2024.

At the time of listing, the PSSBRT considered the major risk factors associated with spatial structure and diversity of Puget Sound steelhead to be: (1) the low abundance of several summer run populations; (2) the sharply diminishing abundance of some winter steelhead populations, especially in south Puget Sound, Hood Canal, and the Strait of Juan de Fuca; and (3) continued releases of out-of-DPS hatchery fish from Skamania-derived summer run and Chambers Creek-derived winter run stocks (Hard et al. 2007; Hard et al. 2015). Loss of diversity and spatial structure were judged to be "moderate" risk factors (Hard et al. 2007). In 2011 the BRT identified degradation and fragmentation of freshwater habitat, with consequential effects on connectivity, as the primary limiting factors and threats facing the Puget Sound steelhead DPS (Ford et al. 2011). The BRT also determined that most of the steelhead populations within the DPS continued to show downward trends in estimated abundance, with a few sharp declines

(Ford et al. 2011). The 2015 status review concurred with the earlier BRT review that harvest and hatchery production of steelhead in Puget Sound were at low levels and not likely to increase substantially in the foreseeable future, thus these risks have been reduced since the time of listing. However, unfavorable environmental trends previously identified (Ford et al. 2011a) were expected to continue (Hard et al. 2015). The Ford (2022) assessment also indicated that poor environmental conditions, including warm stream temperatures, reduced summer river flow, and low marine survival are expected to continue and will likely constrain any rebound in VSP parameters for Puget Sound steelhead in the near term

As part of the recovery planning process, NMFS convened The Puget Sound Steelhead Technical Recovery Team (PSSTRT) in 2011 to identify historic populations and develop viability criteria for the recovery plan. The PSSTRT delineated populations and completed a set of population viability analyses (PVAs) for these Demographically Independent Populations (DIPs) and Major Population Groups (MPGs) within the DPS that are summarized in the final draft viability criteria reports (Puget Sound Steelhead Technical Recovery Team 2011; PSSTRT 2013; NWFSC 2015). This framework and associated analysis provided a technical foundation for the recovery criteria and recovery actions identified in the subsequent Puget Sound Steelhead Recovery Plan (NMFS 2019e) at the watershed scale, and higher across the Puget Sound Steelhead DPS.

The populations within the Puget Sound steelhead DPS are aggregated into three extant MPGs containing a total of 32 DIPs (Figure 8) based on genetic, environmental, and life history characteristics (Puget Sound Steelhead Technical Recovery Team 2011; Hard et al. 2015; Ford 2022). Populations 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). Figure 8 illustrates the DPS, MPGs, and DIPs for Puget Sound steelhead.

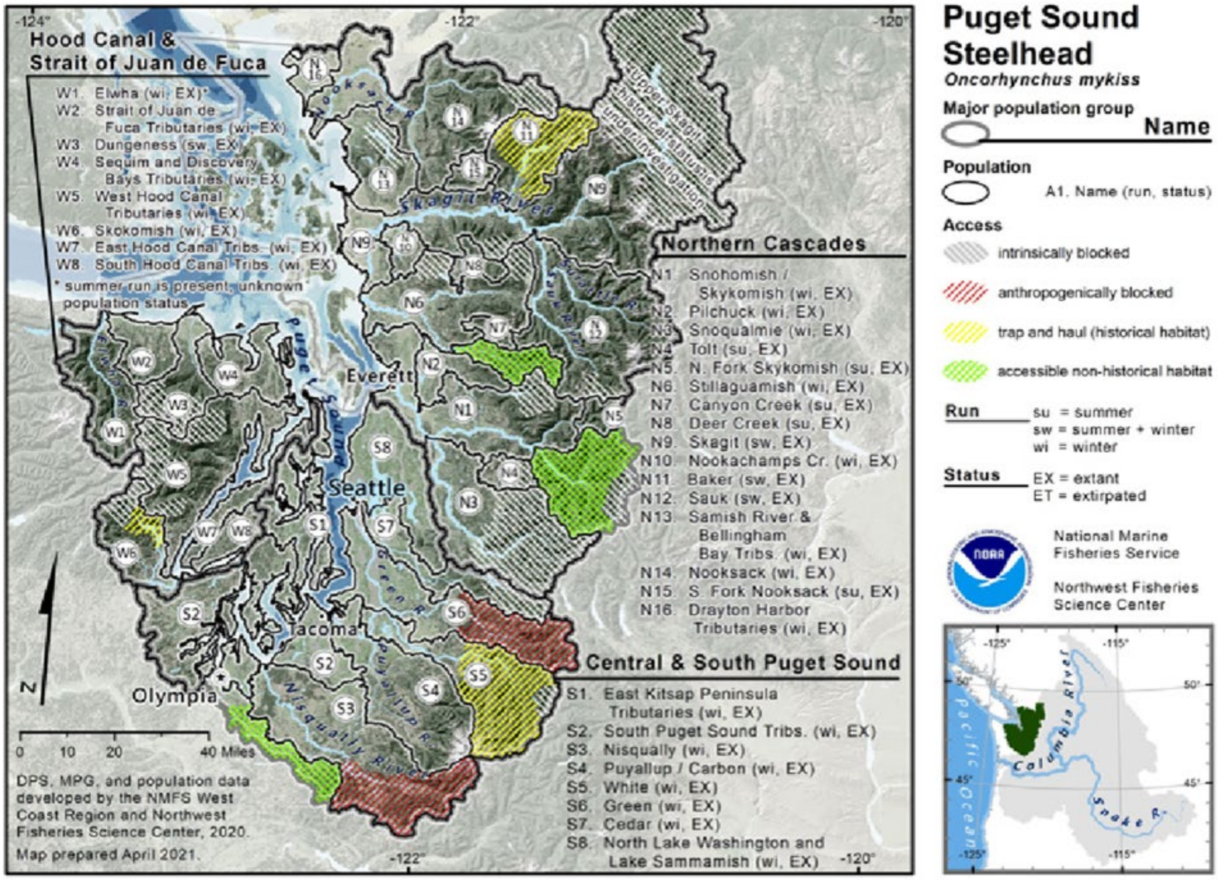

Figure 8. Map of the Puget Sound Steelhead DPS's spawning and rearing areas, identifying 32 demographically independent populations (DIPs) within 3 major population groups (MPGs). The 3 steelhead MPGs are Northern Cascades, Central & South Puget Sound, and Hood Canal & Strait of Juan de Fuca. Areas where dams block anadromous access to historical habitat is marked in red cross-hatching; and areas where historical habitat is accessible via trap and haul programs is marked in yellow cross-hatching. Areas where the laddering of falls has provided access to non-historical habitat is marked in green cross-hatching. Finally, historically inaccessible portions of watersheds are marked in grey and white cross-hatching (Ford 2022).

NMFS adopted a recovery plan for Puget Sound Steelhead on December 20, 2019 (https://www.fisheries.noaa.gov/resource/document/esa-recovery-plan-puget-sound-steelhead-distinct-population-segment-oncorhynchus). The Puget Sound Steelhead Recovery Plan (Plan) (NMFS 2019e)provides guidance to recover the species to the point that it can be naturally self-sustaining over the long term. To achieve full recovery, steelhead populations in Puget Sound need to be robust enough to withstand natural environmental variation and some catastrophic events, and they should be resilient enough to support harvest and habitat loss due to human population growth. The Plan aims to improve steelhead viability by addressing the pressures that contribute to the current condition: habitat loss/degradation, water withdrawals, declining water quality, fish passage barriers, dam operations, harvest, hatcheries, climate change effects, and reduced early marine survival. NMFS is using the recovery plan to organize and coordinate recovery of the species in partnership with state, local, tribal, and federal resource managers, and the many watershed restoration partners in the Puget Sound. Consultations, including this one, will incorporate information from the Plan (NMFS 2019e).

In the Plan, NMFS and the PSSTRT modified the 2013 and 2015 PSSTRT viability criteria to produce the viability criteria for Puget Sound steelhead, as described below:

- All three MPGs (North Cascade, Central-South Puget Sound, and Hood Canal-Strait of Juan de Fuca) (Figure 8) must be viable (Hard et al. 2015). The three MPGs differ substantially in key biological and habitat characteristics that contribute in distinct ways to the overall viability, diversity, and spatial structure of the DPS.
- There must be sufficient data available for NMFS to determine that each MPG is viable.

The Plan (NMFS 2019e) also established MPG-level viability criteria. The following are specific criteria are required for MPG viability:

- At least 50 percent of steelhead populations in the MPG achieve viability.
- Natural production of steelhead from tributaries to Puget Sound that are not identified in any of the 32 identified populations provides sufficient ecological diversity and productivity to support DPS-wide recovery.
- In addition to the minimum number of viable DIPs (50%) required above, all DIPs in the MPG must achieve an average MPG-level viability that is equivalent to or greater than the geometric mean (averaged over all the DIPs in the MPG) viability score of at least 2.2 using the 1–3 scale for individual DIPs described under the DIP viability discussion in the PSSTRT Viability Criteria document (Hard et al. 2015). This criterion is intended to ensure that MPG viability is not measured (and achieved) solely by the strongest DIPs, but also by other populations that are sufficiently healthy to achieve MPG-wide resilience. The Plan allows for an alternative evaluation method to that in Hard et al. (2015) may be developed and used to assess MPG viability.

The Plan (NMFS 2019e) also identified specific DIPs in each of the three MPGs which must attain viability. These DIPs, by MPG, are described as follows:

For the **North Cascades MPG** eight of the sixteen DIPs in the North Cascades MPG must be viable. The eight (five winter-run and three summer-run) DIPs described below must be viable to meet this criterion:

- Of the eleven DIPs with winter or winter/summer runs, five must be viable:
- Nooksack River Winter-Run;
- 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.

The rationale for this is that there are four major watersheds in this MPG, and one viable population from each will help attain geographic spread and habitat diversity within core extant steelhead habitat (NMFS 2019e). Of the five summer-run DIPs in this MPG, three must be viable, representing each of the three major watersheds containing summer-run populations (Nooksack, Stillaguamish, Snohomish rivers). Therefore, the priority summer-run populations are as follows:

- 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).

As described, these priority populations in the North Cascades MPG include specific, winter or winter/summer-run populations from the Nooksack, Stillaguamish, Skagit or Sauk, and Snohomish River basins and three summer-run populations from the Nooksack, Stillaguamish, and Snohomish basins. These populations are targeted to achieve viable status to support MPG viability. Having viable populations in these basins assures geographic spread, provides habitat diversity, reduces catastrophic risk, and increases life-history diversity (NMFS 2019e).

For the **Central and South Puget Sound MPG** four of the eight DIPs in the Central and South Puget Sound MPG must be viable. The four DIPs described below must be viable to meet this criterion:

- 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 Puget Sound Tributaries, or East Kitsap Peninsula Tributaries.

The rationale for this prioritization is that steelhead inhabiting the Green, Puyallup, and Nisqually River watersheds currently represent the core extant steelhead populations and these watersheds contain important diversity of stream habitats in the MPG.

For the **Hood Canal and Strait of Juan de Fuca MPG** four of the eight DIPs in the Hood Canal and Strait of Juan de Fuca MPG must be viable. The four DIPs described below must be viable to meet this criterion:

- Elwha River Winter/Summer-Run (see rationale below);
- Skokomish River Winter-Run;
- One from the remaining Hood Canal populations: West Hood Canal Tributaries Winter-Run, East Hood Canal Tributaries Winter-Run, or South Hood Canal Tributaries Winter-Run; and
- One from the remaining Strait of Juan de Fuca populations: Dungeness Winter-Run, Strait of Juan de Fuca Tributaries Winter-Run, or Sequim/Discovery Bay Tributaries Winter-Run.

The rationale for this prioritization is that the Elwha and Skokomish rivers are the two largest single watersheds in the MPG and bracket the geographic extent of the MPG. Furthermore, both Elwha and Skokomish populations have recently exhibited summer-run life histories, although the Dungeness River population was the only summer/winter run in this MPG recognized by the PSTRT in Hard et al. (2015). Two additional populations, one population from the Strait of Juan de Fuca area and one population from the Hood Canal area, are needed for a viable MPG to maximize geographic spread and habitat diversity.

Lastly, the Plan (NMFS 2019e) also identified additional attributes, or characteristics which should be associated with a viable MPG.

- All major diversity and spatial structure conditions are represented, based on the following considerations:
- Populations are distributed geographically throughout each MPG to reduce risk of catastrophic extirpation; and
- Diverse habitat types are present within each MPG (one example is lower elevation/gradient watersheds characterized by a rain-dominated hydrograph and higher elevation/gradient watersheds characterized by a snow-influenced hydrograph).

Federal and State steelhead recovery and management efforts will provide new tools and data and technical analyses to further refine Puget Sound steelhead population structure and viability, if needed, and better define the role of individual populations at the watershed level and in the DPS.

Spatial Structure and Diversity

The Puget Sound Steelhead DPS includes all naturally spawned anadromous *O. mykiss* (steelhead) populations originating below natural and manmade impassable barriers from rivers flowing into Puget Sound from the Elwha River (inclusive) eastward, including rivers in Hood Canal, South Sound, North Sound and the Strait of Georgia. Non-anadromous ‘‘resident’’ *O. mykiss* occur within the range of Puget Sound steelhead but are not part of the DPS due to marked differences in physical, physiological, ecological, and behavioral characteristics (Hard et al. 2007). In October of 2016, NMFS proposed revisions to inclusion of the hatchery programs as part of Pacific salmon ESUs and steelhead DPSs listed under the ESA (81 FR 72759). NMFS issued its final rule in December of 2020 (85 FR 81822). This final rule includes steelhead from five artificial propagation programs in the Puget Sound steelhead DPS: the Green River Natural Program; White River Winter Steelhead Supplementation Program; Hood Canal Steelhead and the Fish Restoration Facility Program (85 FR 81822, December 17, 2020).

In 2013, the PSSTRT completed its evaluation of factors that influence the diversity and spatial structure VSP criteria for steelhead in the DPS. For spatial structure, this included the fraction of available intrinsic potential rearing and spawning habitat that is occupied compared to what is needed for viability. For diversity, these factors included hatchery fish production, contribution of resident fish to anadromous fish production, and run timing of adult steelhead. Quantitative information on spatial structure and connectivity was not available for most Puget Sound steelhead populations, so a Bayesian Network framework was used to assess the influence of these factors on steelhead viability at the population, MPG, and DPS scales. The PSSTRT concluded that low population viability was widespread throughout the DPS and populations showed evidence of diminished spatial structure and diversity. Specifically, population viability associated with spatial structure and diversity was highest in the Northern Cascades MPG and lowest in the Central and South Puget Sound MPG (Puget Sound Steelhead Technical Recovery Team 2011). Diversity was generally higher for populations within the Northern Cascades MPG, where more variability in viability was expressed and diversity generally higher, compared to populations in both the Central and South Puget Sound and Hood Canal and Strait of Juan de

Fuca MPG, where diversity was depressed and viabilities were generally lower (NWFSC 2015). Most Puget Sound steelhead populations were given intermediate scores for spatial structure and low scores for diversity because of extensive hatchery influence, low breeding population sizes, and freshwater habitat fragmentation or loss (NWFSC 2015). The Puget Sound Steelhead Technical Recovery Team (PSSTRT) concluded that the Puget Sound DPS was at very low viability, considering the status of all three of its constituent MPGs, and many of its 32 DIPs (Hard et al. 2015). For spatial structure there were a number of events that occurred in Puget Sound during the last review period (since 2015) that are anticipated to improve status populations within several of the MPGs within the DPS. These will be discussed further in the Environmental Baseline Section 2.4 below.

Since the PSSTRT completed its 2013 review, there have been a number of genetic studies related to Puget Sound steelhead population structure and hatchery-origin steelhead introgression. Additional analyses of Puget Sound steelhead population demographics, distribution, and habitat are provided in the 2019 recovery Plan (Ford 2022). Since publication of the NWFSC report in 2015, reductions in hatchery programs founded from non-listed and out-of-DPS stocks (i.e., Skamania) have occurred. The magnitude of these changes will be discussed in detail in Section 2.4.1. In addition, the fraction of out-of-DPS hatchery steelhead spawning naturally are low for many rivers (NWFSC 2015; NMFS 2016c). The fraction of natural-origin steelhead spawners was 0.9 or greater for the 2005-2009 and 2010-2014 time periods for all populations where data was available. For 17 of 22 DIPs across the DPS, the five-year average for the fraction of natural-origin steelhead spawners exceeded 0.75 from 2005 to 2009; this average was near 1.0 for 8 populations, where data were available, from 2010 to 2014 (NWFSC 2015). However, the fraction of natural-origin steelhead spawners could not be estimated for a substantial number of DIPs during the 2010-2014 period, or for the most recent 2015-2019 timeframe (Ford 2022). In some river systems, such as the Green River, Snohomish/Skykomish Rivers, and the Stillaguamish Rivers the estimated levels of hatchery-origin spawners were higher than some guidelines recommend (e.g., no more than 5% hatchery-origin spawners on spawning grounds for isolated hatchery programs (HSRG 2009) over the 2005- 2009 and 2010-2014 timeframes. The 2022 NWFSC Biological Viability Assessment (Ford 2022) states that a third of the 32 Puget Sound steelhead populations continue to lack monitoring of abundance data, and in most cases it is likely that abundances are very low. Steelhead hatchery programs are discussed in further detail in the Environmental Baseline (Section 2.4.3).

Early winter-run fish produced in isolated hatchery programs are derived from Chambers Creek stock in southern Puget Sound, which has been selected for early spawn timing, a trait known to be inheritable in salmonids. Summer-run fish produced in isolated hatchery programs were historically derived from the Skamania River summer stock in the lower Columbia River Basin (i.e., from outside the DPS). The production and release of hatchery fish of both run types (winter and summer) may continue to pose risk to diversity in natural-origin steelhead in the DPS, as described in Hard et al. (2007) and Hard et al. (2015). However, the 2022 NWFSC Biological Viability Assessment (Ford 2022) states that risks to natural-origin Puget Sound steelhead that may be attributable to hatchery-related effects has decreased since the 2015 status review due to reductions in production of non-listed stocks, and the replacement with localized stocks. The three summer steelhead programs continuing to propagate Skamania derived stocks from outside of Puget Sound should be phased out completely by 2031(NMFS 2019e; Ford

2022). Lastly, annual reporting from the operators and current science suggest that risks remain at the same low to negligible levels as evaluated in 2016 and 2019 (NMFS 2016c; 2019e).

More information on Puget Sound steelhead spatial structure and diversity can be found in NMFS's PSSTRT viability report and NMFS's status review update on salmon and steelhead (NWFSC 2015; Ford 2022).

Abundance and Productivity

Steelhead abundance estimates are available for seven of the 11 winter-run DIPs and one of the five summer-run DIPs in the Northern Cascades MPG, five of the eight winter-run DIPs in the Central and South Puget Sound MPG, and seven of the eight winter-run DIPs in the Hood Canal and Strait of Juan de Fuca MPG. Little or no data is available on summer run populations to evaluate extinction risk or abundance trends. Due to their small population size and the complexity of monitoring fish in headwater holding areas, summer steelhead have not been broadly monitored. Data continue to only be available for one summer-run DIP, the Tolt River steelhead population in the Northern Cascades MPG for the 2015-2019-time frame.

Long-term abundance of steelhead in populations for which data are currently available (Figure 7) has shown a generally declining trend across much of the DPS over the full period of the abundance data available for each DIP; however, the latest biological viability assessment update notes that in the nearer term, there has been a relative improvement in abundance and productivity (Ford 2022). Since 2015, 14 of the 22 populations indicate small to substantive increases in abundance, though most steelhead populations remain small. From 2014 to 2019, eight of the 22 steelhead populations had fewer than 250 natural spawners annually, and 12 of the 22 steelhead populations had 500 or fewer natural spawners (Figure 9).

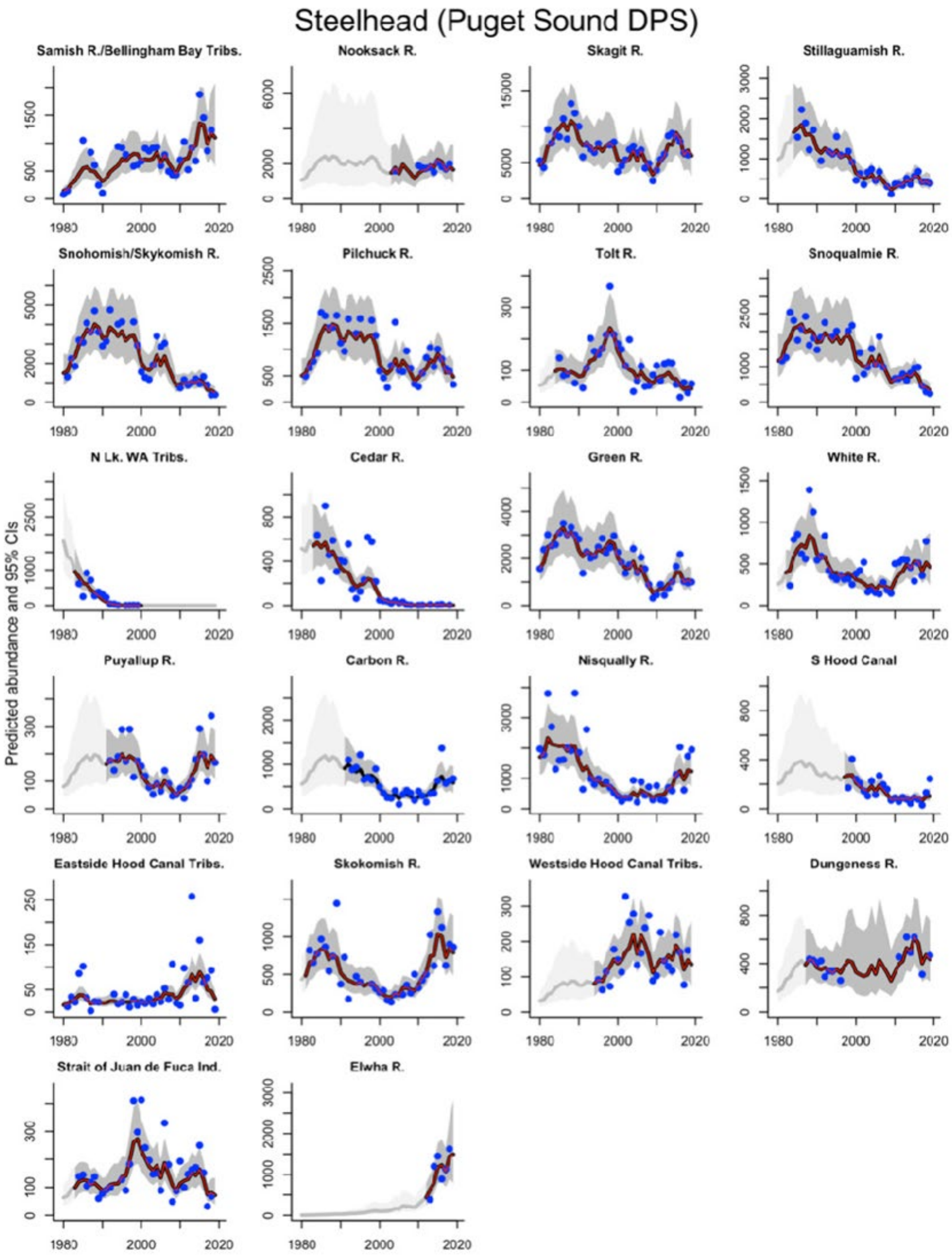

Figure 9. Smoothed trends of estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) Puget Sound steelhead population spawning abundances. In portions of a time series where a population has no annual estimates, but smoothed spawning abundance is estimated from correlations with other populations, the smoothed estimate is shown in light gray. Points show the annual raw spawning abundance estimates. For some trends, the smoothed estimate may be influenced by earlier data points not included in the plot. Note; for this DPS, all abundance data are only natural-origin spawners. No information on hatchery

fraction is available (Ford 2022).

Table 14. Five-year geometric mean of raw natural spawner counts for Puget Sound steelhead. This is the raw total spawner count times the fraction natural estimate, if available. In parentheses, the 5-year geometric mean of raw total spawner counts is shown. A value only in parentheses means that a total spawner count was available but none or only one estimate of natural spawners was available. A single value not in parentheses means that the fraction natural was 1.0 and thus, the total count was the same as the natural-origin count. The geometric mean was computed as the product of counts raised to the power 1 over the number of counts available (2 to 5). A minimum of 2 values was used to compute the geometric mean. Percent change between the most recent two 5-year periods is shown on the far right. Key: HCSJF = Hood Canal & Strait of Juan de Fuca MPG; NC = Northern Cascades MPG; CPSC = Central & South Puget Sound MPG; W = winter; Su = summer (Ford 2022).

Population	MPG	1990-94	1995-99	2000-04	2005-09	2010-14	2015-19	% Change
South Hood Canal W	HCSJF	—	263	176	145	69	91	32
Eastside Hood Canal Tributaries W	HCSJF	27	21	25	37	60	54	–10
Skokomish River W	HCSJF	385	359	205	320	533	938	76
Westside Hood Canal Tributaries W	HCSJF	—	97	208	167	138	150	9
Dungeness River Su and W	HCSJF	356	—	—	—	517	448	–13
Strait of Juan de Fuca and Independent Tributaries W	HCSJF	89	191	212	118	151	95	–37
Elwha River W	HCSJF	—	—	—	—	680	1,241	82
Samish River/Bellingham Bay Tributaries W	NC	316	717	852	535	748	1,305	74
Nooksack River W	NC	—	—	—	—	1,745	1,906	9
Skagit River Su and W	NC	7,202	7,656	5,419	4,677	6,391	7,181	12
Stillaguamish River W	NC	1,078	1,166	550	327	386	487	26
Snohomish/Skykomish Rivers W	NC	3,629	3,687	1,718	2,942	975	690	–29
Pilchuck River W	NC	1,225	1,465	604	597	626	638	2
Snoqualmie River W	NC	1,831	2,056	1,020	1,250	706	500	–29
Tolt River Su	NC	112	212	119	70	108	40	–63
North Lake Washington Tributaries W	CSPS	60	4	—	—	—	—	—
Cedar River W	CSPS	241	295	37	12	4	6	50
Green River W	CSPS	2,062	2,585	1,885	1,045	662	1,289	95
White River W	CSPS	524	311	301	173	514	451	–12
Puyallup River W	CSPS	167	196	93	72	85	201	136
Carbon River W	CSPS	969	800	335	246	290	735	153

Population	MPG	1990-94	1995-99	2000-04	2005-09	2010-14	2015-19	% Change
Nisqually River W	CSPS	1,200	754	409	446	477	1,368	187

The current abundance for Puget Sound steelhead populations, as estimated for the 2015-2019 time period (NMFS 2019e; WDFW 2021; Ford 2022) is based on data for less than 40 percent of the DIPs (WDFW 2021). However, these data indicate that the Puget Sound steelhead DPS is currently at less than 25% of recovery goals, as identified for the DIPs which had sufficient data to assess (WDFW 2021). Where recent five-year abundance information is available, 30% (6 out of 20) of the populations are at less than 10% of their High Productivity Recovery Targets (lower abundance target), 65% (13 out of 20) of the populations are between 10% and 50% of lower abundance recovery targets, and 5% (1 out of 20) of populations are at 50% and 100% of the recovery target (Table 14)(Ford 2022).

Steelhead productivity has been variable for most populations since the mid-1980s (Figure 10). Since around 2000, productivity has fluctuated around replacement for Puget Sound steelhead populations, but the majority have predominantly been below replacement (NWFSC 2015; Ford 2022). Some steelhead populations have shown signs that productivity has been above replacement in the most recent years for which data are available (2015-2019) (Figure 10). Steelhead populations with recent productivity estimates generally above replacement include the Samish River, Nooksack River, Skagit River, Green River, White River, Puyallup River, Nisqually River, the South, East, and West Hood Canal Tributaries, the Skokomish River, and the Elwha River (Figure 10)(NWFSC 2015; Ford 2022).

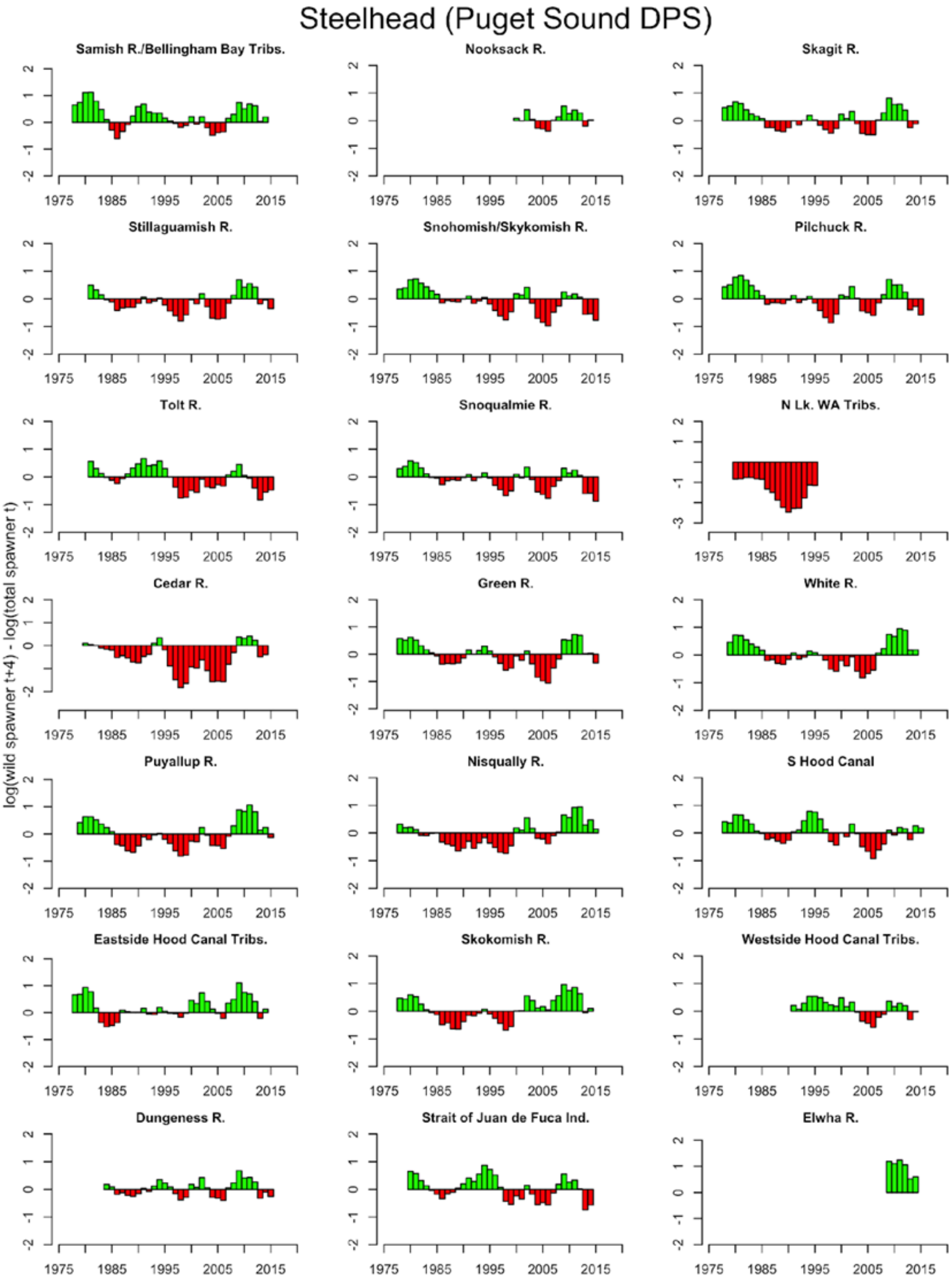

Figure 10. Trends in population productivity of Puget Sound steelhead, estimated as the log of the smoothed natural spawning abundance in year t minus the smoothed natural spawning abundance in year (t – 4) (Ford 2022).

Harvest can affect the abundance and overall productivity of Puget Sound steelhead. Since the 1970s and 1980s, harvest rates have differed greatly among various watersheds, but all harvest rates on Puget Sound steelhead in the DPS have declined (NWFSC 2015a). From the late 1970s to early 1990s, harvest rates on natural-origin steelhead averaged between 10% and 40%, with some populations in central and south Puget Sound at over 60%. Harvest rates on natural-origin steelhead vary widely among watersheds, but have declined since the 1970s and 1980s, and are now stable at generally less than 5% (see Figure 11)(NWFSC 2015; WDFW and PSTIT 2021; Ford 2022; WDFW and PSTIT 2022; 2023b; PSTIT and WDFW 2024).

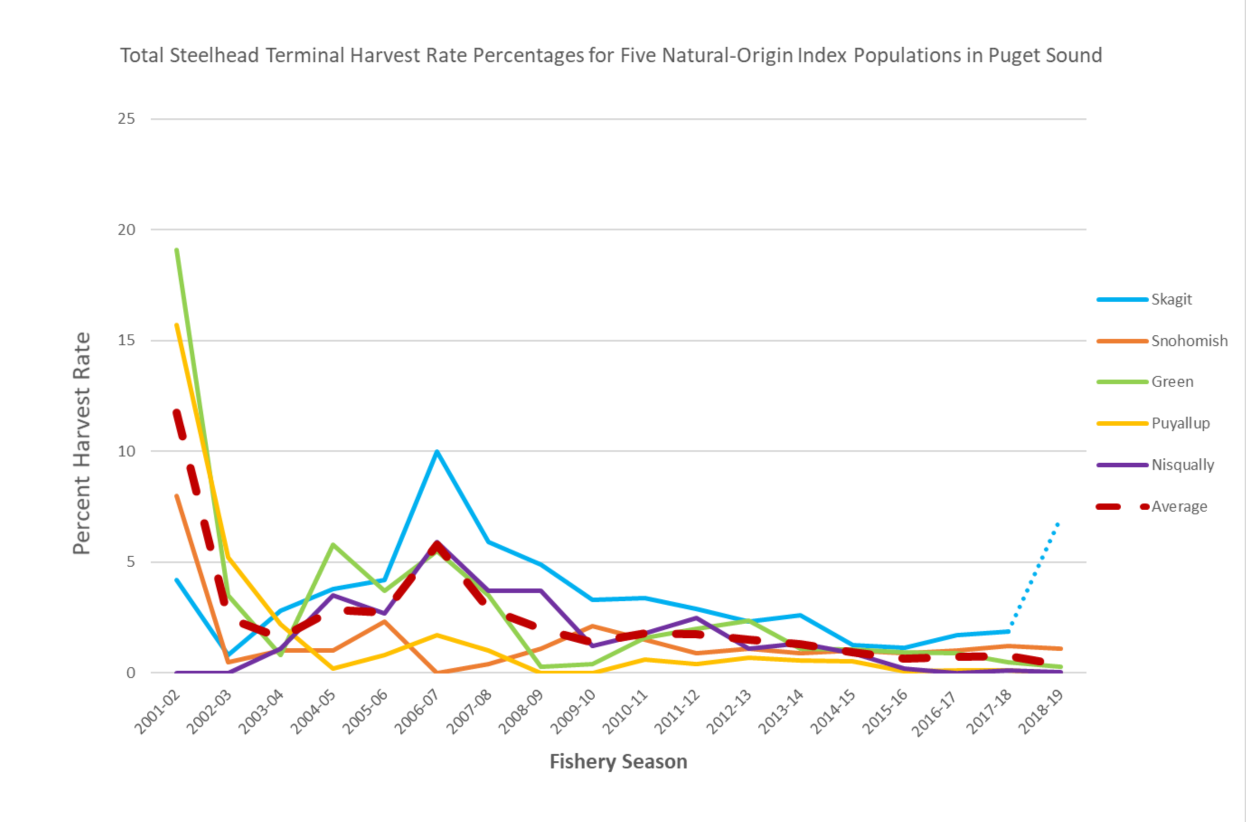

Figure 11. Total Steelhead Terminal Harvest Rate Percentages for Five Natural-Origin Index Populations in Puget Sound from 2001-2019 (NWFSC 2015a; WDFW and PSIT 2016; 2017; WDFW and PSTIT 2018a; 2019; 2020). The dotted line represents harvest rates specific to natural-origin steelhead within the Skagit basin, as reported annually under the Skagit Steelhead Resource Management Plan (RMP) approved by NMFS in 2018 (NMFS 2018a).

Overall, the status of steelhead based on the best available data on spatial structure, diversity, abundance, and productivity has improved since the last status review in 2015 (Ford 2022). Recent increases in abundance observed for the majority (15 out of 21) of steelhead DIPs where data are available from 2015-2019 have been modest, and are generally within the range of variability observed in the time series for which data is available (NWFSC 2015). The production of hatchery fish founded from non-listed stocks of both run types (Chambers (EWS) winter and Skamania (ESS) summer) continues to pose risk to diversity to natural-origin steelhead in the DPS (Hard et al. 2007; Hard et al. 2015; NMFS 2019e; Ford 2022). However, hatchery production has declined in recent years across the DPS, especially for non-listed stocks, and the fraction of hatchery spawners are low for many rivers. In addition, discontinuation of the release of Skamania hatchery-origin summer-run steelhead from the three programs currently operating is planned for the near future (Ford 2022).

Increasing estimates of productivity for a few steelhead populations during the 2011-2015 time frame are encouraging but included only one to a few years, thus, the patterns of improvement in productivity were not widespread, or considered certain to continue into the 2015-2019 time frame (Hard et al. 2015), nor where they widespread or consistent across the MPGs for the 2015-2019 period based on the (Ford 2022). Total harvest rates continue to be at the low levels considered in the last two status updates (NWFSC 2015; Ford 2022), and the Recovery Plan (NMFS 2019e) to be unlikely to substantially reduce spawner abundance for most Puget Sound steelhead populations. These rates are unlikely to increase substantially in the foreseeable future. Recovery efforts in conjunction with improved ocean and climatic conditions have resulted in improved status for the majority of populations in this DPS; however, absolute abundances are still low, especially summer-run populations, and the DPS remains at high to moderate risk (Ford 2022).

Limiting factors

NMFS, in its listing document and designation of critical habitat (77 FR 26722, May 11, 2007; 76 FR 1392, January 10, 2011), noted that the factors for decline for Puget Sound steelhead also persist as limiting factors. Limiting factors are defined as impaired physical, biological, or chemical features (e.g., inadequate spawning habitat, high water temperature, insufficient prey resources) and associated ecological processes and interactions experienced by the fish that result in reductions in VSP parameters (abundance, productivity, spatial structure, and diversity). This analysis, combined with (Ford 2022) and the Puget Sound Steelhead Recovery Plan (NMFS 2019e), identified the following factors, as well as ten primary pressures associated with the listing decision for Puget Sound steelhead, and subsequent affirmations of the listing, as those limiting steelhead recovery:

- In addition to being a factor that contributed to the present decline of Puget Sound steelhead populations, the continued destruction and modification of steelhead habitat is the principal factor limiting the viability of the Puget Sound steelhead DPS into the foreseeable future. This includes agriculture, residential, commercial and industrial development (including impervious surface runoff), timber management activities, water withdrawals and altered flows.
- Fish passage barriers at road crossings and dams.
- Reduced spatial structure for steelhead in the DPS.
- Reduced habitat quality through changes in river hydrology and temperature profile, which are expected to increase with continuing climate change.
- Reduced downstream gravel recruitment, and reduced movement of large woody debris.
- In the lower reaches of many rivers and their tributaries in Puget Sound, urbanization has caused increased flood frequency and peak flows during storms, and reduced groundwater-driven summer flows. Altered stream hydrology has resulted in gravel scour, bank erosion, and sediment deposition.

- Dikes, hardening of banks with riprap, and channelization, which have reduced river braiding and sinuosity, have increased the likelihood of gravel scour and dislocation of rearing juveniles.
- Widespread declines in adult abundance (total run size), despite significant reductions in harvest over the last 25 years. Harvest is not considered a significant limiting factor for PS steelhead due to low harvest rates.
- Threats to genetic diversity and of ecological interactions posed by use of two hatchery steelhead stocks (Chambers Creek and Skamania) inconsistent with wild stock recovery throughout the DPS. However, the risk to the species' persistence that may be attributable to hatchery-related effects has declined since the last status review, based on hatchery risk reduction measures that have been implemented. Improvements in hatchery operations associated with on-going ESA review and determination processes are expected to reduce hatchery-related risks. Further, hatchery releases of steelhead founded from non-native or out of DPS stocks have declined, and are expected to decrease further or cease as a term of recent 4(d) authorizations.
- Declining diversity in the DPS, including the uncertain, but likely weak, status of summer run fish in the DPS.
- High rates of juvenile mortality in estuarine and marine waters of Puget Sound, attributed to marine mammal predation, parasite prevalence, and contaminant loads.
- Concerns regarding existing regulatory mechanisms, including: lack of documentation or analysis of the effectiveness of land-use regulatory mechanisms and land-use management plans, lack of reporting and enforcement for some regulatory programs, certain Federal, state, and local land and water use decisions continue to occur without the benefit of ESA review. State and local decisions have no Federal nexus to trigger the ESA Section 7 consultation requirement, and thus certain permitting actions allow direct and indirect species take and/or adverse habitat effects.

Northern Cascades MPG

Winter-run steelhead are the predominant life history type in Puget Sound. They return to watersheds in the fall or winter and spawn in the spring. Winter-run steelhead are often restricted to low and middle reaches of watersheds below cascades and waterfalls due to lower flows at the time of year they return (NMFS 2019e). Summer-run steelhead returns from the ocean in the late spring and summer. They can travel higher in the watershed and through canyons due to higher flows during this time of year. Summer-run steelhead hold in deep, cool water pools for up to nine months before spawning in the late winter or early spring (NMFS 2019e). There are 16 DIPs the Northern Cascades MPG that includes populations from the Canadian border to the Snohomish River Basin corresponding to the ecological region between the North Cascades and Cascades. This MPG includes the majority of existing summer run steelhead populations in the ESU with five summer run DIPs (SF Nooksack, Deer, Canyon, NF Skykomish, Tolt), three summer/winter run DIPs (Skagit, Baker, Sauk), and eight winter-run DIPs (Drayton Harbor Tributaries, Nooksack, Samish/Bellingham Bay, Nookachamps, Stillaguamish, Snohomish/Skykomish, Pilchuck, Snoqualmie) (Figure 8). Over the last five year period there has been considerable variability in the abundance and productivity of the Northern Cascades DIPs. The Samish River and Bellingham Bay winter-run populations have increased by 74% in the five year geometric mean abundance while the Stillaguamish winter-run population exhibited a moderate increase and the winter-run

Nooksack and Skagit DIPs had only had slight increases. The only summer-run DIP for which there is long term data, the Tolt, exhibited a 63% decline in five year abundance during the most recent period (Table 14). However, abundance of spawners for all DIPs in the Northern Cascades MPG remain well below the respective recovery targets. Abundance for DIPs in the Snohomish River were stable or slightly negative. Productivity for five of the DIPs in the North Cascade MPG is negative indicating downward trends in future abundance (Ford 2022).

Affected Steelhead Populations

The PSSTRT delineated two extant steelhead populations that are native to the Nooksack River watershed and part of the listed Puget Sound steelhead DPS: Nooksack River winter-run and SF Nooksack summer-run (Myers et al. 2015). The Nooksack winter-run DIP spawns in all three forks and several mainstem tributaries of the Nooksack River from mid-February to mid-June. Historical estimates from in-river harvest suggest that there was a substantial run of steelhead into the Nooksack Basin in the early 1900s. Spawner surveys of the North Fork and Middle Fork Nooksack rivers in 1930 identified a number of tributaries that supported steelhead (Myers et al. 2015). The current abundance of the Nooksack River winter-run population is estimated to be 1,850 spawners with a recovery goal of 6,500 to 21,700 spawners depending on productivity (NMFS 2019e). The estimated five-year geometric mean natural spawner count increased 9% for the most recent five-year period 2015-2019 as compared to the previous five year period 2010-2014, from 1,745 to 1,906 spawners; Table 14) (Ford 2022).

The SF Nooksack summer-run steelhead population spawn in the upper mainstem SF Nooksack River and in upper river tributaries above a series of falls and cascades from February to April (Myers et al. 2015). Adult steelhead enter the SF Nooksack River and migrate upstream from April to October and juvenile steelhead outmigrate beginning in March through July (Natural Systems Design 2021). Preliminary genetics evidence suggests the summer- and winter-run Nooksack River steelhead populations are genetically distinct from one another (Myers et al. 2015). There are no estimates for spawner abundance for this population. This population exists but at very low spawner abundance (NMFS 2019e; Ford 2022). Although this summer-run steelhead population is likely very small currently, the recovery goal is 400 to 1,300 spawners depending on productivity (NMFS 2019e).

Outside of the Nooksack watershed, a DIP is recognized in the Samish River and in a series of independent tributaries and creeks that drain into Samish and Bellingham Bay. The Samish River and Bellingham Bay Tributaries winter-run DIP spawns in a lowland basin with rain dominated flow. The main spawning areas are in Friday Creek and the Samish River with the majority of spawning occurring from mid-February to mid-June. The current spawner abundance is 1,090 with a recovery goal of 1,800 to 6,100 depending on productivity (NMFS 2019e). The estimated five-year geometric mean natural spawner count increased 74% for the most recent five-year period 2015-2019 as compared to the previous five year period 2010–2014, from 748 to 1,305 spawners (Table 14) (Ford 2022).

There are no evidence of steelhead populations on the San Juan islands where Glenwood Springs Hatchery is operated (Myers et al. 2015).

Spatial structure of the Nooksack winter-run steelhead natural population has been reduced by habitat loss and degradation in the watershed. The impassable MF diversion dam reduced access to habitat. Prior to the construction of the diversion dam, the MF Nooksack may have supported a summer-run steelhead run (Myers et al. 2015). Dikes, levees and other actions to control the lower reaches of the river and tributaries have reduced natural population spatial structure, particularly through adverse impacts on side channel habitat and increased scour of redds (Haring 1999). These actions have degraded available spawning and migration areas for adult fish, and refugia for rearing juvenile steelhead. Water withdrawals for irrigation and residential use have substantially reduced flows needed during the adult steelhead upstream migration and spawning periods, forcing adults to construct spawning redds in channel areas that are extremely susceptible to sediment scour and aggradation.

Available data indicate that steelhead diversity in the Nooksack River watershed has declined relative to historical levels. It is likely that a summer-run Nooksack River steelhead return was extirpated when the MF diversion dam was constructed (Myers et al. 2015). As with Chinook salmon in the watershed, degradation and loss of habitat in the watershed, and past harvest practices, have reduced the diversity of the species in general relative to historical levels. Releases of non-native early winter steelhead (EWS) from Kendall Creek Hatchery have likely reduced genetic diversity of the native winter-run population in watershed areas where spawn timings for natural and hatchery-origin fish have over-lapped. However, there are no genetic data indicating that introgression associated with planting of the non-native stock has occurred and there are no genetic samples available from populations from before the EWS hatchery programs began (NMFS 2016b).

2.2.1.4. **Status of Critical Habitat for Puget Sound Steelhead**

Critical habitat for Puget Sound steelhead was designated on February 24, 2016 (81 FR 9252). Steelhead critical habitat includes 2,031 stream miles. Critical habitat for Puget Sound steelhead includes freshwater spawning sites, freshwater rearing sites, and freshwater migration corridors.

There are 66 watersheds within the range of this DPS (NMFS 2022j). NMFS also designated approximately 90 stream miles of critical habitat on the Kitsap Peninsula, which were originally proposed for exclusion, after considering public comments and determining that the benefits of exclusion did not outweigh the benefits of designation. The final designation also includes areas in the upper Elwha River where the recent removal of two dams now provides access to areas that were previously unoccupied by Puget Sound steelhead at the time of listing, but are essential to the conservation of the DPS.

NMFS (2015a) could not identify “specific areas” within the marine and ocean range that meet the definition of critical habitat. Offshore marine waters were not designated as critical habitat for this species. Additionally, designated critical habitat for Puget Sound steelhead does not include nearshore areas, as this species does not make extensive use of these areas during the juvenile life stage. Instead, NMFS considered the adjacent marine areas in Puget Sound when designating steelhead freshwater and estuarine critical habitat. Approximately 138 stream miles, in areas where the conservation benefit to the species was relatively low (compared to the economic impacts of inclusion), were also excluded. Additionally, an approximate 1,361 stream miles covered by four habitat conservation plans, and approximately 70 stream miles on tribal lands, were excluded because the benefits of exclusion outweighed the benefits of designation. Critical habitat information for Puget Sound steelhead can be found online at: http://www.westcoast.fisheries.noaa.gov/protected_species/salmon_steelhead/salmon_and_steelhead_listings/steelhead/puget_sound/puget_sound_steelhead_proposed_critical_habitat_supporting_information.html.

Physical or biological features involve those sites and habitat components that support one or more life stages, including general categories of: (1) water quantity, quality, and forage to support spawning, rearing, individual growth, and maturation; (2) areas free of obstruction and excessive predation; and (3) the type and amount of structure and complexity that supports juvenile growth and mobility. For salmon and steelhead, NMFS ranked watersheds within designated critical habitat in terms of the conservation value they provide to each listed species they support at the scale of the fifth-field hydrologic unit code (HUC5). 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 (NMFS 2005b; 2022j).

As of 2019 approximately 8,000 culverts that block steelhead habitat have been identified in Puget Sound (NMFS 2019e), with plans to address these blockages being extended over many years. Smaller scale improvements in habitat, restoration of riparian habitat and reconnecting side- or off-channel habitats, will allow better access to habitat types and niche diversification. While there have been some significant improvements in restoring access, it is recognized that land development, loss of riparian and forest habitat, loss of wetlands, demands on water allocation all continue to degrade the quantity and quality of available fish habitat (Ford 2022; NMFS 2022j).

In summary, even with restoration success, like dam removal and blocked culverts being addressed, critical habitat for salmon and steelhead throughout the Puget Sound basin continues to be 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. As mentioned above, development of shoreline and estuary areas of Puget Sound is expected to continue to adversely impact the quality of marine habitat for PS salmonids. Projected changes in nearshore and estuary development based on documented rates of developed land cover change in Bartz et al. (2015) show that between 2008 and 2060, an additional 14.7 hectares of development of shoreline areas and 204 hectares of estuary development can be expected.

NMFS determines the range-wide status of critical habitat by examining the condition of its physical and biological features (also called "primary constituent elements," or PCEs, in some designations) that were identified when the critical habitat was designated (81 FR 9252, February 24, 2016). 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). PCEs for Puget Sound steelhead include:

- Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation and larval development;
- Freshwater rearing sites with: (i) Water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; (ii) Water quality and forage supporting juvenile development; and (iii) Natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.
- Freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival;
- Estuarine areas free of obstruction and excessive predation with: (i) Water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh- and saltwater; (ii) Natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels; and (iii) Juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation.
- Nearshore marine areas free of obstruction and excessive predation with: (i) Water quality and quantity conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation; and (ii) Natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels.
- Offshore marine areas with water-quality conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation.

The Puget Sound CHART found that habitat utilization by steelhead in a number of Puget Sound areas has been substantially affected by large dams and other manmade barriers in a number of drainages (NMFS 2013b). Affected areas include the Nooksack, Skagit, White, Nisqually, Skokomish, and Elwha River basins. In addition to limiting habitat accessibility, dams have affected steelhead habitat quality through changes in river hydrology, altered temperature profile, reduced downstream gravel recruitment, and the reduced recruitment of large woody debris. In addition, many upper tributaries in the Puget Sound region have been affected by poor forestry practices, while many of the lower reaches of rivers and their tributaries have been altered by agriculture and urban development. Urbanization has caused direct loss of riparian vegetation and soils, significantly altered hydrologic and erosional rates and processes (e.g., by creating impermeable surfaces such as roads, buildings, parking lots, sidewalks etc.), and polluted waterways with stormwater and point-source discharges. The loss of wetland and riparian habitat has dramatically changed the hydrology of many streams all to the detriment of steelhead habitat, with increases in flood frequency and peak flow during storm events and decreases in groundwater driven summer flows. River braiding and sinuosity have been reduced through the construction of dikes, hardening of banks with riprap, and channelization of the mainstem rivers. These actions have led to constriction of river flows, particularly during high flow events, increasing the likelihood of gravel scour and the dislocation of rearing juvenile steelhead. The loss of side-channel habitats has also reduced important areas for spawning, juvenile rearing, and overwintering habitats. Estuarine areas have been dredged and filled, resulting in the loss of important juvenile steelhead rearing areas (NMFS 2013b).

Critical habitat for Puget Sound steelhead includes areas in Bellingham Bay, Whatcom Creek, the Samish River upstream to Bear Creek, the NF Nooksack River and tributaries, the MF Nooksack River upstream to Canyon Creek, the SF Nooksack River upstream to Bell Creek including Skookum Creek and other tributaries. Critical habitat includes a lateral extent as defined by the ordinary high-water line (33 CFR 319.11). The Puget Sound Critical Habitat Analytical Review Team identified management activities that may affect the PCEs in the Nooksack Basin including dams and other barriers, reduced recruitment of woody debris, forestry, urbanization, and water withdrawals (NMFS 2013b; 78 FR 2726, February 24, 2016). Of the five subbasins where the proposed action occurs (Upper North Fork Nooksack, Middle Fork Nooksack, South Fork Nooksack, Lower North Fork Nooksack, Nooksack River), three received high and two received medium (upper NF and MF Nooksack River) conservation value ratings (78 FR 2726, January 14, 2013).

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 for this Proposed Action includes the Nooksack River and Samish River watersheds, their tributaries, Whatcom Creek, and nearshore marine waters of Lummi, Bellingham, Samish, and East Sound Bays, where the proposed action will take place. Additionally, the action area includes locations where fish from the hatchery programs are expected to migrate. NMFS used the FRAM-Shelton model to estimate the in-ocean distribution of fall Chinook salmon that may be expected from the Nooksack Georgia Strait Chinook salmon hatchery programs (Table 15) (Shelton 2024) and used distribution parameters for Nooksack spring Chinook salmon as determined by (PFMC 2020). Based on this analysis, the action area also includes the places within or near Puget Sound, marine waters of the Salish Sea, Georgia Strait and Ocean areas where salmon originating from the twelve hatchery programs would migrate. The action area therefore extends from the Strait of Juan de Fuca at its Western entrance north along the continental shelf to Southeast Alaska. South of the entrance to the Strait of Juan de Fuca on the West Coast, Chinook salmon produced by the hatchery programs considered here contribute so little to Chinook salmon abundance (Table 15) that NMFS cannot detect an effect from Cape Flattery, WA southward to the California coast, therefore, NMFS has determined these areas should not be included in the action area.

Analyses of CWT recoveries indicate that over 99% of Chinook salmon escapement released through the programs considered here return to the hatchery or watershed of release. Small numbers of Chinook salmon produced as part of the programs considered here escape to hatcheries or spawning grounds in other Puget Sound watersheds. One adult Chinook salmon produced as part of the Glenwood Springs Hatchery program was recovered at the Columbia

River Basin at Winthrop National Fish Hatchery in 2015. This tag has since been discarded and was not available for re-examination. Dispersion analysis indicates escapement outside of Puget Sound watersheds is rare and Chinook salmon escaping to these areas are not likely to have spawned successfully, therefore, NMFS cannot detect an effect within the Columbia Basin and is excluding the Columbia Basin from the action area.

Coho salmon released from Puget Sound hatcheries, including the Nooksack-Samish hatcheries, are primarily encountered in marine areas off the coast of Washington and British Columbia with very few being encountered South of Cape Flattery (Weitkamp et al. 1995). Chum salmon produced by the programs are expected to spend up to one month in estuarine shallow waters before moving to the ocean. After leaving estuaries, juveniles may exhibit extended residency within Puget Sound before migrating, and may even overwinter in the sound. In the ocean, juveniles move northward along nearshore areas from the Strait of Juan de Fuca to Alaska (Johnson et al. 1997).

As there is no observable effect of Chinook, coho, or chum salmon from these programs in other Puget Sound watersheds or watersheds outside of Puget Sound and escapement to these areas is extremely rare, such that NMFS cannot detect an effect within these areas, NMFS has determined these areas should not be included in the action area.

Table 15. Proportional distribution of Samish fall and Nooksack spring Chinook salmon in coastal areas estimated during three time periods.

Stock	Time Frame	Salish Sea	North of Falcon	Oregon Coast	California Coast	Ocean Waters North of WA-Canada border including AK	SW West Coast Vancouver Island
Samish Fall	Oct-Dec	0.50	0.09	0.00	0.00	0.41	0.14
	May-June	0.44	0.06	0.00	0.00	0.50	0.24
	July-Sept	0.30	0.04	0.00	0.00	0.66	0.33
Nooksack Spring	Oct-Dec	0.05	0.15	0.02	0.02	0.79	0.15
	May-June	0.15	0.02	0.02	0.02	0.79	0.15
	July-Sept	0.02	0.02	0.02	0.02	0.92	0.15

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 impacts to listed species or designated critical habitat from Federal agency activities or existing Federal agency facilities that are not within the agency's discretion to modify are part of the environmental baseline (50 CFR 402.02).

2.4.1. Habitat

Pacific Ocean

In the oceanic portion of the action area, salmonid growth and survival is influenced by a variety of interrelated local physical (temperature, upwelling, currents) and biological (primary productivity, abundance of predators, prey, and competitors) variables. These local variables are driven by larger-scale processes that operate on longer time scales, such as the Pacific Decadal Oscillation (PDO), the North Pacific Gyre Ocillation (NPGO), and the El Niño Southern Oscillation (ENSO). These variables and processes combine each year to result in conditions that may be unfavorable, intermediate, or favorable for salmon growth and survival (Beamish 2018). See for example NMFS' Ocean Ecosystem Indicators of Pacific Salmon Marine Survival in the Northern California Current[5].

In the southern part of the action area (west coast of Vancouver Island and south), herring, anchovy, and sardine dominate the surface-oriented fish community (Orsi et al. 2007). These species may compete with juvenile salmonids during their early marine residence (Trudel et al. 2007), but provide a forage resource as the salmon grow larger, particularly for more piscivorous species such as Chinook and coho salmon (e.g., Daly et al. 2009). In these southern areas, juvenile salmon make up a small proportion (about 2–13%) of the surface-oriented fish community. This is in stark contrast to northern areas, where juvenile salmon are most abundant, particularly pink, chum, and sockeye salmon, and to a lesser extent coho salmon (Orsi et al. 2007). Here, juvenile salmon comprise about 35–83% of the surface-oriented fish community.

In the ocean, ESA-listed salmonids are affected by climate change (described in subsection, 2.4.4, Future Environmental Conditions) and by fish harvest activities (described in subsection 2.4.1.4, Harvest). ESA-listed salmonids have also been affected by marine mammal protection (e.g., the 1972 Marine Mammal Protection Act and 1973 Endangered Species Act in the United States; the 1970 Fisheries Act and 2002 Species at Risk Act in Canada). As a result, populations of several marine mammal species have increased throughout the action area, leading, for example, to a substantial increase in consumption of Chinook salmon (Chasco et al. 2017; Couture et al. 2024) and possibly also contributing to the observed decline in body size of Chinook salmon (Ohlberger et al. 2018; Ohlberger et al. 2019).

Puget Sound

Human activities have degraded extensive areas of salmon and steelhead spawning and rearing habitat in Puget Sound (Ford 2022). Most damaging to the long-term viability of salmon has

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[5] https://www.fisheries.noaa.gov/west-coast/science-data/ocean-ecosystem-indicators-pacific-salmon-marine-survival-northern

been the modification of the fundamental natural processes, which allowed habitat to form and recover from disturbances such as floods, landslides, and droughts. Among the physical and chemical processes basic to habitat formation and salmon persistence are floods and droughts, sediment transport, heat and light, nutrient cycling, water chemistry, woody debris recruitment and floodplain structure (SSDC 2007).

Land use activities have limited access to historical spawning grounds and altered downstream flow and thermal conditions. Watershed development and associated urbanization throughout the Puget Sound, Hood Canal, and Strait of Juan de Fuca regions have resulted in direct loss of riparian vegetation and soils, significantly altered hydrologic and erosion rates and processes by creating impermeable surfaces (roads, buildings, parking lots, sidewalks etc.), polluted waterways, raised water temperatures, decreased large woody debris recruitment, decreased gravel recruitment, reduced river pools and spawning areas, and dredged and filled estuarine rearing areas (Bishop and Morgan 1996; NWIFC 2016; Treaty Tribes in Western Washington 2020; Ford 2022). Hardening of nearshore bank areas with riprap or other material has altered marine shorelines, changing sediment transport patterns and reducing important juvenile habitat (SSDC 2007; NWIFC 2016; Treaty Tribes in Western Washington 2020). The development of land for agricultural purposes has resulted in reductions in river braiding, sinuosity, and side channels through the construction of dikes, hardening of banks with riprap, and channelization of the river mainstems (Elwha-Dungeness Planning Unit 2005; SSDC 2007). Poor forest practices in upper watersheds have resulted in bank destabilization, excessive sedimentation and removal of riparian and other shade vegetation important for water quality, temperature regulation and other aspects of salmon rearing and spawning habitat (SSDC 2007). There are substantial habitat blockages by dams in the Skagit and Skokomish River basins, in the Elwha basin until 2014 (prior to the implementation of the Elwha Dam Removal Plan), and minor blockages (including impassable culverts) throughout the region. Historically, low flows resulting from operation of the Cushman dams and habitat degradation of freshwater and estuarine habitat have adversely affected the Skokomish basin. A settlement agreement in 2008 between the Skokomish Tribe and Tacoma Power, the dam operator, resulted in a plan to restore normative flows to the river, improve habitat through on-going restoration activities, and restore an early Chinook salmon life history in the river using supplementation. In general, habitat has been degraded from its pristine condition, and this trend is likely to continue with further population growth and resultant urbanization in the Puget Sound region (Ford 2022).

Habitat utilization by Chinook salmon and steelhead in the Puget Sound area has been historically limited by large dams and other manmade barriers in a number of drainages, including the Nooksack, Skagit, White, Nisqually, Skokomish, and Elwha River Basins (Appendix B in NMFS 2015e). In addition to limiting habitat accessibility, dams affect habitat quality through changes in river hydrology, altered temperature profile, reduced downstream gravel recruitment, and the reduced recruitment of large woody debris. Such changes can have significant negative impacts on salmonids (e.g., increased water temperatures resulting in decreased disease resistance) (Spence et al. 1996; McCullough 1999). However, over the past several years modifications have occurred to existing barriers, which have reduced the number of basins with limited anadromous access to historical habitat. The completion of the Elwha and Glines Canyon dam removals occurred in 2014, though the response of fish populations to this action is still being evaluated (Ford 2022). It is clear, however, that Chinook salmon and steelhead are accessing much of this newly available habitat (Pess et al. 2024). Passage operations have begun on the North Fork Skokomish River to reintroduce steelhead above Cushman Dam, and although juvenile collection efficiency is still relatively low, further improvements are anticipated. Similarly, improvements in the adult fish collection facility at Mud Mountain Dam (White River Basin) are near completion, with the expectation that improvements in adult survival will facilitate better utilization of habitat above the dam (NMFS 2014b).

The recent removals of the diversion dam on the Middle Fork Nooksack Dam (July 2020) and the Pilchuck River Diversion Dam (late 2020) will provide access to important headwater salmonid spawning and rearing habitats. Similarly, the proposed modification of Howard Hanson Dam for upstream fish passage and downstream juvenile collection in the longer term (NMFS 2019f) will allow winter steelhead to return to historical headwater habitat in the Green River (Ford 2022). It has been hypothesized that summer-run steelhead may have been residualized above Howard Hanson Dam (Myers et al. 2015), and restoring access could restore such a run. However, the effects of these two projects on abundance will not be evident for some time. Four of the top six steelhead populations identified by (Cram et al. 2018) as having habitat blocked by major dams are in the process of having passage restored or improved (Ford 2022).

In addition, projects focusing on smaller scale improvements in habitat quality and accessibility are ongoing. As of 2019 approximately 8,000 culverts that block steelhead habitat have been identified in Puget Sound (NMFS 2019e), with plans to address these blockages being extended over many years. Smaller scale improvements in habitat, restoration of riparian habitat and reconnecting side- or off-channel habitats, will allow better access to habitat types and niche diversification. While there have been some significant improvements in restoring access, it is recognized that land development, loss of riparian and forest habitat, loss of wetlands, demands on water allocation all continue to degrade the quantity and quality of available fish habitat (Ford 2022).

Many upper tributaries in the Puget Sound region have been affected by poor forestry practices, while many of the lower reaches of rivers and their tributaries have been altered by agriculture and urban development (Appendix B in NMFS 2015e). Urbanization has caused direct loss of riparian vegetation and soils, significantly altered hydrologic and erosional rates and processes (e.g., by creating impermeable surfaces such as roads, buildings, parking lots, sidewalks etc.) (NMFS 2019e), and polluted waterways with stormwater and point-source discharges (Appendix B in NMFS 2015e). Forestry practices, urban development, and agriculture have resulted in the loss of wetland and riparian habitat, creating dramatic changes in the hydrology of many streams, increases in flood frequency during storm events, and decreases in groundwater driven summer flows (Moscrip and Montgomery 1997; Booth et al. 2002; May et al. 2003). River braiding and sinuosity have also been reduced in Puget Sound through the construction of dikes, hardening of banks with riprap, and channelization of the mainstem (NMFS 2015e). Constriction of river flows, particularly during high flow events, increases the likelihood of gravel scour and the dislocation of rearing juveniles. The loss of side-channel habitats has also reduced important areas for spawning, juvenile rearing, and overwintering habitats. Estuarine areas have been dredged and filled, resulting in the loss of important juvenile rearing areas (NMFS 2015e). In addition to being a factor that contributed to the present decline of Puget Sound Chinook salmon and steelhead populations, the continued destruction and modification of habitat is the principal factor limiting the viability of the Puget Sound Chinook salmon and steelhead into the foreseeable future (72 FR 26722, May 11, 2007). Due to their limited distribution in upper tributaries, summer run steelhead may be at higher risk than winter run steelhead from habitat degradation in larger, more complex watersheds (Appendix B in NMFS 2015e).

NMFS has completed several Section 7 consultations on large-scale projects affecting listed species in Puget Sound. Among these are the Washington State Forest Practices Habitat Conservation Plan (NMFS 2006b), and consultations on Washington State Water Quality Standards (NMFS 2008c), the National Flood Insurance Program (NMFS 2008b), the Elwha River Fish Restoration Plan (Ward et al. 2008), the Washington State Department of Transportation Preservation, Improvement, and Maintenance Activities (NMFS 2013a), and the Salish Sea Nearshore permitting activities with the Corps (NMFS 2022j)). These documents considered the effects of the proposed actions that would occur up to the next 50 years on the ESA-listed salmon and steelhead species in the Puget Sound Basin. Information on the status of these species, the environmental baseline, and the effects of the proposed actions are reviewed in detail in the opinions on these actions. The environmental baselines in these documents consider the effects from timber, agriculture and irrigation practices, urbanization, hatcheries and tributary habitat, estuary, and large-scale environmental variation. These opinions and HCPs, in addition to the watershed specific information in the Puget Sound Salmon Recovery Plan mentioned above, provide a comprehensive overview of baseline habitat conditions in Puget Sound and are incorporated here by reference.

The Nooksack River basin has been greatly impacted by timber harvest and clearing land for agriculture as well as other residential and commercial developments (Treaty Tribes in Western Washington 2020). Development in the Nooksack River watershed has led to armoring of over 88 miles of marine shoreline, pollution from nonpoint sources, wastewater treatment, and marinas, and removal of 65% of the forest cover with the remaining forest in poor condition. From 2014 to 2019 the number of culverts that act as barriers to anadromous fish have increased by 58 to a total of 662 (Treaty Tribes in Western Washington 2020). The WRIA 1 barrier removal work plan include plans to address approximately 40 fish passage barriers in Whatcom county. Current projects underway to include replacing the Kenney Creek culvert with a bridge allowing salmon access to approximately four miles of historical habitat in the NF Nooksack River and removing multiple culverts on the Black Slough area which will allow salmon access to approximately four miles of historic habitat in the SF Nooksack River (WRIA 1 Watershed Management Board 2023).

Through 2020, 52 restoration projects have been completed in the Nooksack River basin with 33 implemented in the SF Nooksack River (Coe 2022). Habitat restoration projects being conducted in the SF Nooksack River focus on decreasing water temperatures, creating deep pools for thermal refugia, and increasing habitat diversity (Natural Systems Design 2021). As previously mentioned, the removal of the MF Diversion dam and Canyon Creek levee each opened approximately 16 miles of habitat for Chinook salmon. Engineered log jams were installed in Canyon Creek, a tributary to the NF Nooksack River, and the flood plain was replanted with native plants and trees (Coe 2022). By 1998, wetlands in the lower Nooksack River floodplain had been reduced to 10% of their historical conditions. Wetland restoration in the Nooksack

Delta includes planting 80 acres of willow and over 100 acres of deciduous forest enhancement (Treaty Tribes in Western Washington 2020).

The SF Nooksack River is a lower elevation watershed that is fed by rainfall and snowmelt resulting in lower flows and higher water temperatures compared to glacier fed rivers (PSIT and WDFW 2022). The SF Nooksack River is classified as a 303(d) water body as it does not meet Federal Clean Water Act (CWA) water quality standards due to the high water temperatures (Kennedy et al. 2020). Degradation of habitat in the SF Nooksack River is primarily due to timber harvest which began around 1900. This ongoing removal of vegetation has contributed to elevated water temperature, the primary limiting factor for salmon and steelhead. Reaches of the SF Nooksack River that are most impaired by high water temperatures correspond with the most intense timber harvest activities.

Removal of vegetation related to timber harvest and conversion of habitat to farmland and other developments has also resulted in erosion of the stream channel increasing sediment load in the SF Nooksack River. Increased sediment load further increases water temperature by widening the channel, filling in deep pools, and reducing cooler hyporheic flows (Kennedy et al. 2020). The River lacks diverse habitat features such as deep pools with woody cover, side channels, and edge habitats to provide thermal refugia during hot weather (Natural Systems Design 2021). The elevated water temperature and low summer flow has led to recent mass pre-spawn mortality of adult Chinook salmon (Figure 12) (Lummi Nation 2021; Chance 2022). The 2021 heat-related mass mortality event killed 72% of the adult Chinook salmon holding in the SF Nooksack river, based on 2390 dead adults recovered and an estimated 943 that spawned not including escapement to hatchery. The SF Nooksack hatchery-origin Chinook salmon had ~76% pre-spawn mortality in 2021as compared to 30-31% for natural-origin NF and SF Nooksack Chinook salmon because the hatchery-origin fish hold downstream of the hatchery where temperatures were likely higher compared to tributaries or upstream mainstem habitats.

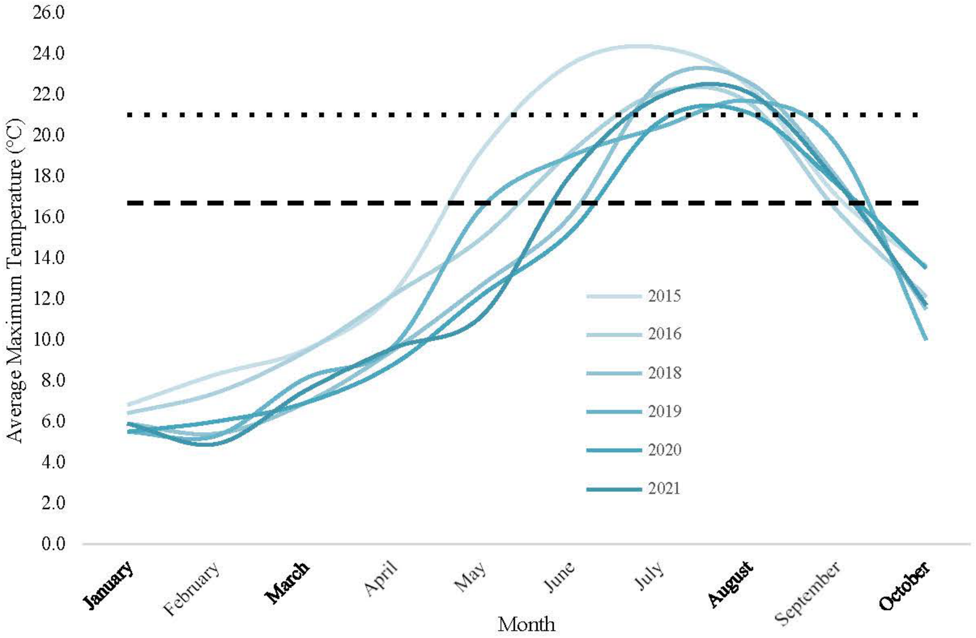

Figure 12. Daily maximum temperature (°C) of the SF Nooksack River measured at the Saxon Gauge (USGS Station 12210000) (Lummi Nation 2021). The critical lethal temperature for Chinook salmon of 21 °C is indicated by the dotted line. The dashed line at 16.7 °C is the threshold for the proliferation and spread of the bacterium Columnaris which can lead to mortality events.

High altitude glacier-fed streams drain into the North and Middle forks (PSIT and WDFW 2022). The headwaters of the Nooksack River are fed by melt from glaciers on Mount Baker, relying on melting snowpack and glaciers to sustain runoff during the warm season from April–September (Grah and Beaulieu 2013). Glaciers are important in maintaining sufficient discharge and low stream temperatures to support salmon populations. During hot weather, increased glacial melt increases runoff which counteracts low water levels and increases in stream temperature that cause heat events to be stressful for salmon populations. However, glaciers are declining which is already resulting in declining glacier runoff. Continued glacier loss will lead to reductions in discharge leading to reduced flow and increased stream temperatures during hot weather which will increase stress and mortality for salmon populations (Pelto et al. 2022).

2.4.2. Fisheries

The fishing seasons and regulations developed specifically to harvest salmon produced by hatchery programs operating in Puget Sound have previously been reviewed under the ESA, and NMFS' authorization for 'take' from fisheries in the 2024-2025 fishing season has already completed consultation (NMFS 2024b). In the 1980s and prior, Puget Sound Chinook salmon were harvested at an average, total exploitation rate of over 70%, across all summer/fall stocks and at nearly 50% across early/spring stocks (NMFS 2004c). By the 1990s overall abundance of Puget Sound Chinook salmon had fallen and the harvest rates began to be reduced, with the summer/fall average total exploitation rates reduced to roughly 50% and the early/spring stock average total exploitation rates moved to the low 30% range (NMFS 2024b). Since the ESA listing in 1999, harvest rates have continued to be reduced, with the average total exploitation rates across all summer/fall stocks moving to 40% in the 2000s and into the 30% range in the 2010s and average exploitation rates across all early/spring stocks moving down to 28% in the 2000s and 26% in the 2010s (NMFS 2024b). These total exploitation rates represent averages across all similar run-timing stocks in Puget Sound. The rate changes over time have varied across individual populations, with some rates being reduced more dramatically and being sustained at these low levels, and with other populations' rates still much lower than the historical levels but increasing in recent years as some abundances have rebounded. There have been no directed commercial fisheries on Nooksack spring Chinook salmon in Bellingham Bay and the Nooksack River since the late 1970s. Incidental harvest of Nooksack early Chinook in fisheries directed at fall hatchery-origin Chinook salmon in Bellingham Bay and the lower Nooksack River was reduced in the late 1980s by significantly restricting fisheries in July. Release, marking and acclimation strategies on fall hatchery Chinook salmon further reduced incidental impacts on early Chinook salmon and reduced straying into Nooksack River spawning areas (PSIT and WDFW 2022).

NF and SF Nooksack Chinook salmon populations are combined as a single Management Unit for harvest planning purposes. Due to current conservation concerns, Chinook salmon-directed commercial fisheries are of limited scope and most are directed at harvestable hatchery production in terminal areas, including Bellingham and Samish Bays and the Nooksack River (PSIT and WDFW 2022). Most recently, a 12.5% reduction in exploitation rates on Nooksack Chinook salmon relative to the 2009-15 average exploitation rate for Canadian individual stock-based management regimes (ISBM) fisheries was required in the PST Chinook salmon agreement which took effect in 2019.

The harvest management objectives for Nooksack Chinook salmon were developed to ensure that Southern US (SUS) harvests do not impede recovery or jeopardize the genetic diversity of the NF and SF Nooksack Chinook salmon populations so both populations are managed to allow escapement of natural origin spawners. In recent analyses of Nooksack early Chinook salmon populations' abundance and productivity, a rebuilding threshold of 500 adult natural-origin spawners was identified for the combined NF/MF and for the SF populations (Table 11) (NMFS 2017a; Ford 2022). The Upper Management Threshold (UMT) for the NF Nooksack population is set at 1,000 natural-origin spawners, a level that is twice the identified rebuilding threshold. Importantly, the attainment of abundances above the UMT will not allow higher harvest rates on this management unit. When preseason projected natural spawning escapement are below the low abundance thresholds (LAT) of 400 for the NF Nooksack Chinook salmon population and 200 for the SF Nooksack Chinook salmon population, fisheries in the SUS will be planned so as not to exceed the Critical Exploitation Rate Ceiling (CERC). The CERC is 10.9% SUS exploitation rate on the natural-origin components of the combined populations (NMFS 2024b). However, to allow some flexibility in conducting directed fisheries on harvestable surplus of healthy stocks, the SUS ER ceiling may increase to 14.1% in one out of five years. Northern fisheries continue to account for the majority of harvest-related mortality on Nooksack spring Chinook salmon and further reductions of fishery impacts in Washington waters below the CERC limits used for management in the past would not materially influence spawning escapement. Closing all Puget Sound fisheries would only allow, on average (2014-2018), an additional 9 NF Nooksack and 7 SF Nooksack natural-origin adults to the reach the spawning grounds. The limited amount of SUS harvest permitted under the CERC limits for 2024-2025 was determined by NMFS to not be likely to jeopardize the Puget Sound Chinook ESU (NMFS 2024b). Total harvest rates continue to be at the low levels considered in the last two status updates, approximately 30% since 2010 (NWFSC 2015; Ford 2022; NMFS 2024b). These rates are unlikely to increase substantially in the foreseeable future.

Puget Sound steelhead are harvested in terminal Tribal and mark-selective recreational fisheries. From the 1970s to the 1980s harvest rates averaged between 10% to 40% depending on the population being examined. Harvest rates were reduced in 2003 in response to declining abundance and currently average less than 2% (Ford 2022). Hatchery steelhead stocks have been selected for an earlier run timing than natural-origin Puget Sound steelhead to minimize indirect harvest impacts on natural-origin steelhead. Tribal fishery impacts to natural-origin Puget Sound steelhead occur incidentally during harvest of salmon and hatchery steelhead (Ford 2022). The elimination of direct harvest on Puget Sound steelhead in the mid-1990s largely addressed the declines to the DPS due to harvest impacts, the current low levels of harvest are not likely to affect steelhead spawner abundance (Ford 2022; NMFS 2024b).

Limited tribal treaty Ceremonial and Subsistence (C&S) fisheries in the Nooksack River have occurred between April and June since 2010. C&S fisheries on Nooksack spring Chinook salmon occur throughout the lower Nooksack River and target Kendall Creek and Skookum Creek Hatchery returns utilizing selective gear to enable the release of natural-origin Chinook salmon. All fish in these C&S fisheries are sampled and any natural-origin mortalities are counted towards the overall take limit.

In recent years, the portions of the mainstem Nooksack from the confluence of the North and South forks to approximately 1.3 miles downstream, and of the South Fork Nooksack from the confluence to the mouth of Wanlick Creek have been closed to all recreational fishing during much of the trout season (through September 30) to protect holding and spawning Chinook salmon. Similar closures are expected to remain in place given the status of the Chinook salmon population and environmental conditions likely to persist in the near future (PSIT and WDFW 2022). There is limited recreational fishing in the Nooksack River which is monitored and managed by WDFW (NMFS 2024b).

A fishery directed on hatchery-origin EWS fishery occurs in the Nooksack River terminal area. For the most recent season for which data is available, 2022–2023, low returns were forecast resulting in fisheries co-managers delaying the opening of the respective fisheries until broodstock needs were met at Kendall Creek hatchery. This occurred after January 15 when the Tribal fishery typically closes, so Nooksack tribe and Lummi Nation harvested no steelhead, hatchery or wild, in the EWS fishery. The Nooksack Tribe caught three natural-origin winter run steelhead during the 2023 spring chinook Ceremonial and Subsistence (C&S) fisheries (PSTIT and WDFW 2024). The Lummi Nation's selective spring Chinook C&S fishery encountered and released eight natural-origin winter steelhead and one hatchery-origin steelhead during a selective tangle-net fishery. An additional ten unclipped steelhead were retained in Lummi Nation's traditional net subsistence fishery and eight natural-origin steelhead were released resulting in an estimated two natural-origin mortalities. After the hatchery EWS steelhead broodstock goal was met, the recreational season on the North Fork Nooksack opened from

February 4 through February 15, 2023 per the 2022–2023 permanent fishing rules. The North Fork Nooksack River was monitored for the duration of the gamefish season. Creel results indicated that an estimated total catch of 193 wild steelhead and two hatchery steelhead were caught and released during this period. After applying a 10% hooking mortality, there was a total of 19.3 wild steelhead mortalities. No hatchery steelhead were harvested during the 2023 gamefish creel survey. The North Fork spring Chinook fishery creel recorded three wild steelhead were caught and released (PSTIT and WDFW 2024).

2.4.3. Hatcheries

Hatcheries can provide benefits to the status of Puget Sound Chinook salmon and steelhead by reducing demographic risks and preserving genetic traits for populations at low abundance in degraded habitats. In addition, hatcheries help to provide harvest opportunity, which is an important contributor to the meaningful exercise of treaty rights for the Northwest tribes. In the past, hatcheries have been used to compensate for factors that limit anadromous salmonid viability (e.g., harvest, human development) by maintaining fishable returns of adult salmon and steelhead. A new role for hatcheries emerged during the 1980s and 1990s as a tool to conserve the genetic resources of depressed natural populations and to reduce short-term extinction risk (e.g., Snake River sockeye salmon). Hatchery programs also can be used to help improve viability by supplementing natural population abundance and expanding spatial distribution. As the long-term benefits and risks of hatchery supplementation are being determined, addressing the factors limiting viability is essential for long-term viability. Effects of salmon and steelhead hatchery programs are discussed in detail in Appendix A.

Hatchery steelhead releases in Puget Sound have declined in most areas (Ford 2022). Between 2007 and 2014 Puget Sound steelhead annual hatchery releases averaged about 2,500,000 annually (NMFS 2014a). Reductions since 2014 from this average total have largely been in response to the need to reduce risks to natural Puget Sound steelhead after the 2007 listing and subsequent risk analyses (Warheit 2014). Reductions were focused on unlisted steelhead programs in response to the risk of introgression between native steelhead populations and hatchery-origin. In addition, Chambers Creek (EWS) releases were discontinued in the Elwha and Skagit River basins during the last five year period (Ford 2022). Currently, hatchery programs propagating unlisted steelhead in Puget Sound total 1,076,000 annually (this total includes 350,000 summer steelhead and 531,000 winter steelhead) in the Puget Sound DPS (Ford 2022), which have been approved under Limit 6 of the 4(d) Rule.

There have also been recent changes associated with several integrated rebuilding programs, including increased production goals for the Green River Native Winter Steelhead and White River Winter Steelhead Supplementation programs; and addition of the North Fork Skokomish Winter Steelhead program, which first released fish in 2017 (Ford 2022). Once the non-Puget Sound hatchery summer steelhead programs sunset, as required by 4(d) authorization (NMFS 2019d; 2021c), and the integrated programs rebuilding listed populations achieve their intended release goals, by 2031, Puget Sound steelhead hatchery releases will total roughly 1.3 million. This release level represents a 52 percent total reduction in Puget Sound hatchery steelhead releases since listing, and a transition away from programs releasing out of DPS stocks.

Chinook, coho, chum, sockeye, and pink salmon and steelhead stocks are propagated through 41 programs in Puget Sound— total hatchery production for all species of programs with completed Section 7 consultations are summarized in Table 16. Currently, most of Chinook salmon hatchery programs produce fall-run (also called summer/fall) stocks for fisheries harvest augmentation purposes. Supplementation programs implemented as conservation measures to recover early returning Chinook salmon operate in the White, Dungeness (NMFS 2022o), and NF Nooksack Rivers, and for summer Chinook salmon on the North Fork Stillaguamish (NMFS 2019c) and Elwha Rivers (NMFS 2014a). Supplementation or re-introduction programs are in operation for early Chinook salmon in the SF Nooksack River, fall Chinook salmon in the South Fork Stillaguamish River (NMFS 2019c), and spring and late-fall Chinook salmon in the Skokomish River.

Table 16. Summary of completed Section 7 consultations for hatchery programs in Puget Sound.

Biological Opinion	Programs Analyzed in Opinion	Signature Date	Citation
Lake Ozette Sockeye Salmon	Umbrella Ck Supplementation/Reintroduction	June 9, 2015	NMFS (2015b)
Elwha	Lower Elwha Hatchery Native Steelhead	December 10, 2012 December 15, 2014	NMFS (2012b) NMFS (2014a)
	Lower Elwha Hatchery Elwha Coho		
	Elwha Channel Hatchery Chinook		
	Lower Elwha Hatchery Elwha Chum		
	Lower Elwha Hatchery Pink		
Dungeness	Dungeness River Hatchery Spring Chinook	May 31, 2016 September 24, 2019	NMFS (2016d) NMFS (2019a)
	Dungeness River Hatchery Coho		
	Dungeness River Hatchery Fall Pink		
Early Winter steelhead #1	Kendall Creek Winter Steelhead	April 15, 2016	NMFS (2016b)
	Dungeness River Early Winter Steelhead		
	Whitehorse Ponds Winter Steelhead		
Early Winter Steelhead #2	Snohomish/Skykomish Winter Steelhead	April 15, 2016	NMFS (2016e)
	Snohomish/Tokul Creek Winter Steelhead		
Stillaguamish	Stillaguamish Fall Chinook Natural Stock Restoration	June 20, 2019	NMFS (2019c)
	Stillaguamish Summer Chinook Natural Stock Restoration		
	Stillaguamish Late Coho		
	Stillaguamish Fall Chum		
Snohomish	Tulalip Hatchery Chinook Sub-yearling	September 27, 2017 May 3, 2021 December 13, 2022	NMFS (2017c) NMFS (2021a) NMFS (2022f)
	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		
Hood Canal	Hoodsport Fall Chinook	September 30, 2016	NMFS (2016a)
	Hoodsport Fall Chum		

Biological Opinion	Programs Analyzed in Opinion	Signature Date	Citation
	Hoodsport Pink	March 8, 2022	NMFS (2022l)
	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	April 15, 2019	NMFS (2019d)
	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		
Skykomish Summer Steelhead	South Fork Skykomish Summer Steelhead	October 21, 2021	NMFS (2021c)
Lake Washington	University of Washington Aquatic Research Facility Hatchery – Fall Chinook salmon	December 23, 2021	NMFS (2021b)
	University of Washington Aquatic Research Facility Hatchery coho		
	Issaquah Fall Chinook Hatchery Program		
	Issaquah coho Hatchery Program		
	Lake Washington Sockeye Program		
Skagit Chum	Upper Skagit Chum	October 26, 2022	NMFS (2022e)
	Skagit River Fall Chum		
	Chum Remote Site Incubator		
	University of Washington Aquatic Research Facility Hatchery coho		

From brood year (BY) 1951 to 2023, a total of 3.35 billion Chinook salmon were released from hatcheries into the Salish Sea. The release abundance levels are complicated by the different life-history phases fish were released as young-of-the-year fish can range from small, unfed fry, to feed fry, to pre-smolts, or age 0+ smolts (generally 3 grams in size or larger and occur after March). Less common are fish released during their next year of life- age 1+ yearling smolts. Release abundances can be divided into four release periods. The first period (BY 1951 – 1969) can be described as low and increasing release abundance, with increasing numbers and proportions of smolt-size fish being released. For example, brood year 1952 release consisted of 15.6 million Chinook but with only ~23% being smolt-size juveniles, whereas brood year 1969 included a release of 36.7 million Chinook but with over 50% being smolt-size fish (representing an increase of ~700% smolt-size fish). Releases increased during second period, BY 1970-1989, the period of the highest total releases as well as release of the largest sized smolts. The end of period 1, saw a release of 19.3 smolt-size Chinook, whereas the average total and smolt-size releases were 58.4 million and 45.0 million, in period 2, respectively. Within period 2 there were also two different ranges of total smolt production, with the first half averaging 35.9 million (BY 1980-1989) and the second half averaging 56.0 million smolts. Similar numbers of smolt-size fish were released during period 3 averaging 48.3 million (10% more than all of period 2, but about 14% fewer fish than during the second half of period 2) and fry releases into the Salish Sea were discontinued. After BY 1998, fry-size fish made up only 2.5% of all Chinook released into the Salish Sea. Period 4, BY 1999 through 2023, releases averaged 44.9 million, with the first five years averaging 46.8 million, then a 13-year period with average production of 42.7 million, which was followed by 7-year average of 48.7 million.

Salish Sea coho salmon smolt releases peaked at 35 million in 1981, and steadily declined to current levels of 11-12 million released annually. During the early period (1973-2000) annual coho salmon smolt releases averaged 19 million. During the most recent period (2001-2018) coho salmon smolt releases averaged 11.5 million (range: 13.1M to 9.7M).

From brood year 1951 to 2023, a total of 2.6 billion chum salmon were released by WDFW and tribes into the Salish Sea. The release abundance levels can be separated into four time periods 1951-1971 (low and variable), 1972 -1984 (period of increasing production), 1985- 2007 (period of decreasing production), and 2008-present (current production). During the period 1951-1971 there were an average of 2.3 million chum released annually (range 8.3M-160k). Production rapidly increased from 1972 to its peak in 1984 at 89.6 million, averaging 48.6 million annually. The period of 1985-2007 was a period of decreasing production averaging 53.3 million with a maximum release of 74.9 million (1986) and minimum release of 25.6 million (BY 2000). During the most recent period (2008-present) releases have averaged 44.7 million with a range of 53.3 to 30.0 million released. From broodyear 1952 through 2023, a total of 141.5 million chum salmon were released at 52 locations within the Nooksack-Samish Area. Prior to brood year 1973, average chum salmon releases were below 500k. After broodyear 1972, chum salmon releases averaged 2.6 million with a low of about 400k and a high of 5.1 million. The ten-year moving average chum salmon release peaked in 1999 (3.7 million) and declined to 1.3 million in 2012, then rose again to the most recent level of 3 million in broodyear 2020.

Nooksack River Basin Hatchery Programs

The Skookum Creek and Kendall Creek Hatchery spring Chinook salmon programs were initiated for integrated recovery purposes to conserve and restore the indigenous Chinook salmon populations in the Nooksack River and contribute to harvest. The fall Chinook, coho, and chum salmon programs at the hatchery facilities considered here as well as the Lummi Bay spring Chinook salmon program operate for fisheries harvest augmentation purposes to partially mitigate for lost natural-origin salmon resulting from degradation and loss of habitat as a result of human developmental activities in the watershed.

The Samish Hatchery Fall Chinook salmon program began in 1914 with eggs originating from the Columbia River. In 1929, the Columbia stock was replaced with stock originating from the Green River. Stock was transferred from Soos Creek Hatchery to Samish Hatchery as needed to meet production objectives through the early 1990's (WDFW 2024a). Fall Chinook salmon originating from Samish Hatchery were released from Lummi Bay from 1978 through 2016 and were then replaced with NF Nooksack stock from Kendall Creek Hatchery (Lummi Nation 2024e). Glenwood Springs Hatchery began releasing fall Chinook salmon in 1979 using Green River origin stock sourced from Samish and Kendall Creek Hatcheries (WDFW 2024d). In 2018, a fall Chinook salmon hatchery program was initiated at Whatcom Creek Hatchery using fall Chinook salmon eggs transferred from Samish Hatchery. This program will be supported by egg transfers from Samish Hatchery (WDFW 2024f).

The NF Nooksack Chinook salmon program began operating at Kendall Creek Hatchery in 1980 using adults captured in the NF Nooksack River to support the preservation of the NF/MF Nooksack spring Chinook population and reduce the risk of the population's extinction while habitat is protected and restored to properly functioning conditions (WDFW 2024c). Kendall Creek Hatchery also released Green River origin stock until the fall Chinook program was discontinued in 2000 (WDFW 2024c). The termination of this segregated, out-of-basin Chinook salmon program operating in the NF Nooksack River greatly reduced the potential for genetic introgression into the SF and NF Nooksack Chinook salmon populations.

The SF Nooksack Chinook salmon program was initiated at Skookum Creek Hatchery in 2007 with natural-origin juvenile Chinook salmon collected in the SF Nooksack with identity confirmed by genotyping. Juvenile Chinook salmon were collected until 2012 and reared as a captive brood program until 2016 when the program transitioned to relying entirely on returning anadromous adults. To ensure only SF Nooksack Chinook are propagated, unmarked adult Chinook salmon have not been incorporated as broodstock (Lummi Nation 2024d).

The Kendall Creek Hatchery coho salmon program began in the 1950s using a composite of stocks sourced from the Nooksack as well as out of basin stocks from other Puget Sound hatcheries. This coho salmon program was discontinued in 2009 and a coho salmon program was reinitiated in 2018 using natural-origin adults volunteering to the Kendall Creek Hatchery rack. The adult coho salmon used as the original broodstock for the currently operating program are likely from a self-sustaining naturalized population supported by hatchery-origin adults passed above the weir on Kendall Creek from 1999-2008 (WDFW 2024e). The coho salmon program operating at Skookum Creek Hatchery began operating in 1977 and is a composite of out-of-basin stocks (Lummi Nation 2024c). In the past, adult coho salmon were collected for broodstock at Lummi Bay Hatchery but these collections were discontinued in 2018. A coho salmon program has been initiated at Lummi Bay Hatchery using adults collected at Skookum Creek Hatchery (Lummi Nation 2024b).

Lummi Bay Hatchery began releasing chum salmon originating from out-of-basin stocks in 1978. Releases of these chum salmon stocks were terminated in the 1990s and the current program was initiated in 2013 using eggs transferred from Kendall Creek Hatchery (Lummi Nation 2024a). The fall chum salmon program at Kendall Creek Hatchery was terminated in 2004 then reinitiated in 2011 by collecting adults from the NF Nooksack River for broodstock. Since 2020, all broodstock have been hatchery and natural-origin volunteers to the Kendall Creek Hatchery. The program may utilize returning adults for broodstock but will be supported by egg transfers from Kendall Creek and Whatcom Creek Hatcheries (WDFW 2024e). The Whatcom Creek Hatchery chum salmon program began operating in 1979 using eggs collected at Samish Hatchery from a composite of local and Hood Canal stocks. From 1999 through 2001, the program transitioned to using local chum salmon stocks sourced from Kendall Creek Hatchery. In 2004, adult returns from the local stock began to return to Whatcom Hatchery in numbers needed to support the program. In years where there are broodstock shortages, eggs have been transferred from Kendall Creek Hatchery to support the program (WDFW 2024b).

A segregated early-winter steelhead program has been and continues to be operated at Kendall Creek Hatchery (WDFW 2014a). Steelhead were first released in 1998 as part of this program which propagates an out of basin stock which is not considered part of the listed Puget Sound steelhead DPS. The effects of this program were previously analyzed in a NMFS Biological Opinion (NMFS 2016b) and are therefore part of the environmental baseline.

Past operation of the Chinook, chum, and coho salmon hatchery programs in the Nooksack River watershed may have affected the viability of listed natural-origin Chinook salmon and steelhead populations as well as the diversity, spatial structure, and productivity of the natural-origin Chinook salmon populations that are the subject of the conservation efforts. The captive broodstock and hatchery programs rearing Nooksack Chinook salmon have likely preserved genetic diversity as declining numbers of natural spawners and reduced productivity due to habitat degradation leads to genetic variation lost through genetic drift.

Collection of juvenile and adult Chinook salmon from the river and selection of fish for spawning may have reduced within-population diversity of the propagated population relative to the naturally spawning aggregation if all the adults collected for broodstock were not completely genetically representative of the natural population. Creation of a captive population as a brood source may have further contributed to within-population diversity loss. However, in creating the original captive broodstock, juveniles were collected from the SF Nooksack River to establish the captive brood program to ensure that the brood source would exhibit no genetic differences from the natural spawning population. The captive broodstock program was terminated in 2017, and the program was transitioned to an integrated supplementation program. By limiting the length of the original captive broodstock program (2007–2017), the potential for adverse genetic effects on the listed natural fish resulting from selection in the hatchery were reduced (Kalinowski et al. 2012). The SF Nooksack Chinook salmon collected and spawned as part of the captive brood program were genotyped to ensure genetic variation was being maintained. For the NF and SF Nooksack supplementation programs, measures were implemented to collect and spawn adult fish representative of the run-at-large in terms of run timing, fish size, age class, and sex ratio that may have reduced this genetic risk. Propagation of Nooksack Chinook salmon in Kendall and Skookum hatcheries may have reduced productivity of adult fish returning to spawn naturally relative to natural-origin fish. The Chinook salmon programs have also likely benefited the abundance of the Nooksack Chinook salmon populations by increasing the number of naturally spawning Chinook salmon, considering the degraded state of natural fish habitat which decreases natural-origin fish productivity in the action area (Berejikian and Doornik 2018; Johnson et al. 2020). The hatchery programs for Chinook salmon have likely helped preserve the Nooksack Chinook salmon populations and increased the population’s total abundance.

The salmon hatchery programs, along with the non-listed, early winter steelhead smolt release program operating at Kendall Creek Hatchery (WDFW 2014a; NMFS 2016b), may have adversely affected listed Nooksack Chinook salmon and steelhead through ecological effects. Predation on migrating and rearing juvenile Chinook salmon by hatchery yearling Chinook and coho salmon as well as steelhead may occur in the portion of the Nooksack River downstream of Kendall Creek and Skookum Creek Hatcheries. The timing of hatchery yearling releases has coincided with the out-migration timing of natural-origin Chinook salmon of an average size vulnerable to predation. The magnitude of past predation effects is unknown, but the practice of releasing migration-ready smolts limits the level and duration of interaction with juvenile natural-origin fish, which rear and migrate from areas throughout the watershed. None of the hatchery-origin species produced in the action area have likely competed with natural-origin Chinook salmon and steelhead at substantial levels for food or space as the habitat capacity has been underutilized. All of the hatchery salmon and steelhead from past releases were released as smolts that quickly emigrated seaward, and releases from Glenwood Springs, Samish, Whatcom, and Lummi Bay released fish into the lower portion of the watershed or into marine waters. For these reasons, the duration of, and opportunities for, interactions that would lead to competition with listed juvenile fish have been limited.

Past Nooksack River hatchery facility operations may have adversely affected the viability status of natural-origin salmon and steelhead populations in the action area. Currently, screening at water intakes at Glenwood Springs, Kendall Creek, and Skookum Creek Hatcheries are not in compliance with current standards (NMFS 2022c). However, the stream where the Glenwood Springs Hatchery intake is located is not fish bearing. Chinook salmon or steelhead do not use the habitat above Kendall Creek Hatchery that is impacted by the weirs and intake structures. Funding has been secured to update the Skookum Creek Hatchery intake with construction beginning summer 2024 (Section 1.5).

Juvenile outmigrant trapping using a rotary screw trap in the mainstem Nooksack River is conducted annually. Data collected through operation of the juvenile out-migrant trap allows assessment of emigrating natural- and hatchery-origin fish abundance and overlap in timing between natural-origin species and newly released hatchery-origin fish. Other data collected at the trap used to assess hatchery effects are fish size, origin (marked/tagged vs. unmarked/untagged), and other biological data (e.g., tissues sampled for genetic analyses). The effects of take associated with these activities were analyzed and determined not to result in a decrease in the likelihood of survival and recovery of the listed species (NMFS 2017b; 2018b). For the Puget Sound Steelhead DPS, up to 2% of the juvenile proportion, and 6% of the adult proportion of the DPS have typically been handled, with estimated < 1% mortality. For the Puget Sound Chinook Salmon ESU, up to 12% of the juvenile proportion and < 1% of the adult proportion have typically been handled, with estimated < 1% mortality.

The effects of salmon and steelhead hatchery programs outside of the action area on Nooksack River Chinook salmon and steelhead are likely minimal. The closest hatchery programs outside of the action area are located in the Skagit River. Juvenile and adult fish from the Skagit River are unlikely to interact with Nooksack River Chinook salmon and steelhead in the action area at a level leading to substantial genetic or ecological effects. All available data indicates the Chinook salmon and steelhead produced as part of programs operating outside of the Nooksack basin stray into the Nooksack River at low levels (Haggerty 2024). Among-population diversity reduction risks associated with out-of-basin hatchery salmon and steelhead straying into the Nooksack River are not likely and can be monitored with the co-managers proposed genetic monitoring program along with analysis of CWT data.

2.4.4. Future Environmental Conditions

Climate change has negative implications for designated critical habitats in the Pacific Northwest (Climate Impacts Group 2004; Scheuerell and Williams 2005; Zabel et al. 2006; ISAB 2007).

The distribution and productivity of salmonid populations in the region are likely to be affected (Beechie et al. 2006). Average annual Northwest air temperatures have increased by approximately 1ºC since 1900, or about 50% more than the global average over the same period (ISAB 2007). The latest climate models project a warming of 0.1 ºC to 0.6 ºC per decade over the next century. According to the Independent Scientific Advisory Board (ISAB), these effects pose the following impacts over the next 40 years:

- Warmer air temperatures will result in diminished snowpacks and a shift to more winter/spring rain and runoff, rather than snow that is stored until the spring/summer melt season.
- With a smaller snowpack, these watersheds will see their runoff diminished earlier in the season, resulting in lower stream-flows in the June through September period.
- River flows in general and peak river flows are likely to increase during the winter due to more precipitation falling as rain rather than snow.
- Water temperatures are expected to rise, especially during the summer months when lower stream-flows co-occur with warmer air temperatures.

Climate change is also predicted to cause a variety of impacts on Pacific salmon as well as their ecosystems (Mote et al. 2003; Crozier et al. 2008a; Martins et al. 2012; Wainwright and Weitkamp 2013). While all habitats used by Pacific salmon will be affected, the impacts and certainty of the change vary by habitat type. Some impacts (e.g., increasing temperature) affect salmon at all life stages in all habitats, while others are habitat-specific (e.g., stream flow variation in freshwater). The complex life cycles of anadromous fishes including salmon rely on productive freshwater, estuarine, and marine habitats for growth and survival, making them particularly vulnerable to environmental variation (Morrison et al. 2016). Ultimately, the specific nature, level, and rate of change and the synergy between interconnected terrestrial/freshwater, estuarine, nearshore, and ocean environments will determine the effect of climate change on salmon and steelhead across the Pacific Northwest. The primary effects of climate change on Pacific Northwest salmon and steelhead are:

- Direct effects of increased water temperatures on fish physiology
- Temperature-induced changes to stream flow patterns
- Alterations to freshwater, estuarine, and marine food webs

How climate change will affect each stock or population of salmon also varies widely depending on the level or extent of change and the rate of change and the unique life history characteristics of different natural populations (Crozier et al. 2008b). Juveniles may out-migrate earlier if they are faced with less tributary water and lower and warmer summer flows may be challenging for returning adults (Dittmer 2013). In addition, the warmer water temperatures in the summer months may persist for longer periods and more frequently reach and exceed thermal tolerance thresholds for salmon and steelhead (Mantua et al. 2009). Larger winter stream flows may increase redd scouring for those adults that do reach spawning areas and successfully spawn.

These changes will not be spatially homogeneous across the entire Pacific Northwest. Low-lying areas are likely to be more affected. Climate change may have long-term effects that include, but are not limited to, depletion of coldwater habitat, variation in quality and quantity of tributary rearing habitat, alterations to migration patterns, and accelerated embryo development. However, Habitat preservation and restoration actions can help mitigate the adverse impacts of climate change on salmonids. For example, restoring connections to historical floodplains and freshwater and estuarine habitats would provide fish refugia and areas to store excess floodwaters (Battin et al. 2007; ISAB 2007). Harvest and hatchery actions can respond to changing conditions associated with climate change by incorporating greater uncertainty in assumptions about environmental conditions, and conservative assumptions about salmon survival, in setting management and program objectives and in determining rearing and release strategies (Beer and Anderson 2013).

The effects of climate change in the Nooksack river basin, in addition to the broader effects across the region, are likely to include higher air and water temperatures, decreased snowpack, changing seawater chemistry due to ocean acidification, and rising sea level consistent with impacts expected throughout Puget Sound (Mauger et al. 2015). Climate change will have a direct effect on the magnitude and timing of stream flow in the Nooksack River especially during the low-flow critical summer season (Grah and Beaulieu 2013). The North Cascade glaciers that drain into the NF Nooksack River are losing mass due to receiving less snow accumulation in the winter season and increased melting during the summer season. Overall warmer temperatures cause precipitation to more frequently fall as rain rather than snow. Precipitation trends in the Nooksack River watershed indicate that winter snow precipitation is decreasing which means glaciers on Mount Baker will accumulate increasingly less snow leading to reduced streamflow (Grah and Beaulieu 2013). Salmon are expected to experience declines in abundance and productivity due to the change in timing and amount of winter rains and flooding, scouring of egg redds during high flows, thermal stress from higher water temperature, and less water availability in the summer (Treaty Tribes in Western Washington 2020). These changes have already been observed with lethal temperatures leading to mass adult Chinook salmon mortality events in the SF Nooksack River in 2021 and 2022 (Lummi Nation 2021).

Modeling predicts that without restoration of riparian shade, maximum water temperatures during critical summer low-flow conditions could increase by almost 6°C by the 2080s. Restoration of full riparian shading can help buffer against temperature increases. However, even with riparian shade, the average stream water temperatures are expected to increase by 1.1 to 3.6° C by the 2080s and the percent of stream miles affected by critically high water temperatures potentially lethal to salmon is predicted to increase from about 18% at present to between 60% and 90% in the 2080s (Kennedy et al. 2020).

Current restoration activities in the Nooksack River basin include re-establishing the floodplain. This will be important in mitigating the effects of climate change as floodplains offer additional rearing capacity for fishes and are especially important during wet months in providing increased growth and survival for juvenile salmon by offering abundant prey, optimal rearing temperatures, and refuge from predators. Floodplains also provide juvenile fish protection from floods by attenuating high flows and providing refuge habitats from high flow conditions in the mainstem river (Hall et al. 2018). The probable effects of climate change emphasizes how important increasing habitat complexity through restoration projects will be in protecting the productivity of sub-yearling Chinook in Puget Sound rivers including the Nooksack as Chinook salmon populations are more resilient and productive during periods of environmental variation in watersheds with greater habitat complexity (Hall et al. 2018). The addition of large woody debris from the restoration projects will produce deep, complex pools connected with hyporheic flows that will cool the river water. This cooler habitat will be essential for adult and juvenile salmon to survive periods of increased thermal stress precipitated by climate change (Kennedy et al. 2020).

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 but that are not part of the action. 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 402.02).

2.5.1. Factors That Are Considered When Analyzing Hatchery Effects

NMFS has substantial experience with hatchery programs and has developed and published a series of guidance documents for designing and evaluating hatchery programs following best available science (Hard et al. 1992; McElhany et al. 2000; NMFS 2004b; 2005d; Jones 2006; NMFS 2008a; 2011c). For Pacific salmon, NMFS evaluates extinction processes and effects of the Proposed Action beginning at the population scale (McElhany et al. 2000). NMFS defines population performance measures in terms of natural-origin fish and four key parameters or attributes; abundance, productivity, spatial structure, and diversity and then relates effects of the Proposed Action at the population scale to the MPG level and ultimately to the survival and recovery of an entire ESU or DPS.

"Because of the potential for circumventing the high rates of early mortality typically experienced in the wild, artificial propagation may be useful in the recovery of listed salmon species. However, artificial propagation entails risks as well as opportunities for salmon conservation" (Hard et al. 1992). A Proposed Action is analyzed for effects, positive and negative, on the attributes that define population viability: abundance, productivity, spatial structure, and diversity. The effects of a hatchery program on the status of an ESU or steelhead DPS and designated critical habitat "will depend on which of the four key attributes are currently limiting the ESU, and how the hatchery fish within the ESU affect each of the attributes" (70 FR 37215, June 28, 2005). The presence of hatchery fish within the ESU can positively affect the overall status of the ESU by increasing the number of natural spawners, by serving as a source population for repopulating unoccupied habitat and increasing spatial distribution, and by conserving genetic resources. "Conversely, a hatchery program managed without adequate consideration can affect a listing determination by reducing adaptive genetic diversity of the ESU, and by reducing the reproductive fitness and productivity of the ESU".

NMFS' analysis of the Proposed Action is in terms of effects it would be expected to have on ESA-listed species and on designated critical habitat, based on the best scientific information available. This allows for quantification (wherever possible) of the effects of the six factors of hatchery operation on each listed species at the population level (in Section 2.5.2), which in turn allows the combination of all such effects with other effects accruing to the species to determine the likelihood of posing jeopardy to the species as a whole (Section 2.8).

Information that NMFS needs to analyze the effects of a hatchery program on ESA-listed species must be included in an HGMP. Draft HGMPs are reviewed by NMFS for their sufficiency before formal review and analysis of the Proposed Action can begin. Analysis of an HGMP or Proposed Action for its effects on ESA-listed species and on designated critical habitat depends on six factors. These factors are:

1. The hatchery program does or does not remove fish from the natural population and use them for hatchery broodstock
2. Hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds and encounters with natural-origin and hatchery fish at adult collection facilities
3. Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas, migratory corridor, estuary, and ocean
4. Research, monitoring, and evaluation (RM&E) that exists because of the hatchery program
5. The operation, maintenance, and construction of hatchery facilities that exist because of the hatchery program
6. Fisheries that exist because of the hatchery program, including terminal area fisheries intended to reduce the escapement of hatchery-origin fish to spawning grounds

NMFS analysis assigns an effect category for each factor (negative, negligible, or positive/beneficial) on population viability. The effect category assigned is based on: (1) an analysis of each factor weighed against the affected population(s) current risk level for abundance, productivity, spatial structure, and diversity; (2) the role or importance of the affected natural population(s) in salmon ESU or steelhead DPS recovery; (3) the target viability for the affected natural population(s) and; (4) the environmental baseline, including the factors currently limiting population viability. For more information on how NMFS evaluates each factor, please see Appendix A.

2.5.2. Effects of the Proposed Action

This section discusses the effects of the Proposed Action on the ESA-listed species in the action area.

2.5.2.1. Factor 1. The hatchery program does or does not remove fish from the natural population and use them for broodstock

The Skookum Creek and Kendall Creek Hatchery Chinook salmon programs both remove ESA listed adults Chinook salmon from the natural population for broodstock. The fall Chinook salmon programs do not incorporate listed fish into broodstock. While some of the coho and chum hatchery salmon programs considered in this Opinion may use natural-origin salmon as broodstock, these are not ESA listed and will not be considered here.

The Skookum Creek Hatchery Chinook salmon program currently only collects hatchery-origin returning adults that volunteer to the hatchery brood pond. The identity of adults used as broodstock is confirmed by CWT analysis to ensure only program Chinook salmon that are genetically representative of the SF Nooksack population are spawned. Use of only hatchery-origin adults has allowed natural-origin adults to spawn naturally and contribute to increasing abundance and productivity. As the SF Nooksack population increases, the Skookum Creek program will begin to incorporate natural-origin Chinook salmon with identity verified by genetic analysis as broodstock. Integrating natural-origin Chinook salmon will ensure genetic drift and domestication do not lead to genetic differences between the natural and hatchery components of the population (Waters et al. 2015). Natural-origin broodstock will only be used as broodstock if the critical escapement threshold is exceeded and a sliding scale will be used to avoid demographic effects (Table 3). Volunteering Chinook salmon not used for broodstock are returned to the lower SF Nooksack River so they may spawn naturally. Use of a sliding scale to determine the number of natural-origin Chinook salmon collected for broodstock avoids negative demographic effects of reducing the number of spawners while providing the beneficial genetic effects of incorporating natural-origin adults into the broodstock.

The Skookum Creek Chinook salmon program was initiated in response to the decline of the SF Nooksack population to critically low levels. This hatchery program has likely preserved the genetic ancestry and phenotypic variation of the SF Nooksack Chinook salmon population by increasing the number of spawners to avoid the loss of diversity through genetic drift. Hatchery fish are genetically identical to natural-origin fish. The collection of adult natural-origin SF Nooksack Chinook salmon will result in fewer natural-origin spawners escaping to spawning grounds. However, the co-managers will limit the total number of adults collected proportional with the forecasted escapement (Table 3). The Skookum Creek hatchery Chinook salmon program has increased spawner abundance in this population (Ford 2022). NMFS expects this supplementation program will continue to increase overall spawner abundance as well as spatial diversity over the long term, which will offset the effects of any spawners that are taken into the hatchery as has been observed in watersheds with similar programs operating (Fast et al. 2015; Berejikian and Doornik 2018). Although hatchery-origin Chinook salmon can have lower reproductive success than natural-origin Chinook salmon on natural spawning grounds (Williamson et al. 2010; Koch and Narum 2021; Koch et al. 2022), their offspring are as productive as those of natural-origin salmon and contribute to recovery (Nuetzel et al. 2023; Dayan et al. 2024).

The Kendall Creek Hatchery Chinook salmon program is an integrated program which incorporates natural-origin NF Nooksack Chinook salmon as broodstock. Escapement of natural-origin adult Chinook salmon to the NF/MF Nooksack River has been low for decades (Figure 6) which has resulted in very few natural-origin adults volunteering to the hatchery to be incorporated into the broodstock. Increased production and increased off station releases (Table 4) are expected to increase natural-origin abundance as hatchery-origin adults spawn in natural spawning areas. NMFS expects two generations, eight to ten years, of increased hatchery releases will be needed to increase natural-origin escapement above the CET so the population can support the removal of adult natural-origin spawners for use as broodstock at Kendall Creek

Hatchery. After natural origin abundance increases, hatchery managers plan to use a strategic approach to increasing the number and effectiveness of natural-origin broodstock used by the program and a subsequent increase in the amount of natural versus hatchery genetic influence. Future integration scenarios for the Kendall Creek hatchery NF Chinook salmon program would maximize the positive genetic effects of natural-origin Chinook salmon used as broodstock. NMFS is expecting integration would take place in the future after NOR abundance has increased after two generations of increased production and off station releases.

The collection of adult natural-origin Nooksack Chinook salmon as part of in-river collection activities as well as those volunteering to the weir and hatchery trap for use as broodstock will result in fewer natural-origin spawners escaping to spawning grounds. However, the co-managers will limit the total number of natural-origin SF Nooksack Chinook salmon collected according to the total escapement (Table 3), and return unused natural-origin volunteers to the river. Only natural-origin NF Nooksack Chinook volunteering to Kendall Creek Hatchery will be used as broodstock until adults produced as part of the increased off station releases return to the watershed. NMFS expects these integrated programs will increase overall spawner abundance as well as spatial diversity over the long term, which will offset the effects of any spawners that are taken into the hatchery as has been observed in watersheds with similar programs operating (Fast et al. 2015; Berejikian and Doornik 2018).

2.5.2.2. **Factor 2. Hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds and encounters with natural-origin and hatchery fish at adult collection facilities**

Although the proposed Chinook hatchery programs may pose both genetic and ecological risks, NMFS expects the two Nooksack Chinook salmon populations will benefit from the integrated programs designed to supplement the natural population, providing an overall beneficial effect on within-population diversity and to viability. Only ecological and physical broodstock collection effects are relevant for Puget Sound steelhead because the proposed programs do not propagate steelhead. The overall ecological effect to steelhead is very limited, and the broodstock collection effect is low, as discussed below.

2.5.2.2.1. Genetic Effects to ESA-listed Chinook salmon

For each hatchery program rearing ESA-listed salmon, NMFS considers three major areas of genetic effects: within-population diversity, outbreeding effects, and hatchery-influenced selection.

Skookum Creek and Kendall Creek Hatcheries

The SF Nooksack natural-origin Chinook salmon escapement has been trending upward since averaging only 49 adult natural-origin SF Nooksack Chinook salmon (2011-2015) to an annual average of 204 naturally spawning natural-origin SF Nooksack Chinook salmon adults during the most recent period for which data is available (2016-2021) (Haggerty 2024). In the NF Nooksack, the average annual adult escapement during the most recent period analyzed by the NWFSC (2015-2019) was 1,553 with the majority of those being hatchery-origin adults. This is a slight increase from the average annual adult escapement of 1,205 for the period of 2010-2014

(Ford 2022). Natural-origin productivity has been below replacement in both the SF and NF Nooksack Chinook salmon populations since the 1980s (Ford 2022).

The two Nooksack Basin Chinook salmon hatchery programs are intended to increase returning hatchery-origin adults spawning in the natural spawning environment. Since not all hatchery-origin fish return to the hatchery facilities and the number of natural-origin spawners is low, the proportion of hatchery-origin spawners (pHOS) is projected to be at the levels of ~90%. From 1999 through 2015 less than 16% of adult escapement in the SF Nooksack consisted of SF-origin Chinook salmon, with 46% of spawners assigning to the NF Nooksack population and 38% assigning to fall stocks. Since 2016 that has been completely reversed with SF Nooksack escapement being dominated by SF Nooksack origin adult Chinook salmon, averaging 81% of all spawners in the SF Nooksack. Contributions to spawning in the SF from both Nooksack Chinook salmon populations during this same period averaged 91%, with fall stocks composing the remaining 9%. Fall stock contributions continue to decline averaging less than 5% in the most recent 3-years (2019-2021) and less than half of the fall or other stock contribution coming directly from hatchery-origin fish, with 4.8%, 0.6%, and 2.0% pHOS from hatchery fall Chinook salmon estimated for each of these years.

Spawning habitats in the Nooksack Basin are thought to be under-utilized (SSDC 2007). Habitat capacity has been increased due to removing barriers to fish passage, habitat restoration projects, and increasing connectivity throughout the Watershed (Natural Systems Design 2021). As habitat improvements lead to increased rearing habitats productivity may increase as the watershed increases its ability to support higher numbers of fish (Anderson and Topping 2018). The co-managers' goal from increasing production is to produce more returning adults escaping to the Nooksack spawning grounds, which, if successful, would result in lower pHOS and increased proportionate natural influence (PNI) as the natural-origin progeny of the increased numbers of hatchery-origin adult Chinook salmon return to spawn naturally. The expectation is a resulting boost in productivity to the natural-origin populations. As productivity increases in the Nooksack Basin, it is reasonable to expect that this goal will be achieved and, long-term, the Nooksack Chinook salmon hatchery program will provide beneficial demographic effects by producing more adults to spawn naturally and beneficial genetic effects by increasing the populations' effective size, which will maintain genetic variation (SSDC 2007; Dayan et al. 2024).

In the short term, NMFS recognizes that negative genetic effects such as domestication or loss of genetic variation are possible with using hatchery programs to increase production. Rearing salmon in captivity can lead to domestication, which reduces genetic variation and adaptive potential, which can negatively affect the adaptive potential of the population (Frankham 2008; Fraser 2008). However, the Nooksack Hatchery programs will use a sliding scale to integrate natural-origin fish as broodstock in numbers appropriate given the forecasted annual escapement, which minimizes genetic risk by minimizing genetic divergence from the natural source population (Waters et al. 2015; Waters et al. 2018) as well as reducing adaptation to captivity (Janowitz-Koch et al. 2018). Recent genomics analysis of fish produced by hatchery programs segregated for multiple generations indicate they maintain levels of genetic variation and heterozygosity similar to their wild source populations (Howe et al. 2024) so although levels of natural-origin broodstock integration have been low in these programs the hatchery populations are likely to have maintained genetic variation through large effective size. The low PNI of <10% in the Nooksack Chinook salmon hatchery program is influenced by high pHOS and low numbers of natural-origin Nooksack broodstock. As these programs were founded from native Nooksack River Chinook salmon with their identity confirmed by genotyping, the hatchery and natural-origin spawners are genetically indistinguishable. Thus, the negative genetic effects generally associated with high pHOS and low PNI are likely not as detrimental for this population. The increased numbers of hatchery origin spawners will benefit the populations by increasing the effective size of the spawning population which will maintain genetic variation. Increased productivity of populations including both hatchery and natural spawners has been found to not be associated with PNI or pHOS, but rather the total number of spawners as well as ocean conditions and stream flow (Courter et al. 2022). From a genetics standpoint, the most detrimental scenario for the Nooksack River spring Chinook salmon populations is genetic drift caused by continued low numbers of spawners leading to loss of genetic variation (Willi et al. 2006; SSDC 2007; Kardos et al. 2021).

Fall Chinook Salmon Hatchery programs

The fall Chinook salmon programs do not incorporate listed fish into broodstock, therefore, only genetic effects related to fish from these programs escaping to natural spawning areas will be considered here.

The Fall Chinook salmon programs operated at Samish, Whatcom, and Glenwood Springs Hatcheries are segregated programs developed using Green River-origin ancestry Fall Chinook salmon and are intended for harvest augmentation. Returning adults from these three programs are not intended to spawn naturally and natural-origin adults are not collected for broodstock. If adults produced by these programs successfully spawn in natural spawning areas with native Nooksack Chinook salmon they could have genetic effects to natural populations including loss of genetic variation and domestication.

Analysis of CWT recoveries was used to determine the escapement of adult Fall Chinook salmon from these programs to natural spawning areas. The Fall Chinook salmon are temporally separated from the native SF and NF Nooksack populations so not all Fall Chinook adults reaching natural spawning areas are present at the same time as native NF and SF- Nooksack Chinook salmon (Haggerty 2024). Additionally, not all adults reaching the spawning areas successfully spawn. For these reasons, CWT recoveries likely overrepresent the impact of Fall Chinook salmon adults spawning naturally (Koch et al. 2022).

Expanded estimates of CWT recoveries from 2000 through 2016 indicate 95.3% of tagged adult Chinook salmon produced by the Samish Hatchery program that escape fisheries return to the Hatchery. The majority of the adults which do not return to the Hatchery return to the Samish River and only 0.37% escape to hatcheries or spawning areas in other watersheds. These results indicate that for every million Chinook salmon released from Samish Hatchery 1 adult Chinook salmon is estimated to escape to the SF Nooksack River and 1 adult Chinook salmon is estimated to escape to the NF Nooksack River. NMFS does not expect this low number of adults from the Samish Hatchery program escaping to the Nooksack River basin will affect the genetic variation of the Spring Chinook salmon populations.

Expanded estimates of CWT recoveries since 2008 indicate 89% of tagged adult Chinook salmon produced by the Glenwood Springs Hatchery program that escape fisheries return to the hatchery and 6% were recovered at Samish Hatchery. Approximately 2% of CWT recoveries from Glenwood Spring Hatchery were found volunteering to other Puget Sound Hatcheries or on natural spawning grounds. NMFS does not expect this low number of adults from the Glenwood Springs Hatchery program escaping to other watersheds in Puget Sound will affect the genetic variation of the Puget Sound Chinook Salmon ESU.

Whatcom Creek Hatchery recently began releasing fall Chinook salmon originating from Samish Hatchery. This is a harvest augmentation program and the salmon will be subjected to intensive harvest efforts in Bellingham Bay. NMFS expects the majority of the low numbers of adults produced as part of the Whatcom Creek hatchery program escaping harvest will return to the hatchery consistent with the other two fall Chinook salmon hatchery programs.

2.5.2.2.2. Effects on steelhead

Hatchery-origin salmon and their progeny on the spawning grounds are not expected to have ecological effects to Nooksack steelhead. Adult salmon spawn before steelhead arrive on the Nooksack spawning grounds and generally spawn in different areas of the watershed (WDFW 1994; SSDC 2007).

Broodstock collection for the Nooksack-Samish hatchery programs is not expected to affect Puget Sound steelhead for several reasons. Steelhead have not been observed volunteering to the hatcheries considered here. For the most part, steelhead have different run timing than the salmon reared at these hatcheries. NF Nooksack Chinook, coho, and chum salmon collected at Kendall Creek Hatchery return to spawn before ESA listed steelhead so broodstock collection has ended before adult steelhead are present (WDFW 2024e; 2024c; WDFW and Lummi Nation 2024). Kendall Creek Hatchery has prior authorization to collect and handle steelhead as part of their Early winter steelhead hatchery program (NMFS 2016b). Lummi Bay hatchery is geographically isolated from the Nooksack River basin and ESA listed steelhead have not been observed at that facility (Lummi Nation 2024e; 2024b; 2024a). Chinook salmon broodstock collection at Samish Hatchery occurs before winter steelhead return to freshwater. Steelhead have not been observed at Samish Hatchery since 1998 (WDFW 2024a). Steelhead have not volunteered to Skookum Creek Hatchery (Lummi Nation 2024d; 2024c). In-river coho brood collection for the Skookum Hatchery program will occur after adult Chinook have finished spawning and before the earliest returning adult winter steelhead are known to enter the South Fork Nooksack River. In-river coho broodstock collection will not occur in the South Fork Nooksack River tributaries or mainstem where summer steelhead adults could be encountered (Lummi Nation 2024c).

NMFS expects future encounters with steelhead will be rare. Any steelhead incidentally captured during broodstock collection activities would be returned to the river unharmed. NMFS expects that in years when steelhead are encountered and released during broodstock collection activities, only low numbers of steelhead will be encountered (e.g., 0-10 individuals) and they will be returned to the river unharmed.

2.5.2.3. **Factor 3. Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas, migratory corridor, estuary and ocean**

2.5.2.3.1. Competition and Predation in Freshwater

Specific risks associated with competitive impacts of hatchery salmonids on listed natural-origin salmonids may include competition for food and rearing sites (). Several factors influence the risk of competition posed by hatchery releases: whether competition is intraspecific or interspecific; the duration of freshwater co-occurrence of hatchery 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 freshwater co-occurrence. Hatchery smolts are commonly larger than natural-origin fish, and larger fish usually are superior competitors. However, natural-origin fish have the competitive advantage of prior residence when defending territories and resources in shared natural freshwater habitats. Tatara and Berejikian (2012) further reported 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.

En masse hatchery salmon smolt releases may cause displacement of rearing natural-origin juvenile salmonids from occupied stream areas, leading to abandonment of advantageous feeding stations, or premature outmigration by natural-origin juvenile salmonids. As an example, Pearsons et al. (1994) reported small-scale displacement of juvenile naturally produced rainbow trout from stream sections by hatchery steelhead. Small-scale displacements and agonistic interactions observed between hatchery steelhead and natural-origin juvenile trout were most likely a result of size differences and not something inherently different about hatchery fish.

A proportion of the smolts released from a hatchery may not migrate to the ocean but rather reside for a period of time in the vicinity of the release point. These non-migratory smolts (residuals) may directly compete for food and space with natural-origin juvenile salmonids of similar age. Although this behavior has been studied and observed, most frequently in the case of hatchery steelhead, residualism has been reported as a potential issue for hatchery coho and Chinook salmon as well. Adverse impacts of residual hatchery Chinook and coho salmon on natural-origin salmonids can occur, especially given that the number of smolts per release is generally higher; however, the issue of residualism for these species has not been as widely investigated compared to steelhead. Therefore, for all species, monitoring of natural stream areas in the vicinity of hatchery release points may be necessary to determine the potential effects of hatchery smolt residualism on natural-origin juvenile salmonids.

Hatchery programs typically minimize risk associated with competitive interactions between hatchery- and natural-origin fish by:

- Releasing hatchery smolts that are physiologically ready to migrate. Hatchery fish released as smolts emigrate seaward soon after liberation, minimizing the potential for

competition with juvenile naturally produced fish in freshwater (Steward and Bjornn 1990; California HSRG 2012).
- Operating hatcheries such that hatchery fish are reared to a size sufficient to ensure that smoltification occurs in nearly the entire population.
- Releasing hatchery smolts in lower river areas, below areas used for stream-rearing by naturally produced juveniles.
- Monitoring the incidence of non-migratory smolts (residuals) after release and adjusting rearing strategies, release location, and release timing if substantial competition with naturally rearing juveniles is determined likely.

Another potential ecological effect of hatchery releases is predation. Salmon and steelhead are piscivorous and can prey on other salmon and steelhead. Predation, either direct (consumption by hatchery fish) or indirect (increases in predation by other predator species due to enhanced attraction), can result from hatchery fish released into the wild. Considered here is predation by hatchery-origin fish, the progeny of naturally spawning hatchery fish, and avian and other predators attracted to the area by an abundance of hatchery fish. Hatchery fish originating from egg boxes and fish planted as non-migrant fry or fingerlings can prey upon fish from the local natural population during juvenile rearing. Hatchery fish are released at a later stage, so they are more likely to emigrate quickly to the ocean, and can prey on fry and fingerlings that are encountered during the downstream migration. Some of these hatchery fish do not emigrate and instead take up residence in the stream (as residuals) where they can prey on stream-rearing juveniles over a more prolonged period, as discussed above. The progeny of naturally spawning hatchery fish also can prey on fish from a natural population and pose a threat. 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.

Rensel et al. (1984) rated most risks associated with predation as unknown because there was relatively little documentation in the literature of predation interactions in either freshwater or marine areas at the time. More studies are now available, but they are still too sparse to allow many generalizations to be made about the risk assumed to be associated with predation. Newly released hatchery-origin yearling salmon and steelhead may prey on juvenile fall Chinook salmon and steelhead and other juvenile salmon in the freshwater and marine environments (Hargreaves and LeBrasseur 1986; Hawkins and Tipping 1999; Pearsons and Fritts 1999). However, predation rates have been reported for released steelhead juveniles as low (Hawkins and Tipping 1999; Naman and Sharpe 2012). Hatchery steelhead release timing and protocols used widely in the Pacific Northwest were shown to be associated with negligible predation by migrating hatchery steelhead on fall Chinook salmon fry, which had already emigrated or had grown large enough to reduce or eliminate their susceptibility to predation when hatchery steelhead entered the rivers (Sharpe et al. 2008). Hawkins (1998) documented hatchery spring Chinook salmon yearling predation on naturally produced fall Chinook salmon juveniles in the Lewis River. Predation on smaller Chinook salmon was found to be much higher in naturally produced smolts (coho salmon and cutthroat, predominately) than their hatchery counterparts.

Predation may be greatest when large numbers of hatchery smolts encounter newly emerged fry or fingerlings, or when hatchery fish are large relative to naturally produced fish (Rensel et al.

1984). Due to their location in the stream or river, size, and time of emergence, newly emerged salmonid fry are likely to be the most vulnerable to predation. Their vulnerability is believed to be greatest immediately upon emergence from the gravel and then their vulnerability decreases as they move into shallow, shoreline areas (USFWS 1994). Emigration out of important rearing areas and foraging inefficiency of newly released hatchery smolts may reduce the degree of predation on salmonid fry (USFWS 1994).

Some reports suggest that hatchery fish can prey on fish that are up to 1/2 their length (Pearsons and Fritts 1999; HSRG 2004b), but other studies have concluded that salmonid predators typically prey on fish 1/3 or less their length (Horner 1978; Hillman and Mullan 1989; Beauchamp 1990; Cannamela 1992; CBFWA 1996). Hatchery fish may also be less efficient predators as compared to their natural-origin conspecifics, reducing the potential for predation impacts (Sosiak et al. 1979; Bachman 1984; Olla et al. 1998).

Within the context discussed above, we expect hatchery programs producing salmon for the Nooksack-Samish hatchery programs to minimize risk associated with predation of hatchery-origin fish on natural-origin fish by implementing most or all of the following practices:

- Releasing all hatchery fish as fry or actively migrating smolts through volitional release practices so that the fish migrate quickly seaward, limiting the duration of interaction with any co-occurring natural-origin fish downstream of the release site.
- Ensuring that a high proportion of the population have physiologically achieved full smolt status. Juvenile salmon tend to migrate seaward rapidly when fully smolted, limiting the duration of interaction between hatchery fish and naturally produced fish present within, and downstream of, release areas.
- Releasing hatchery smolts in lower river areas near river mouths and below upstream areas used for stream-rearing young-of-the-year naturally produced salmon fry, thereby reducing the likelihood for interaction between the hatchery and naturally produced fish.
- Operating hatchery programs and releases to minimize the potential for residualism.

While competition and predation are important factors to consider, these events are rarely if ever observed and directly calculated, particularly in large open systems characterized by saltwater ecosystems. However, researchers have analyzed these behaviors enough to where NMFS can model these potential effects on the species based on known factors that lead to competition or predation occurring. Here, the predation-competition-delayed mortality (PCD) Risk model version 4.0 of (Pearsons and Busack 2012) was used to quantify the potential number of natural-origin Chinook salmon and steelhead juveniles lost to competition and predation from hatchery-origin juvenile Chinook, coho, and chum salmon from the Nooksack-Samish hatchery programs.

The logic used in the PCD Risk model was originally described by (Pearsons and Busack 2012), but has since been modified to increase supportability and reliability. Notably, the current version no longer operates in a Windows environment and no longer has a probabilistic mode. The model was further refined by allowing for multiple hatchery release groups of the same species to be included in a single iteration. The one modification to the logic was a 2018 elimination of competition equivalents and replacement of the disease function with a delayed mortality parameter.

The rationale behind the change described above was to make the model more realistic; in the model competition rarely directly results in mortality because it takes many competitive interactions to suffer enough weight loss to cause mortality. Weight loss is how adverse competitive interactions are captured in the model. However, fish that experience competition and resulting weight loss are likely more vulnerable to mortality from other factors such as disease. Now, at the end of each run, the competitive impacts for each fish are assessed, and the fish has a probability of delayed mortality based on the competitive impacts. This function will be subject to refinement based on research. For now, the probability of delayed mortality is equal to the proportion of a fish's weight loss. For example, if a fish has lost 10% of its body weight due to competition and a 50% weight loss kills a fish, then it has a 20% probability of delayed mortality, (0.2 = 0.1/0.5).

Similar to the use of models for biological systems elsewhere, this model cannot possibly account for all the variables that could influence competition and predation on natural-origin juveniles. For example, the model assumes that if a hatchery fish is piscivorous and stomach capacity is available, the hatchery fish will consume natural-origin prey. In reality, hatchery-origin fish could choose to eat a wide variety of invertebrates, such as other fish species (e.g., minnows), and other hatchery-origin fish in addition to natural-origin steelhead smolts. However, NMFS believes that with this model we are, to the best of our ability, not underestimating the effects on natural-origin juvenile steelhead. There are caveats to consider in interpreting the results of the PCD Risk model. Importantly, the PCD Risk model is not a total simulation of ecological interactions between hatchery and wild fish. Competition is represented in the model as only direct interactions between hatchery- and natural-origin fish; the model does not include potential density-dependent effects from resource depletion, for example. The model does not include predation or competition from non-hatchery fish (salmonids or otherwise) nor from non-fish species such as piscivorous birds or mammals. It also does not account for the possible beneficial effects of juvenile hatchery-origin fish releases, such as providing prey for natural-origin salmon and steelhead or buffering effects from non-hatchery origin predators. Another limitation is that neither species grows during the simulation. In reality, of course, fish growth could greatly change competition dynamics and susceptibility to predation. Finally, and perhaps most relevant, PCD Risk is limited to evaluating interactions between one hatchery-origin species and one natural-origin species under specified conditions in a specified area over a limited time.

PCD Risk analyses of Nooksack-Samish hatchery Chinook, coho, and chum salmon on steelhead resulted in a range of different mortalities depending upon the scenario being modeled. Hatchery coho salmon effects on steelhead were modeled using two scenarios: A mid-April release and a late-May release. Modeled results ranged from a low of 0.5% mortality (0.7% of the adult equivalent run-size [pAEQ] and 1.8% total mortality (pAEQ=2.1%). Chinook salmon effects on steelhead were modeled with four scenarios; a mid-April release and May release both with two travel time rates. Modeled mortalities ranged from a low 0.4% (pAEQ=0.5%) to a high of 0.5% total mortality (pAEQ=1.3%). Three scenarios were run to evaluate the effects of hatchery chum salmon on steelhead, all scenarios assumed a mid-April or early May release period with a range of transit times to clear the system of 7 to 21 days; all runs resulted in low mortality rates (<<0.1%) and caused modeled mortality of less than 0.01% of the adult equivalent run sizes.

In general, modeled mortality rates were much lower during the period when no age 0+ fish were present, and increased when abundant fry were present. A review of steelhead spawning escapement from 2014-2022 indicates that approximately 24% of steelhead spawning occurs within the migration corridor of the salmon hatchery releases within the Nooksack Watershed. PCD risk modelling was conducted to evaluate predation and competition risks associated with the release of 5.7 million subyearling Chinook salmon from Kendall and Skookum hatcheries on the natural-origin Nooksack steelhead populations. Four scenarios were modeled: an early-May and late-May release, both with 14-day and 21-day transit times from release location to the marine environment. Total mortality rates ranged from 0.5% to 0.6% between the four scenarios, and pAEQ averaged 0.6% for the early-May release and 1.1% for the late-May release. PCD risk modelling was conducted to evaluate predation and competition risks associated with the release of 5 million age 0 chum salmon from Kendall Hatchery on the natural-origin Nooksack steelhead populations. Three scenarios were modeled: a mid-April release with 7-, 14-, and 21-day early-May and late-May release, both with 14-day and 21-day transit times from release location to the marine environment. Total mortality rates ranged were less than 0.01% in all scenarios, and pAEQ was also below 0.01% for all scenarios. PCD risk modeling was also conducted to evaluate predation and competition risks associated with the release of 6.0 million subyearling Chinook salmon from Samish hatchery on the natural-origin steelhead population. A total of four scenarios were modeled: an early-May and late-May release, both with 7-day and 14-day transit times from release location to the marine environment. Little variation in mortality rates was observed between scenarios. Mortality rates ranged from 0.02% to 0.05% with a pAEQ ranging from 0.04% to 0.06% (or less than one adult steelhead).

PCD Risk analyses of Nooksack-Samish hatchery coho and chum salmon on Chinook salmon resulted in a range of different mortalities depending upon the scenario being modeled. Within the Nooksack basin, ten coho salmon model scenarios were run allowing natural-origin juvenile abundance to range from 100,000 to 1 million, with releases ranging from April through early-June. At low natural-origin abundance hatchery related competition and predation moralities ranged from 1.9% (at the lowest abundance with an April release) to 0.2% with an early June release, most morality from the April release is from predation, whereas little to no predation was modeled to occur after April once Chinook salmon juveniles attain a size too large to be consumed by coho salmon in the model. Within the Nooksack basin, eleven chum salmon model scenarios were run allowing natural-origin juvenile abundance to range from 100,000 to 1 million, with releases in May at different varying transit times (7-21 days) and at varying average size of natural-origin Chinook salmon. Little variation in mortality rates were observed across abundance levels and travel times with total mortality ranging from 0.02% to 0.04%. When smaller natural-origin Chinook salmon (60mm vs 68mm) were simulated in the model, mortalities increased from 0.03% to 0.12% and from 0.04% to 0.15%.

2.5.2.3.2. Ecological Effects in Marine Areas

Ecological effects from hatchery fish in marine areas may be negative, positive, or neutral. Primary risks to natural-origin ESA-listed fish arise from competition and predation. This section first describes the expected marine distribution of Chinook, coho, and chum salmon produced by the Nooksack-Samish hatchery programs. Next, evidence for competition and predation in marine areas is described in separate subsections. Then, risk of competition and predation to ESA-listed ESUs and DPSs is analyzed.

2.5.2.3.2.1. Marine Distribution of Nooksack-Samish Hatchery Salmon

Hatchery-origin Puget Sound Chinook salmon migrate from freshwater to estuaries as sub-yearlings with peak migration mid-June and have a short nearshore residence time before moving to marine areas (Beamer et al. 2024). In terms of marine distribution, Chinook salmon produced by the Nooksack-Samish hatchery programs remain mostly or entirely on the continental shelf primarily from northern Oregon (north of Cape Falcon) to southeast Alaska, as well as within the Salish Sea. This is based on coastwide juvenile survey data (Trudel et al. 2009; Tucker et al. 2012; Trudel and Hertz 2013; Fisher et al. 2014; Teel et al. 2015; Hassrick et al. 2016), and immature and adult coded-wire tag and genetic stock identification data (Quinn 2018; Riddell et al. 2018, and references therein; Shelton et al. 2019; Shelton et al. 2021). On average, approximately 0.02% of fall Chinook salmon from the combined regions of the Nooksack-Samish hatchery programs move to areas south of Cape Falcon, Oregon (Shelton et al. 2019) and Nooksack spring Chinook salmon have not been encountered south of Cape Falcon (Shelton 2024). Coho salmon released from Puget Sound hatcheries, including the Nooksack-Samish hatcheries, reside in estuaries for a short period before migrating to marine area and are primarily encountered in marine areas off the coast of Washington and British Columbia with very few being encountered South of Cape Falcon (Weitkamp et al. 1995). Chum salmon produced by the programs are expected to spend up to one month in estuarine shallow waters before moving to the ocean. After leaving estuaries, juveniles may exhibit extended residency within Puget Sound before migrating, and may even overwinter in the sound. In the ocean, juveniles move northward along nearshore areas to Alaska (Johnson et al. 1997). Because of the very small projected increases in southern areas, we expect that the Nooksack-Samish hatchery programs will have immeasurable competitive effects and discountable predation effects to ESA-listed salmonids in these areas south of Cape Falcon, Oregon, based on the evidence for competition and predation in marine areas described below.

2.5.2.3.3. Evidence for Competition in Marine Areas

Nooksack-Samish program hatchery salmon have the potential to adversely affect natural populations of ESA-listed salmon and steelhead through competition in marine areas. As juvenile salmon arrive in the estuaries, they may compete with other salmon and steelhead in areas where they co-occur, if shared resources are limiting. Effects may be more pronounced in estuaries and nearshore marine waters adjacent to river mouths where hatchery-origin salmon may initially be concentrated. Interactions and effects likely diminish as the fish disperse into more offshore areas.

The main limiting resource for salmon and steelhead that could be affected through competition posed by hatchery-origin fish is food. The early estuarine and nearshore marine life stage, when juvenile fish have recently entered the estuary and populations are concentrated in a relatively small area, is a critical life history period during which there may be short term instances where food is in short supply, and growth and survival declines as a result (e.g., Duffy 2003; Pearcy and McKinnell 2007). The degree to which food is limiting depends upon the density of prey species. This does not discount limitations in available food resources in more seaward areas as a result of competition, as data are available that suggests that marine survival rates for salmon are density dependent, and thus possibly a reflection of the amount of food available (e.g., Brodeur 1991; Holt et al. 2008). Researchers have looked for evidence that marine area carrying capacity can limit salmonid survival (e.g., Beamish et al. 1997; HSRG 2004a; Ruggerone et al. 2023). Some evidence suggests density-dependence in the abundance of returning adult salmonids (Emlen et al. 1990; Lichatowich et al. 1993; Bradford 1995), associated with cyclic ocean productivity (Nickelson et al. 1986; Beamish and Bouillon 1993; Beamish et al. 1997). Collectively, these studies indicate that competition for limited food resources in the marine environment may affect survival (also see Brodeur et al. 2003). The possibility that large-scale hatchery production could exacerbate density dependent effects in the ocean, particularly when ocean productivity is low, deserves consideration. For example, Puget Sound origin salmon survival may be intermittently limited by competition with almost entirely natural-origin odd-year pink salmon originating from Puget Sound and the Fraser River watersheds (Ruggerone and Goetz 2004), particularly when ocean productivity is low (Nickelson et al. 1986; Beamish and Bouillon 1993; Beamish et al. 1997; Mahnken et al. 1998). Evidence for competition in marine areas, and the potential role of the Nooksack-Samish hatchery programs Chinook salmon, is described below.

Evidence from the North Pacific Ocean

Ruggerone et al. (2023) provide evidence that pink salmon is a primary driver of ecosystem dynamics in the Pacific Ocean, affecting a multitude of species, including other salmonids. In short, correlative evidence suggests that pink salmon have negative consequences to other salmon species in marine habitats, including Chinook, coho, chum, and sockeye salmon and steelhead. Such negative consequences are presumed to arise via food web interactions. That is, large numbers of pink salmon may: 1) overconsume the same prey that other salmonids rely on; and/or, 2) overconsume prey at lower trophic levels (e.g., plankton) leading to less abundance of prey at the higher levels (e.g., fish) that other salmonids, such as Chinook and coho salmon, rely on (i.e., a “trophic cascade”). Further, evidence is presented that climate change has benefitted pink salmon to the detriment of other salmon species, contributing to a steady increase in ocean-wide pink salmon abundance from the mid-20th century to now. Ruggerone et al. (2022) note that 5.5 billion juvenile hatchery salmon were released into the Pacific Ocean in 2019 (citing North Pacific Anadromous Fish Commission (NPAFC) data), and that approximately 40% of the total salmon biomass in the Pacific Ocean during 1990–2015 was made up of hatchery salmon, especially chum and pink salmon (citing Ruggerone and Irvine 2018). The implication is that hatchery fish deepen the negative competition and density-dependent effects triggered by climate change and pink salmon.

At the scale considered by Ruggerone et al. (2022)–the entire Pacific Ocean–hatchery- and natural-origin Chinook salmon contribute very little to overall salmon foragin demand. Chinook salmon make up a small proportion of salmon in the Pacific Ocean, approximated to be less than 1.3% by Ruggerone and Irvine (2018) based on NPAFC catch weight data (1992–2015). Also, hatchery Chinook salmon make up a small proportion of hatchery salmon releases, averaging just 4.8% annually (range 4.6–5.1%) of all Pacific Ocean hatchery salmon releases from 2013 to 2022 (NPAFC 2023).

Though not addressed by Ruggerone et al. (2022), Ruggerone et al. (2023) acknowledge that regional differences may exist whereby researchers in some regions (western Bearing Sea and western North Pacific Ocean) argue that the oceanic salmonid prey base is plentiful, but that much of the research providing evidence of the opposite (i.e., negative competitive effects) is from other regions of the ocean. For example, the substantial majority of the evidence presented by Ruggerone et al. (2023) of negative pink salmon effects to Chinook salmon is from two regions: Alaska and the Salish Sea. For the Alaska-based evidence, negative pink salmon effects to Chinook salmon occurred after the Chinook salmons first ocean year, whereas that presented for Salish Sea Chinook salmon occurred earlier, during the first ocean year. This difference in timing of apparent negative effects may be related to several factors. Both species—Chinook and pink salmon—spend their first ocean year in continental shelf areas (Radchenko et al. 2018; Riddell et al. 2018). However, Alaskan Chinook salmon are "stream-type" fish, meaning they outmigrate to marine habitats as yearlings after spending one year in freshwater. Thus, they are substantially larger during shelf residence than pink salmon, which outmigrate to marine waters as fry, likely limiting potential for competitive interactions between the species. That is, larger juvenile Chinook salmon the size of yearling migrants are generally piscivorous (Hertz et al. 2015; Riddell et al. 2018), while juvenile pink salmon during their first ocean year are planktivores (Radchenko et al. 2018). After their first ocean year, both species move to open ocean habitats off the continental shelf until they mature (Healey 1983). This is the time when the Alaskan-based studies have detected competitive effects to Chinook salmon (i.e., during the years they overlap with pink salmon in the open ocean).

In contrast to the "stream-type" Alaskan Chinook salmon described in the preceding paragraph, most Salish Sea Chinook salmon are "ocean-type", meaning they outmigrate to marine waters as subyearlings rather than spending a full year of life in freshwater. Thus, when they enter marine waters in late spring, they are comparable in size to the pink salmon that outmigrated several months earlier as fry but grew while the Chinook were rearing in freshwater (Duffy et al. 2005). The comparable size lends itself to greater competition, as subyearling Chinook salmon feed heavily on zooplankton while rearing in Puget Sound (Duffy et al. 2010). Further, fall Chinook salmon comprise the majority of Chinook salmon in Puget Sound. Puget Sound fall Chinook salmon are known to remain mostly or entirely on the continental shelf during the entirety of their marine residence (Shelton et al. 2019), where overlap with pink salmon after their first ocean year would be would be minimal. This may be why Sobocinski et al. (2021) observed only very weak effects on ocean abundance on Puget Sound Chinook salmon SARs (see additional discussion below).

The Alaskan studies that have specifically investigated pink salmon effects to Chinook salmon have found relatively minor effects with weak support (Cunningham et al. 2018; Oke et al. 2020). Cunningham et al. (2018) found that Japanese hatchery chum salmon abundance had a noticeably larger and more supported effect on Yukon River Chinook salmon than pink salmon. Japanese hatchery chum salmon typically make up about 30% of all salmon hatchery releases into the Pacific Ocean, and would not affect Chinook salmon from the continental United States. Oke et al. (2020) evaluated the continuous decline in body size of 202 Alaskan Chinook salmon populations from 1975 to 2018. Both climate and competition variable were evaluated for their effects. Competition from pink and sockeye salmon were negatively correlated with Chinook salmon body size. The combined effects of climate and competition explained only 29% of the variation in Chinook salmon body size, indicating that the combined effects from unexplored factors were more influential. In contrast to Cunningham et al. (2018), Oke et al. (2020) observed a positive correlation between chum salmon abundance and Chinook salmon body size.

Buckner et al. (2023) evaluated the effects of climate and oceanographic variables and pink salmon abundance on growth to adult stage (length-at-size) of 48 hatchery Chinook salmon stocks from the Columbia River basin, coastal Washington and Oregon, and Puget Sound. They found a negative correlation between Chinook salmon growth and North American pink salmon abundance for Chinook salmon stocks that have a more northerly distribution (north of Vancouver Island). Chinook salmon growth trends have been declining as pink salmon abundance has been increasing. Thus, Buckner et al. (2023) acknowledge that their observations may be the result of the match of these long-run trends rather than an underlying casual causal relationship. Nonetheless, juvenile pink salmon abundance on the continental shelf is lowest along the Washington-to-California coast, moderate along the west coast of Vancouver Island, and highest to the north of Vancouver Island (Fisher et al. 2007a). Further, some far northerly migrating Chinook salmon populations from the continental United States move to the open ocean after their first ocean year (i.e., upper Columbia River and Snake River spring Chinook salmon) (Shelton 2024), where immature and adult pink salmon are also found. In contrast, populations that do not migrate far north remain mostly or entirely on the continental shelf (i.e., fall-, summer-, and spring-run populations other than upper Columbia River and Snake River spring Chinook salmon) (Shelton et al. 2019; Shelton 2024), where overlap with immature and adult pink salmon is minimal. Thus, the difference in spatial overlap with pink salmon between the more northerly and southerly distributed groups may at least partially explain why the more northerly migrating stocks showed evidence of pink salmon effects.

The above evidence suggests that pink salmon may have a negative effect on growth of other salmon species when they overlap in marine areas. In years of high pink salmon abundance and/or unfavorable ocean conditions, forage resources for other salmon species may become limited. Though it is possible that this may trigger negative density-dependent inter- and intra-specific competition among salmon species that utilize similar habitats and forage resources, effects are likely small relative to those from pink salmon. There is no direct evidence that competition from hatchery Chinook salmon negatively affects natural Chinook salmon or other salmon species in these areas. This is likely due to the fact that Chinook salmon make up a relatively small proportion of salmon in the North Pacific Ocean, and hatchery Chinook salmon make up a very small proportion of hatchery fish released into the ocean.

Little is known about the ecology of coho salmon in marine environments, however, their diet seems to consist largely of juvenile non-salmonid fishes and small crustaceans. Analysis of coho prey did not include salmon of any species. Chinook and coho salmon seem to differ from one another (Weitkamp and Sturdevant 2008). Due to the lack of predation on juvenile salmonids and the differences in preferred prey items it is unlikely that the Nooksack-Samish hatchery coho salmon will have a detectable effect of ESA listed salmon and steelhead species in marine areas.

In marine waters, the diet of chum salmon differs from that of other salmonid species which reduces the likelihood that hatchery chum compete with ESA listed salmon and steelhead in marine areas and consists largely of zooplankton which reduces the likelihood hatchery chum salmon are predating on ESA listed salmon and steelhead in marine areas (Brodeur et al. 2007).

Evidence from Puget Sound

For Chinook salmon, the time spent rearing in Puget Sound is one of the most critical periods impacting their fitness and survival (Greene et al. 2005; Sobocinski et al. 2020; Pearsall et al. 2021). However, assessment of the effects of hatchery fish on natural-origin Chinook salmon in Puget Sound marine areas is problematic because relevant scientific knowledge is incomplete, albeit rapidly evolving (Pearsall et al. 2021). In their 2021 comprehensive review of the available science, the Synthesis Committee of the Salish Sea Marine Survival Project[6] (SCSSMSP) noted that the following factors appear to be most influential to Chinook mortality in Puget Sound: predator abundance (particularly seals), contaminants, water quality, prey availability, and growth during the early marine "critical period" (Pearsall et al. 2021). With regards to effects from hatchery fish, competitive interactions that negatively affect natural Chinook salmon (e.g., depleting prey resources and negatively impacting growth) are of particular concern. The SCSSMPS concluded that: 1) there is some evidence that intra- and inter-specific competition during some time periods and in some places of the Salish Sea impacts Chinook salmon marine survival; 2) study results are mixed; and, 3) if competition does occur, it is most likely dictated by factors other than Chinook abundance that deplete or limit prey availability or habitat (e.g., dynamic environmental variables, ecosystem productivity, and food web interactions involving natural-origin species such as pink salmon, herring, and crab) (Pearsall et al. 2021). Therefore, hatchery releases could exacerbate density-dependent effects during years of low productivity in Puget Sound.

Sobocinski et al. (2021) also evaluated density-dependent indicators in isolation from other groupings of indicators (e.g., predator buffering, water quality). Ocean salmon abundance (pink, chum, and sockeye only) was one of the two strongest predictors of Chinook salmon SAR, the other being Salish Sea sea surface temperature. A weak and variable relationship was observed with subyearling hatchery Chinook salmon abundance, whereby SAR increased with increasing hatchery Chinook salmon abundance to a point, then declined as hatchery Chinook salmon abundance increased further. This relationship was only about one-fifth as strong as the strongest density-dependent metrics (sea surface temperature and ocean salmon abundance) and was absent from the 7 best performing density-dependence models. The best performing density-dependence models explained no more than 24% of the variation in Chinook SAR.

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[6] The Salish Sea Marine Survival Project, launched in 2013, describes itself as follows (Pearsall et al. 2021): "[The Salish Sea Marine Survival Project is] a US-Canada research collaboration to identify the primary factors affecting the survival of juvenile Chinook, Coho, and steelhead in the Salish Sea marine environment. From 2014–2018, this international collaborative of over 60 Federal, state, tribal, nonprofit, academic, and private entities implemented a coordinated research effort that encompassed all major hypothesized impacts on Chinook, Coho, and steelhead as they entered and transited the Salish Sea. Ultimately, several hundred scientists collaborated to implement over 90 studies…[The Synthesis Report (i.e., Pearsall et al. 2021)] synthesizes the work to date and provides [the Synthesis Committee's] perspectives regarding the primary factors affecting survival and the next steps in research and management."

Kendall et al. (2020) evaluated the influence of pink salmon presence and hatchery Chinook salmon abundance, among a few other variables, on survival (smolt to ocean age 1) of 33 Salish Sea yearling and subyearling Chinook salmon hatchery stocks for ocean entry years 1983–2012. con smolt-to-adult return rate (SAR) of 25 Puget Sound subyearling and yearling Chinook salmon hatchery stocks for ocean entry years 1975–2012[6]. The best performing model explained 41% of the variation in survival. There was a strong relationship observed between survival and region of origin (e.g., northern Washington, south Puget Sound). The interaction of pink salmon presence and hatchery Chinook salmon abundance had significant exploratory power. That is, in even-numbered years (pink salmon present), hatchery Chinook salmon survival from some regions decreased with increasing release abundances, suggesting that pink salmon were mediating ecosystem dynamics and triggering negative density-dependent interactions in hatchery Chinook salmon. Conversely, in odd-numbered years (pink salmon absent), hatchery Chinook salmon survival in some regions increased with increasing release abundances, suggesting possible predator buffering effects. Hatchery-released fry, which have extremely high mortality immediately after release, were a substantial proportion of the hatchery fish included in the early part of the time series, potentially biasing results and leading to spurious findings.

Ruggerone and Goetz (2004) evaluated influence of the even-odd year pink salmon cycle for its influence on SAR of 22 hatchery Chinook salmon populations from the Salish Sea and Washington coast for hatchery release years 1972–1997. During the latter part of the time series (1984–1997), pink salmon presence (even-numbered years) was associated with lower Chinook salmon growth during early marine residence, delayed maturity, and lower survival (SAR) in Salish Sea Chinook salmon stocks. This suggested that pink salmon were mediating ecosystem food-web dynamics and triggering negative density-dependent interactions in hatchery Chinook salmon during their first ocean year. However, during the early part of the time series (1972–1983), Chinook salmon survival was greater during years of pink salmon presence, suggesting predator buffering effects. The authors provide evidence of an El Niño-based "regime shift" that occurred around 1982–1983, whereby abundances of many predators shifted in Puget Sound, altering the influence of pink salmon within the ecosystem generally, and on hatchery Chinook salmon specifically. The Salish Sea hatchery populations included in the study were, with only on exception, Green River-derivative. Thus, the findings may not be broadly applicable to other Salish Sea natural- or hatchery-origin populations.

Losee et al. (2019) evaluated changes in adult body size, abundance, and survival (SAR) of Puget Sound salmon and steelhead from 1970–2015. Correlations between species and origin (hatchery or natural) were evaluated, though correlations were reported in a color-coded format making it difficult to interpret in the strength of correlation in many cases. In addition, statistical significance of correlations were not provided for most pairings. In evaluating the relationship between hatchery- and natural-origin Chinook salmon, weal negative correlations were observed in both abundance and survival (statistical significance not reported). Pink and natural-origin Chinook salmon abundance was strongly negatively correlated ($p<0.05$), but survival was positively correlated (weak to moderate). Conversely, for both abundance and survival, pink and hatchery-origin Chinook salmon were positively correlated either weakly (survival) or weak to moderately (abundance).

Claiborne et al. (2021) evaluated the influence of pink salmon abundance in Puget Sound on early marine growth and survival of three Puget Sound natural fall Chinook salmon populations from 7 outmigration years with contrasting survival rates. There was a moderate to strong correlation observed between early marine growth and survival in all three populations (Pearson Correlation Coefficients, r=0.06, 0.89, 0.96). There was a strong negative correlation between growth and Puget Sound pink salmon abundance in one population (r+-0.89), and a weak negative correlation in the other two (r = -0.29, -0.33).
Nelson et al. (2019) evaluated the influence of seal density and hatchery Chinook salmon abundance on productivity (spawner to ocean age 2) of 20 Salish Sea and Washington coast naturally-spawning Chinook salmon stocks for brood years 1972–2008[7]. The best models explained 67–69% of the variation in productivity, the substantial majority of which was explained by seal density. They found little evidence of any wide-spread negative relationships between regional-scale hatchery Chinook salmon release abundances and natural-origin productivity, concluding that "…effects of hatchery abundance on wild stock productivity were mixed and weak in most populations…" One stock (Stillaguamish) showed a positive relationship between relationship between hatchery release abundance and natural stock productivity, perhaps due to predator swamping effects. In contract, seal density was found to have a strong negative influence on productivity in 14 of the 20 stocks evaluated.

By not accounting for pink salmon, it is possible that effects of hatchery release abundances were obscured in the Nelson et al. (2019) study. However, it is also possible that hatchery release abundances are more negatively influential on survival of hatchery-, but not natural-origin fish. Relative to natural-origin Chinook salmon, hatchery Chinook salmon enter Puget Sound over a condensed time period, at a larger size, and with less fish size variability (Nelson et al. 2019). Thus, intra-specific competitive effects on survival may be more accurate among hatchery-origin fish themselves.

Greene et al. (2023) evaluated the influence of prey availability and foraging demand by 12 prominent planktivorous taxa, including Chinook salmon, on subyearling natural- and hatchery-origin Chinook salmon in Puget Sound epipelagic waters during June-August, a time when both: 1) most juvenile Chinook salmon have entered these areas from nearshore and estuary habitat and forage heavily on zooplankton; and 2) juvenile Chinook salmon grow very rapidly. One part of the study (spatially extensive) evaluated effects on Chinook salmon growth (as measured by IGF-l[8]) across Puget Sound in 2011. Another part of the study (temporally extensive) evaluated the effects on Chinook salmon estimated growth (represented by monthly size change) within one focal area (Skagit Bay) during 2014–2021. A third part of the study evaluated effects of estimated total annual foraging demand by epipelagic planktivores during 2001–2017 on survival (SAR) of Skagit River natural Chinook salmon. Results showed that hatchery- and natural-origin Chinook salmon generally placed a relatively low demand on forage resources compared to other forage resources were generally sufficient to support the demand in 8 of the 9 years evaluated. Evaluation of the 17-year SAR time series indicated a week correlation of SAR with total foraging demand by all planktivores (Pearson r = 0.386) and no correlation with either natural (unmarked) juvenile Chinook salmon density (Pearson r = 0.017) or total juvenile Chinook salmon density (Pearson r = 0.052).

Davis et al. (2020) sampled IGF-l from juvenile Chinook salmon in nearshore and pelagic areas across Puget Sound during June–August, 2014–2015, two of the years that Greene et al. (2023) found no evidence of forage limitations. These years, 2014 and 2015, had the second and fourth lowest foraging demand, respectively, and the highest and fifth highest SAR, respectively, in the 17-year SAR time series evaluated by Greene et al. (2023). IGF-l was about 45-50ng/ml for 101-125 mm FL fish in pelagic areas during these years (Davis et al. 2020). In contrast, the one year that (Greene et al. 2023) observed likely forage resource limitations (2011), juvenile Chinook salmon experienced lower growth during the June–August time period than in 2014–2015: in 2011, IGF-l was 32–45 ng/mL for comparable size fish in comparable areas, with some expectations (Chamberlin et al. 2017). The year 2011 had the third largest estimated foraging demand and was one of two years with the lowest SARs in the 17-year time series evaluated by Greene et al. (2023).

Rice et al. (2011) evaluated the influence of location (Puget Sound sub-basins) and juvenile Chinook salmon density (hatchery- and natural-origin) on their growth 9represented by residual fish lengths) in Puget Sound epipelagic waters adjacent to shore from April to November, 2003. Models that included sub-basin and any one of three juvenile Chinook salmon density metrics (hatchery-origin only, natural-origin only, hatchery- plus natural-origin combined) explained 51-54% of the variation in natural Chinook salmon growth. A model that included only sub-basin explained 36% of the variation. Thus, sub-basin appeared to be the dominant factor, with the various metrics of Chinook salmon density explaining an additional 15-18% of the variation in growth. Interestingly, the one year (2003) evaluated by Rice et al. (2011) had the second largest foraging demand by pelagic planktivores of the 17-year time series evaluated by Greene et al. (2023) that showed evidence of limited pelagic foraging resources with concomitant negative consequences to Chinook salmon growth. Thus, in the context of observations by Greene et al. (2023), it appears that Rice et al. (2011) sampled during a year when competition for foraging resources among epipelagic planktivore community was particularly intense, and that the observed density-dependent effects, though relatively minor, were uncommonly large.

Greene et al. (2021) evaluated the potential for density-dependence in the inner estuaries (tidal deltas) of four large Puget Sound rivers (Nisqually, Nooksack, Skagit, and Snohomish rivers). Subyearling Chinook salmon make extensive use of natal inner estuaries until they are about 70–75 mm FL, at which point they disperse to other habitats (e.g., outer estuary, epipelagic, intertidal nearshore) (Healey 1980; Greene et al. 2021). One part of the study examined 6–22 years (depending on the river) of data on juvenile Chinook salmon outmigration abundance (stock) and their densities in inner estuary habitat (recruit) at fine spaciotemporal scales. Results showed that exceedances of estimated capacity were driven almost entirely by natural-origin fish in three of the river deltas examined, though there was substantial variability in the data used to estimate capacity. Hatchery fish were a minor to nearly non-existent contributor to exceedances of estimated capacity. Another part of the study evaluated bioenergetic demand of juvenile Chinook salmon in these habitats relative to prey availability during one year (2014). In general, forage resources did not appear to be limiting during times when hatchery fish were present in more than minor proportions.

The above evidence suggests that intra- and inter-specific competition occurs at some times and in some places of Puget Sound marine waters. To the extent that competition does occur, hatchery salmon abundance does not appear to be a primary driver. Rather, ocean conditions and abundance of pink salmon are the dominant factors influencing forage availability and competitive effects. In years of high competitor abundance and/or unfavorable ocean conditions, forage resources for salmonids may become limited. Though it is possible that this may trigger negative density-dependent inter- and intra-specific competition among salmon species that utilize similar habitats and forage resources, effects are likely small relative to those from other non-salmonid competitors.

Evidence from the Oregon and Washington Coast

Evidence for competition along the Washington and Oregon coast is limited and equivocal. Spawning populations of pink salmon do not occur along the Washington coast, in the Columbia River, or in areas to the south (Hard et al. 1996). Pink salmon are therefore relatively rare in Washington and Oregon coastal waters (Fisher et al. 2007b). This likely at least partially explains why Ruggerone and Goetz (2004) did not observe any odd-year patterns in survival of Chinook salmon populations that spawn in Washington coastal rivers. Thus, to the extent that pink salmon is a primary driver of marine food web interactions, these effects are extremely minor, if nonexistent, along the Washington and Oregon coast.

Early studies suggested that juvenile Chinook and coho salmon along the Washington and Oregon coast were not food-limited during their early marine residence (Peterson et al. 1982; Brodeur et al. 1992). These studies occurred during times when Columbia River Chinook salmon were at their peak. However, Daly et al. (2009) found that the percent of empty stomachs in both juvenile Chinook and coho salmon along the Oregon and Washington coast increased by 63% and 69%, respectively, from the 1980’s to the early 2000’s, despite 24% fewer Columbia River hatchery Chinook salmon being released during the latter time period. The authors noted that oceanographic condition changed during this time, affecting the fish community and potentially the quality of food available. Thus, the changing ocean conditions may have triggered forage limitations that outweighed the reduction in hatchery production, and induced competitive effects that previously did not exist or were minor.

Brodeur et al. (2007) evaluated juvenile salmon feeding patterns (stomach contents) in coastal waters from northern California to the western Gulf of Alaska during April–November, 2000–2002. For Chinook and coho salmon, there were proportionally more empty stomachs along the Oregon and Washington coast (about 5–15% of sampled fish), than in more northerly areas (about 0–3% of sampled fish). With some exceptions, feeding intensity (prey consumed as a percent of predator body weight) was also lower for both species along the Oregon and Washington coast. These findings suggest that competition may have been more intense along the Oregon and Washington coast during the few years studied, although feeding intensity may not be correlated with prey availability (e.g., Brodeur 1990b; 1990a).

Trudel et al. (2007) evaluated regional variation in summer marine growth (millimeters per day) of juvenile coho salmon and subyearling and yearling Chinook salmon along the North American west coast during 2002–2004. There were no apparent differences in growth of subyearling Chinook salmon (about 0.7–1.0 mm/day) along the Washington-Oregon coast in comparison to the other regions sampled. Coho salmon growth along the Washington-Oregon coast (1.2–1.3 mm/day) was slightly lower than in southeast Alaska (about 1.3–1.4 mm/day). Similarly, yearling Chinook salmon growth was lower along the Washington-Oregon coast (about 0.7–0.9 mm/day) than in southeast Alaska (about 1.0–1.3 mm/day). The authors speculated that the lower growth along the Washington-Oregon coast was likely due in part to more intense interspecific competition here relative to the more northern areas (e.g., southeast Alaska) citing Orsi et al. (2007) and Brodeur et al. (2007).

Daly et al. (2012) evaluated early marine characteristics of hatchery- and natural-origin juvenile Chinook salmon yearling outmigrants from five Columbia River spring Chinook populations during May and June across 11 years (1999–2009) along the Washington and northern Oregon coast. The authors found extensive spatial and dietary overlap between the hatchery- and natural-origin fish. Each group of fish had similar feeding intensities and growth rates, despite the natural-origin fish being consistently smaller, suggesting that neither group was outcompeting the other. Growth rates (IGF-1) were sampled in May (4 years) and June (2 years). For May, the two years with the highest growth (2007 and 2008) had the highest catch per unit effort (CPUE), suggesting that ocean conditions or other variables were more important than intraspecific competition in determining fish growth. Similar results were apparent in June. The two low-growth years (2006 and 2007) corresponded with low adult returns two years later. Feeding intensity was comparable across years, indicating that feeding intensity had no bearing on growth or survival.

Orsi et al. (2007) observed that, along the continental shelf, juvenile Chinook salmon density was 31–44 times greater and adult Chinook salmon density was 1.7–3.0 times greater in the south (California to Vancouver Island) compared to the north (northern southeast Alaska to the western Gulf of Alaska). Areas between the northern tip of Vancouver Island and northern southeast Alaska were not sampled. Epipelagic fish abundance was about 10 times greater in the south (California to Vancouver Island) than the north (northern southeast Alaska to the western Gulf of Alaska), with much of the abundance in the south consisting of Pacific herring, Pacific sardines, and northern anchovies. These species may compete with juvenile Chinook and coho salmon during their early marine residence, but may provide a forage resource as the salmon grow larger. In the southern areas (California to Vancouver Island), juvenile and immature/adult Chinook salmon comprised only 0.6–0.7% and 0.1–0.2% of the catch, respectively, indicating that Chinook salmon are a minor component of the continental shelf epipelagic fish assemblage. However, their greater densities and the greater abundance of competitors may increase the likelihood of both interspecific and intraspecific competition relative to that in Alaskan waters.

Miller et al. (2013) evaluated survival (SAR) of upper Columbia River summer-fall Chinook salmon subyearling outmigrants during an 11-year time series (outmigration years 1998–2008). Variables that were evaluated for their effect on survival included river and ocean environmental conditions, and fish size, condition (length-weight relationship), growth, and abundance[7] during early ocean residence (June and September) along the Washington and Oregon coast. Unexpectedly, the authors found that survival was negatively related to September juvenile condition indices, and that these condition indices were the best individual predictors of survival. That is, years with smaller, slower-growing, "poorer" condition fish in September had better survival than years with larger, faster-growing, and better condition September fish. Similar

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[7] The abundance metric included all subyearling Chinook salmon regardless of origin.

results were observed along the California coast for Central Valley fall Chinook salmon (Sabal et al. 2016). No density-dependent response was observed in juvenile attributes (length, weight, condition factor, growth), which the authors thought may have been due to the absence of intraspecific competition or inadequate spatial coverage of ocean sampling (Miller et al. 2013). Nonetheless, competition or size-selective mortality could have led to the findings of smaller yet better surviving fish during years of more productive ocean conditions (Miller et al. 2013; Sabal et al. 2016).

Daly et al. (2009) noted a near doubling in the percentage of empty Chinook san dcoho stomachs along the Oregon and Washington coast from the 1980s (observed by Brodeur et al. 1992) to the late 1990s and early 2000s. The authors suggest that changes in oceanographic conditions and the pelagic nekton community were likely responsible. This suggests that forage resources are more limiting and competition more intense now as compared to the recent past.

The above evidence suggests that intra- and inter-specific competition occurs at some times and in some places of Puget Sound marine waters. To the extent that competition does occur, hatchery salmon abundance does not appear to be a primary driver. Rather, ocean conditions and abundance of pink salmon are the dominant factors influencing forage availability and competitive effects. In years of high competitor abundance and/or unfavorable ocean conditions, forage resources for salmonids may become limited. Though it is possible that this may trigger negative density-dependent inter- and intra-specific competition among salmon species that utilize similar habitats and forage resources, effects are likely small relative to those from other non-salmonid competitors.

2.5.2.3.4. Marine Ecological Effects

Puget Sound Chinook Salmon

The effects of competition and predation in Puget Sound natal inner estuaries and tidal deltas operate at localized scales. The effects in these areas are primarily or exclusively from hatchery fish released within the corresponding river basin (Beamer et al. 2016; Hayes et al. 2019). Subyearling Chinook salmon make extensive use of natal inner estuaries until they are about 70–75 mm FL, at which point they disperse to other habitats (e.g., outer estuary, epipelagic, intertidal nearshore) (Healey 1980; Greene et al. 2021). Hatchery subyearling Chinook salmon are typically released at a larger size (i.e., greater than 70–75 mm FL), and thus would be expected to make little use of and have short residence times in natal inner estuary habitat. In addition, hatchery Chinook salmon are often released later in the year after many natural Chinook salmon have left natal inner estuary habitats for other areas. Many Puget Sound river estuaries are substantially diminished in size and habitat quality as a result of historical diking and other forms of degradation (Section 2.4). Thus, even moderate release abundances of hatchery fish may have negative effects in natal inner estuary areas, though these effects would be tempered by the limited residence time and limited temporal overlap of hatchery fish in these areas. The findings of Greene et al. (2021), described in Section 2.5.2.3.3, indicates a low to moderate degree of risk. The degree of risk to individual ESA-listed populations in natal inner estuary areas will vary depending on many factors, including but not limited to the following: the abundance of the affected population(s); the abundance, body size, and timing of hatchery fish released within the watershed; and, the quantity and quality of inner estuary habitat available.

In marine areas of Puget Sound outside of natal inner estuaries, competition among Puget Sound Chinook salmon has been investigated perhaps more so than anywhere else. These studies are described in detail in Section 2.5.2.3.3. Risk to ESA-listed natural Chinook salmon in Puget Sound marine waters may increase slightly from the Nooksack-Samish hatchery program salmon. However, based on the evidence described above in Section 2.5.2.3.3, the increased risk is likely to be greatest during even years when juvenile pink salmon are also resources were adequate to support epipelagic fish planktivores in most years, including of the planktivorous epipelagic fish community, though fish prey—which become more important to juvenile Chinook salmon as they grow larger—were not evaluated. Nonetheless, the weight of evidence suggests that at recent historical hatchery release abundances, negative competitive effects are minimal, and driven by marine environmental conditions and other competitors. The Nooksack-Samish hatchery programs may exacerbate these effects, when they occur. The level to which this would occur would be minimal, given the overall contribution the suite of programs have to the biomass in the area.

The evidence described above in Section 2.5.2.3.3, suggests that low-level negative intraspecific density-dependent effects to salmon may occur at some times and in some places along the continental shelf depending primarily on ocean conditions and interspecific competitor abundance. The addition of hatchery salmon via the Nooksack-Samish hatchery programs may have a small affect in exacerbating these effects. However, these programs would not be a primary driver of or substantial contributor to these effects due to the much larger abundance of other salmonid and non-salmonid competitors, including other hatchery- and natural-origin salmon. Available information is insufficient to be able to quantify a relationship between hatchery salmon abundance and adverse competitive effects to natural listed Chinook salmon and steelhead (e.g., slower growth, decreased survival).

Based on the information described in Section 2.5.2.3.3, the Nooksack-Samish hatchery programs present a low risk of predation to ESA-listed Puget Sound Chinook salmon in Puget Sound. Outside of Puget Sound, risk of predation is very low. Numerous diet surveys have demonstrated the extreme rarity of predation on juvenile salmonids by Chinook salmon in marine waters, particularly in coastal areas. Further, Nooksack-Samish hatchery program salmon are expected to be a relatively small proportion of the piscivorous salmon in these areas.

<u>Puget Sound Steelhead</u>

Puget Sound steelhead populations experience extremely high mortality during their short residence in Puget Sound (Moore et al. 2010; Moore et al. 2015), much more so than during their time in the Pacific Ocean (Kendall et al. 2017; Sobocinski et al. 2020). There is strong evidence that predation—particularly though not exclusively by harbor seals—is the most dominant cause of mortality (PSSMSW 2018, and references therein; Sobocinski et al. 2020; Pearsall et al. 2021). Though recent reviews and investigations do not rule out ecological interactions from hatchery fish as one potential source of reduced fitness and mortality, they do indicate that any such causes are probably minor. This is likely due to the fast transit time of juvenile Puget Sound steelhead through the marine waters of Puget Sound and the Strait of Juan de Fuca, on the order of 6–12 days (Moore et al. 2010; Moore et al. 2015). The SCSSMSP recently concluded that competition (intra- and inter-specific) and foraging opportunities are likely not factors or not very important for steelhead survival in Puget Sound (Pearsall et al. 2021).

(Sobocinski et al. 2020) from Chinook salmon hatchery practices and a variety of other potential drivers of Puget Sound steelhead marine survival over a recent 30-year time series. The authors found a positive correlation between steelhead marine survival and hatchery Chinook salmon abundance in Puget Sound, suggesting that ecological interactions from hatchery Chinook salmon were at the very least not detrimental, and potentially beneficial to steelhead trout. Similarly, (Malick et al. 2022) Chinook salmon releases into south and middle Puget Sound watersheds did not affect early marine mortality of juvenile steelhead trout from the Nisqually River, a south Puget Sound watershed.

Risk along the continental shelf is similarly low. Though direct observations of juvenile Puget Sound steelhead transit time across the continental shelf are lacking, there are no indications that their behavior would be any different from that of steelhead from the Columbia River or other areas, which show a rapid transit across the continental shelf to open ocean areas. For example, Columbia River basin steelhead migrate rapidly from the river mouth to the outer edge of the continental shelf. Based on 13–14 years of sampling along the Washington and northern Oregon coast, including the Columbia River plume, (Daly et al. 2014) determined that juvenile steelhead from the Columbia River basin reached the western edge of the continental shelf in just a few days, and spent about 10 days in continental shelf waters before moving to open ocean areas off the shelf. Juvenile Puget Sound steelhead's rapid migration through Puget Sound (described above) further supports the likelihood of a short continental shelf residence.

In open ocean areas (off the continental shelf), Puget Sound steelhead may overlap at a very broad spatial scale with immature and adult spring Chinook salmon, including any from the Nooksack-Samish hatchery programs. The exact distribution and overlap in the open ocean of Puget Sound steelhead and these spring Chinook salmon stocks is unknown. However, it is unlikely that these fish overlap at a spatiotemporal range sufficient to induce any detectable effects to steelhead trout given the length of time both species spend in the ocean, the very broad area over which they may range, and the much larger abundance of other salmonid and non-salmonid competitors. Steelhead generally remain in open ocean waters until they mature and migrate back across the shelf as adults, likely making an equally rapid transit across the shelf and through Puget Sound to the river mouths of their origin (Hayes et al. 2011).

Juvenile steelhead in Puget Sound are too large to be preyed upon by hatchery-released Chinook salmon, except for those that may remain as residents or transients in Puget Sound. However, Beauchamp et al. (2020) found no steelhead trout in the stomachs of resident Chinook salmon (n=232) sampled in Puget Sound during May–September, 2018–2019. Similarly, (Chamberlin 2021) found no steelhead trout in stomachs of resident Chinook salmon (n=419) sampled in Puget Sound during November–April, 2015–2019. These results suggest that resident hatchery-origin Chinook salmon present a low to negligible risk of predation to steelhead trout. Outside of Puget Sound, risk of predation is discountable. Numerous diet surveys have demonstrated the extreme rarity of predation on juvenile salmonids by Chinook salmon in marine waters, particularly in coastal areas. Further, Nooksack-Samish hatchery program Chinook salmon are expected to be a relatively small proportion of the piscivorous salmon in these areas.

Puget Sound steelhead, upon exiting freshwater, migrate rapidly through the Salish Sea and continental shelf waters to the open ocean, minimizing any potential for ecological interactions. Nooksack-Samish hatchery program salmon present a low risk of predation to ESA-listed Puget Sound steelhead in continental shelf areas based on the information described in Section 2.5.2.3.3, coupled with the very short residence time of juvenile steelhead in continental shelf waters. Predation risk is discountable in the open ocean. Numerous diet surveys have demonstrated the extreme rarity of predation on juvenile salmonids by salmon in marine waters, particularly in coastal areas. Further, Nooksack-Samish hatchery program salmon are expected to be a relatively small proportion of the piscivorous salmon in these areas.

2.5.2.4. **Factor 4. Research, monitoring, and evaluation**

RM&E actions are important for collecting information that improves conservation and management of fishery stocks but can cause harmful changes in behavior and reduced survival; such actions include, but are not limited to:

- Observation during surveying
- Collecting and handling (purposeful or inadvertent)
- Holding the fish in captivity, sampling (e.g., the removal of scales and tissues)
- Tagging and fin-clipping

Observing/Harassing

Direct observation is the least disruptive method for determining a species' presence/absence and estimating their relative numbers. Its effects are also generally the shortest-lived and least harmful of the research activities discussed in this section because a cautious observer can effectively obtain data while only slightly disrupting fishes' behavior. Fry and juveniles frightened by the turbulence and sound created by observers are likely to seek temporary refuge in deeper water, or behind/under rocks or vegetation. In extreme cases, some individuals may leave a particular pool or habitat type and then return when observers leave the area. At times, the research involves observing adult fish, which are more sensitive to disturbance. These avoidance behaviors are expected to be in the range of normal predator and disturbance behaviors.

Capturing/handling

Any physical handling or psychological disturbance is known to be stressful to fish. Decreased survival can result from high stress levels because stress can be immediately debilitating, and may also increase the potential for vulnerability to subsequent challenges (Sharpe et al. 1998). Primary contributing factors to stress and death from handling are excessive doses of anesthetic, differences in water temperatures (between the river and holding vessel), dissolved oxygen conditions, the amount of time fish are held out of the water, and physical trauma. Stress increases rapidly if the water temperature exceeds 18ºC or dissolved oxygen is below saturation. Fish transferred to holding tanks can experience trauma if care is not taken in the transfer process, and fish can experience stress and injury from overcrowding.

Fin clipping and tagging

Many studies have examined the effects of fin clips on fish growth, survival, and behavior. The results of these studies are somewhat varied, but fin clips do not generally alter fish growth (Brynildson and Brynildson 1967; Gjerde and Refstie 1988). Mortality among fin-clipped fish is variable, but can be as high as 80% (Nicola and Cordone 1973). In some cases, though, no significant difference in mortality was found between clipped and un-clipped fish (Gjerde and Refstie 1988; Vincent-Lang 1993). The mortality rate typically depends on which fin is clipped. Recovery rates are generally higher for adipose- and pelvic-fin-clipped fish than for those that have clipped pectoral, dorsal, or anal fins (Nicola and Cordone 1973), probably because the adipose and pelvic fins are not as important as other fins for movement or balance (McNeil and Crossman 1979). However, some work has shown that fish without an adipose fin may have a more difficult time swimming through turbulent water (Reimchen and Temple 2003; Buckland-Nicks et al. 2011).

In addition to fin clipping, Passive Integrated Transponder (PIT) tags and/or CWTs may be used. PIT tags are inserted into the body cavity of the fish just in front of the pelvic girdle. The tagging procedure requires that the fish be captured and extensively handled. Tagging needs to take place where there is cold water of high quality, a carefully controlled environment for administering anesthesia, sanitary conditions, quality control checking, and a recovery holding tank. Most studies have concluded that PIT tags generally have very little effect on growth, mortality, or behavior. Early studies of PIT tags showed no long-term effect on growth or survival (Prentice and Park 1984; Prentice et al. 1987; Rondorf and Miller 1994). In a study between the tailraces of Lower Granite and McNary Dams (225 km), (Hockersmith et al. 2000) concluded that the performance of yearling Chinook salmon was not adversely affected by orally or surgically implanted sham radio tags or PIT tags. However, Knudsen et al. (2009) found that, over several brood years, PIT tag induced smolt-adult mortality in Yakima River spring Chinook salmon averaged 10.3% and was at times as high as 33.3%.

CWTs are made of magnetized, stainless-steel wire and are injected into the nasal cartilage of a salmon and thus cause little direct tissue damage (Bergman et al. 1968; Bordner et al. 1990). The conditions under which CWTs should be inserted are similar to those required for PIT tags. A major advantage to using CWTs is cost, and that they have a negligible effect on the biological condition or response of tagged salmon (Vander Haegen et al. 2005); however, if the tag is placed too deeply in the snout of a fish, it may kill the fish, reduce its growth, or damage olfactory tissue (Fletcher et al. 1987; Peltz and Miller 1990). This latter effect can create problems for species like salmon because they use olfactory clues to guide their spawning migrations (Morrison and Zajac 1987).

Mortality from tagging is both acute (occurring during or soon after tagging) and delayed (occurring long after the fish have been released into the environment). Acute mortality is caused by trauma induced during capture, tagging, and release—it can be reduced by handling fish as gently as possible. Delayed mortality occurs if the tag or the tagging procedure harms the animal. Tags may cause wounds that do not heal properly, may make swimming more difficult, or may make tagged animals more vulnerable to predation (Howe and Hoyt 1982; Matthews and Reavis 1990; Moring 1990). Tagging may also reduce fish growth by increasing the energetic costs of swimming and maintaining balance.

RM&E associated with the hatchery programs considered here includes foot and boat spawning ground surveys that count spawning fish and sample carcasses for scales, otoliths, adipose-fin clips, CWTs, and tissues for DNA analysis. The same level and types of biological sampling would occur for Chinook salmon escaping to the hatcheries and collected as broodstock. The effects of these activities on ESA-listed adult salmon and steelhead are confined to visual observations during spawning ground surveys that may lead to avoidance behavior and temporary displacement of ESA-listed fish from preferred areas until surveyors move through a stream reach, but no more than would be expected from normal predator avoidance behaviors.

Juvenile outmigrants will be monitored with a rotary screw trap in the SF Nooksack River as well as basin-wide beach seining. Data collected allows for assessment of emigrating natural- and hatchery-origin fish abundance and overlap in timing between natural-origin species and newly released hatchery-origin fish. Other data collected at the trap used to assess hatchery effects are fish size, origin (marked/tagged vs. unmarked/untagged), and other biological data (e.g., tissues sampled for genetic analyses and collection of scales). Juvenile Chinook salmon and steelhead collected may be PIT-Tagged to collect life history and habitat use data (Table 6). Juvenile Chinook salmon and steelhead collected during these monitoring activities will be released unharmed and incidental mortality is expected to be low (Table 6).

2.5.2.5. **Factor 5. The operation, maintenance, and construction of hatchery facilities that exist because of the hatchery program**

The operations of the hatchery facilities are not expected to negatively affect Puget Sound Chinook salmon or steelhead.

Screening

The intake screening at Samish, Lummi Bay, and Whatcom hatcheries as well as McKinnon acclimation ponds is compliant with the most recent NMFS recommendations so are not expected to adversely affect ESA-listed salmon and steelhead (NMFS 2011b). The intake screens at Glenwood Springs and Kendall Creek hatcheries are not compliant with the most recent NMFS recommendations but there are no listed species in the area of Glenwood Springs Hatchery or above the intake at Kendall Creek Hatchery. ESA-listed Chinook salmon, steelhead and bull trout have not been observed above the weir in Kendall Creek so are likely not affected by the intake screens. The intake at Skookum Creek Hatchery is being replaced as soon as possible after issuance of this opinion so will be compliant with NMFS current recommendations at that time.

Skookum Creek Hatchery Construction

The likely effects of the proposed construction to conduct improvements at Skookum Creek Hatchery are temporary, short-term construction impacts with long-lasting effects associated with the removed and replaced structures.

Temporary effects reasonably certain to occur from the Proposed Action include:

- Temporary dewatering of approx. 3,800 square feet (sf) of Skookum Creek at the intake area and block potential migration upstream for approximately 20 days in June or July
- Temporary dewatering of approx. 1,350 sf of Skookum Creek at the fish screen return pipe area for approximately 14 days in August or September
- Temporary rock fill for machinery access to Skookum Creek channel 650 sf (75 cubic yards (cy))
- Temporary increase in turbidity when placing and removing isolation coffer dams
- Temporary clear 455 sf of stream buffer vegetation for fish screen construction

Long-term effects include:

- Fill 1,650 sf of low functioning portion of wetland located on the existing rock access road due to road raise and road resurfacing with gravel
- Fill 980 sf (25 cy) of low functioning riparian habitat within/adjacent to access road due to off-channel fish screen placement and road raise in areas currently trimmed to maintain vehicle access to the intake
- Fill 70 sf (5 cy) within Skookum Creek for fish screen return pipes
- Excavate 250 sf (13 cy) within Skookum Cr. for fish screen return pipe outfall pool
- Add boulder weir to intake area in Skookum Creek covering 500 sf (25 cy), which will increase habitat complexity and pool depth
- Reduced footprint of the intake structure will increase aquatic habitat area by 130 sf
- Increased depth at low summer flow at the intake is expected to improve upstream fish passage conditions at the step boulder cascade upstream of the intake by reducing jump height

Isolation and dewatering of the inside of the intake structure to replace the existing intake structure with a trashrack system is expected to occur in June or July and will last approximately 20 days. Dewatering within the intake structure would not affect in-stream habitat as it would occur entirely within the existing intake facility. Installing a new fish screen structure and boulder weir will temporarily affect a stream segment by placement of streambed gravel used as fill to facilitate construction machinery access to construct the boulder weir at the upstream end of the water intake. The segment would also be temporarily dewatered during flow bypass to install the proposed boulder weir. The existing water supply pipeline will be replaced with a 36-inch ADS (polyethylene) smooth walled corrugated pipe and the intake floor will be steepened somewhat and chamfered slightly to connect to the invert elevation of the new pipeline. A permanent sediment sluice pipe will be installed by expanding an existing opening on the west wall and extend downstream approximately 6 feet. The access road will be elevated by re-graveling over the existing footprint but would not be expanded. This work is outside of Ordinary High Water (OHW). Construction would be done consistent with WDFW Hydraulic Project Approval (HPA) work windows, during periods when migrating juvenile and adult salmonids are least likely to be present and flows are at the lowest point of the year (July 1 through September 15). As described in the Proposed Action, BMPs will be used to limit the effects of the work on listed fish. For these reasons we expect the effects of the work to listed fish to be minor and temporary. Estimates of expected levels of impact to listed fish, given these BMPs, is below.

Capture or handling for worksite isolation is expected to be no more than 150 juvenile Puget Sound Chinook salmon.

Injury or death during handling, or from impingement in the bypass channel is expected to be no more than ten juvenile Puget Sound Chinook salmon.

Capture or handling for worksite isolation is expected to be no more than 100 juvenile Puget Sound steelhead.

Injury or death during handling, or from impingement in the bypass channel is expected to be no more than five juvenile Puget Sound steelhead.

Harm resulting from turbidity and decreased habitat function is difficult to estimate because not all exposed fish, nor all responses can be observed and verified. However, we can describe the expected effects to habitat, specifically, increases in turbidity and decreases in habitat function. For turbidity, we expect that increases will be within Washington Department of Ecology's Water Quality Standards for Surface Waters of the State of Washington, Chapter 173-201A WAC, which allows turbidity to exceed 5 NTU over background up to 300 feet downstream in a river over 100 cfs when background levels are 50 NTU or less; or a 10 percent increase in turbidity over background for up to 300 feet downstream when the background turbidity is more than 50 NTU. For decreased habitat funding, we do not expect an area of more than approximately 5,200 sq. ft. of aquatic habitat to be disturbed or reduced.

Water Withdrawals

Facilities that withdraw a relatively large proportion of water over a relatively large diversion distance may present risks to the migration and survival of listed salmon and steelhead. NMFS does not expect the hatchery facilities considered here will negatively affect ESA listed salmon and steelhead because water use is non-consumptive, the water diversion distance is relatively short, and the proportion of water withdrawn is relatively low. Withdrawal of water up to permitted levels from these facilities is unlikely to lead to a lowering of stream flow that would affect listed fish migration and survival.

Effluent

The direct discharge of hatchery facility and marine net-pen effluent is regulated by the EPA under the CWA through NPDES permits. For discharges from hatcheries not located on Federal or tribal lands within Washington, the Environmental Protection Agency has delegated its regulatory oversight to the State. Washington Department of Ecology is responsible for issuing and enforcing NPDES permits that ensure water quality standards for surface and marine waters remain consistent with public health and enjoyment, and the propagation and protection of fish, shellfish, and wildlife (WAC 173-201A).

All hatchery facilities used by the salmon and steelhead hatchery programs are operated in compliance with NPDES permits issued by Washington Department of Ecology, or do not require a NPDES permit. NPDES permits are not needed for hatchery and net-pen facilities that release less than 20,000 pounds of fish per year or feed fish less than 5,000 pounds of fish feed per year. Additionally, Native American tribes may adopt their own water quality standards for permits on tribal lands (i.e., tribal wastewater plans).

Hatchery effluent at Samish, Whatcom, and Kendall Creek hatcheries passes through pollution abatement ponds. Effluent from McKinnon acclimation passes through a settling box before returning to the stream. The following water quality parameters, selected by EPA and WDOE as important for determining hatchery-related water quality effects, are monitored (WDFW 2013; 2014b).

- Total Suspended Solids - 1 to 2 times per month on composite effluent, maximum effluent and influent samples.
- Settleable Solids - 1 to 2 times per week through effluent and influent sampling.
- In-hatchery Water Temperature - daily maximum and minimum readings.

Though compliance with NPDES permit conditions is not an assurance that effects on ESA-listed salmonids will not occur, because the same water used for rearing (where survival is high compared to the natural environment) is then discharged into the surrounding habitat and then further diluted once it is combined with the river water, we believe effluent will have a minimal impact on ESA-listed salmonids in the area.

Therapeutic chemicals used to control or eliminate pathogens (i.e., formaldehyde, sodium chloride, iodine, potassium permanganate, hydrogen peroxide, antibiotics), can also be present in hatchery effluent. However, these chemicals are not likely to be problematic for ESA-listed species because they are quickly diluted beyond manufacturer's instructions when added to the total effluent and again after discharge into the recipient water body. Therapeutants are also used periodically, not constantly, during hatchery rearing. In addition, many of them break down quickly in the water and/or are not likely to bioaccumulate in the environment. For example, formaldehyde readily biodegrades within 30 to 40 hours in stagnant waters. Similarly, potassium permanganate would be reduced to compounds of low toxicity within minutes. Aquatic organisms are also capable of transforming formaldehyde through various metabolic pathways into non-toxic substances, preventing bioaccumulation in organisms (EPA 2015).

2.5.2.6. **Factor 6. Fisheries**

Fisheries in the action area not part of this Proposed Action, but rather are subject to separate consultation on an annual or multi-year basis, depending on the duration of the Puget Sound fishery management plan submitted by the co-managers (PSIT and WDFW 2022; NMFS 2023; WDFW and PSTIT 2023a). As described in Section 2.4.2, the effects of all fisheries on ESA-listed species are expected to continue at similar levels to those described in the Environmental Baseline 2.4.2. (NMFS 2024b) found that the fisheries are not likely to jeopardize Puget Sound Chinook or steelhead.

2.5.3. Effects of the Action on Critical Habitat

The proposed operation of the salmon hatchery programs considered here will not adversely modify critical habitat. Existing hatchery facilities have not led to: altered channel morphology and stability; reduced and degraded floodplain connectivity; excessive sediment input; or the loss of habitat diversity.

Facility effects are the only component of the Proposed Action of operating the salmon hatchery programs considered here that could potentially lead to adverse effects on critical habitat. Facility effects include both the Skookum water intake improvements, and the effects of operating the facilities. As discussed above, the intake construction will likely have temporary effects to fish passage and water quality. However, these are expected to be limited (due to the small scale of the work and the use of BMPs) and temporary in nature. The beneficial effects of the improvements will be slight but long-term. The operation of the hatchery facilities will likely impact water quality and quantity. However, effects on water quality are quite limited as the diverted water is returned within a short distance, and because the facilities comply with NPDES permits, and effluents from the facilities are used to rear fish and are thus not harmful to fish habitat.

2.6. Cumulative Effects

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

Some continuing non-Federal activities are reasonably certain to contribute to climate effects within the action area. However, it is difficult if not impossible to distinguish between the action area's future environmental conditions caused by global climate change that are properly part of the environmental baseline *vs.* cumulative effects. Therefore, all relevant future climate-related environmental conditions in the action area are described earlier in the discussion of environmental baseline (Section 2.4).

The Federally approved Shared Strategy for Puget Sound Recovery Plan for Puget Sound Chinook Salmon (NMFS 2006a) describes, in detail, the on-going and proposed state, tribal, and local government actions that are targeted to reduce known threats to listed Puget Sound Chinook salmon in the Nooksack and Samish River Basins, Whatcom Creek, and Orcas Island. Future tribal, state, and local government actions will likely be in the form of legislation, administrative rules, policy initiatives, and land use and other types of permits. Government and private actions may include changes in land and water uses, including ownership and intensity, which could affect listed species or their habitat.

Non-Federal actions are likely to continue affecting listed species. State, tribal, and local governments have developed plans and initiatives to benefit listed species. The cumulative effects of non-Federal actions in the action area are difficult to analyze because of the political variation in the action area, and the uncertainties associated with funding and implementation of government and private actions. However, many of these activities have occurred for a long time thus we expect the activities identified in the baseline to continue at similar magnitudes and intensities as in the recent past.

On-going State, tribal, and local government salmon restoration and recovery actions implemented through plans such as the recovery plans (SSDC 2007; NMFS 2018c) would likely continue to help lessen the effects of non-Federal land and water use activities on the status of listed fish species. The temporal pace of such decreases would likely be similar to the pace observed in recent years. Habitat protection and restoration actions implemented thus far have focused on preservation of existing habitat and habitat-forming processes; protection of nearshore environments, including estuaries, marine shorelines, and Puget Sound; instream flow protection and enhancement; and reduction of forest practice and farming impacts on salmon habitat. Because the projects often involve multiple parties using Federal, state, and utility funds, it can be difficult to distinguish between projects with a Federal nexus and those that can be properly described as Cumulative Effects.

With these improvements, however, based on the trends discussed above, there is also the potential for adverse cumulative effects associated with some non-Federal actions to increase such as urban development (Judge 2011). However, the effects of such development are likely limited by Federal, state, and tribal laws, regulations, and policies are designed to conserve air, water, and land resources. A few examples include the Federal Navigable Waters regulations of the Clean Water Act, and in Washington State, laws such as the state Shoreline Management Act and the Washington Department of Natural Resources (DNR) Forest Practices Rules which are addressed in an HCP (WDNR 2005).

In Washington, local land use laws, regulations, and policies will also help protect the natural environment from future development effects. For example, the Puget Sound Regional Council (PSRC) developed Vision 2040 to identify goals that support preservation and restoration of the natural environment ongoing with development through multicounty policies that address environmental stewardship (Puget Sound Regional Council 2009). Vision 2040 is a growth management, environmental, economic, and transportation strategy for central Puget Sound. These objectives also include preserving open space, focusing on sustainable development, and planning for a comprehensive green space strategy. Other local policies and initiatives by counties and municipalities include designation of areas best suited for future development, such as local sensitive areas acts and shoreline protection acts.

Some continuing non-Federal activities are reasonably certain to contribute to climate effects within the action area. However, it is difficult, if not impossible, to distinguish between the action area's future environmental conditions caused by global climate change that are properly part of the environmental baseline versus cumulative effects. Therefore, all relevant future climate-related environmental conditions in the action area are described in the environmental baseline (Section 2.4) and incorporated into our conclusions as part of that section.

2.7. Integration and Synthesis

The Integration and Synthesis section is the final step in assessing the risk that the Proposed Action poses to species and critical habitat. In this section, we add the effects of the action

(Section 2.5) to the environmental baseline (Section 2.4) and the cumulative effects (Section 2.6), taking into account the status of the species and critical habitat (Section 2.2), to formulate the agency's Biological Opinion as to whether the Proposed Action is likely to: (1) reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing its numbers, reproduction, or distribution; or (2) appreciably diminish the value of designated or proposed critical habitat as a whole for the conservation of the species.

2.7.1. Puget Sound Chinook salmon

The best available information indicates that the Puget Sound Chinook Salmon ESU remains threatened (NWFSC 2015; Ford 2022). Nooksack Chinook salmon spawner abundance is currently depressed with escapement below the recovery planning abundance target but above the critical threshold (Ford 2022). The NF and SF Nooksack River Chinook salmon populations currently have primary roles for recovery of the Puget Sound ESU (NMFS 2010). Our environmental baseline considers the effects of dams, habitat condition, fisheries, and hatcheries on Puget Sound Chinook salmon. Although all may have contributed to the listing of Puget Sound Chinook salmon, there have been improvements in the way these factors are managed or operated. As the climate continues to change, management of these factors may also alleviate some of the potential adverse effects, as is the case for the integrated Kendall Creek and Skookum Creek Chinook salmon hatchery programs considered here, which serve as genetic reserves for the natural population.

Chinook salmon populations in the throughout the Puget Sound ESU may be adversely affected by climate change (see Section 2.4.4). Predictions of rapid changes over a geological scale in climate conditions in the PNW would be expected to reduce spring and summer flows, impairing water quantity and water quality in primary fish rearing habitat, including that located in the Nooksack River. Predicted increases in rain events would increase the frequency and intensity of floods in mainstem river areas, leading to scouring flows that would threaten the survival and productivity of natural- and hatchery-origin ESA-listed fish species. The proposed NF and SF Nooksack Chinook salmon hatchery programs are expected to help attenuate climate change impacts over the short term by providing a refuge for the listed population from risks affecting critical life stages for naturally produced fish through circumvention of potentially adverse natural spawning, incubation, and rearing conditions.

Effects of the Proposed Action include effects to fish and critical habitat from fish handling, monitoring, repair/maintenance and operation of facilities that are expected to occur immediately, as well as effects of operation of the programs that will occur over time, including genetic and ecological effects. The co-managers have proposed ongoing monitoring activities to assess productivity, diversity, and abundance of both hatchery- and natural-origin fish and may adapt aspects of the hatchery program, including release location, number of juveniles released, and the use of natural-origin Chinook salmon to limit impacts on VSP parameters in the ESU.

Broodstock collection at the two integrated Chinook programs would remove ESA listed adults from the natural population, no other programs in the proposed action would affect listed species through broodstock collection. Broodstock collection will reduce the number of natural-origin spawners reaching the spawning grounds but the comanagers will limit broodstock collection taking account of natural origin abundance, and these programs will benefit these populations and the ESU as described above. Broodstock collection additionally requires ongoing annual handling of a portion of the population (juvenile and adult) and handling mortality is low. Broodstock collection is an essential component of the action. While broodstock collection may have adverse effects to individual fish, it is not expected to have adverse population-level effects on the Nooksack Chinook salmon populations.

Genetic effects on the Nooksack Chinook salmon populations by fish from the Skookum Creek and Kendall Creek programs are limited by integrating natural-origin Chinook salmon into broodstock to ensure the hatchery population retains its genetic ancestry and is therefore genetically representative of the natural-origin population. The Skookum and Kendall Creek hatchery programs are intended to increase the number of natural spawners to avoid loss of genetic variation due to inbreeding and genetic drift. The NF and SF Nooksack Chinook salmon populations are tier 1 populations essential to the recovery of the ESU and the actions taken to protect the genetic variation of these populations will benefit the Puget Sound Chinook Salmon ESU. These programs are unlikely to have an adverse effect at the ESU level as these hatchery programs incorporate measures to preserve the genetic integrity of the populations. Moreover, considering the populations' degraded status, the programs' intent to boost abundance as a way to preserve the genetic integrity of the population is on balance a benefit to the recipient population that outweighs the expected negative effects. The other programs in the proposed action are unlikely to have adverse genetic effects on ESA listed Chinook. Fish from the fall Chinook programs return to the SF and NF of the Nooksack River, and other systems where listed fish reside, in very small numbers that would not be expected to have genetic effects. The coho and chum programs would not have genetic effects on Chinook salmon.

Modeling ecological effects to natural-origin juvenile Chinook salmon associated with the coho salmon hatchery program releases from due to competition and predation in fresh water are equivalent to an estimated loss of 0.1–1.9% of the age 0 natural-origin Chinook salmon abundance. Modeling ecological effects to natural-origin juvenile Chinook salmon associated with the chum salmon hatchery program releases from due to competition and predation in fresh water are equivalent to an estimated loss of 0.02–0.15% of the age 0 natural-origin Chinook salmon abundance. Based on current information, this is likely to be a maximum loss because of the assumptions and simplicity inherent in the model, and, while these effects could result in a decrease in adult abundance, this decrease is at a level that is likely to have little effect on the Nooksack populations or the ESU. As we continue to improve the model, these estimates will become more refined in the future, and will likely indicate a smaller percentage of adults that are lost from this modeled scenario.

In Puget Sound natal inner estuaries and tidal deltas, the effects of competition and predation primarily stem from hatchery fish released within the corresponding river basin, with subyearling Chinook salmon using these habitats until they reach 70-75 mm FL and then dispersing to other areas. Hatchery subyearlings, released at larger sizes and later times, have minimal overlap with natural origin fish and minimal residence in these estuaries. Historical habitat degradation further moderates their impact, resulting in a low to moderate risk to ESA-listed populations, influenced by various factors like population abundance, hatchery fish size and timing, and habitat quality. In marine areas, competition is more thoroughly studied than predation, with slight increased risk of adverse effects during even years when juvenile pink salmon are present, though adequate forage resources generally support the fish. Negative competitive effects are minimal and influenced by marine conditions and other competitors, with the Nooksack-Samish hatchery programs having a small exacerbating effect. Predation risk from these programs to ESA-listed Chinook salmon is low within Puget Sound and negligible outside, supported by diet surveys indicating rare predation on juvenile salmonids by hatchery salmon. To reduce the risk of spatial and temporal overlap between juvenile hatchery-origin and listed natural-origin fish that might lead to competition effects, hatchery management practices would be implemented to minimize the duration of interaction between newly released hatchery-origin Chinook, coho, and chum salmon and natural-origin Chinook salmon and steelhead.

The operations of the hatchery facilities and anticipated improvements are not expected to negatively affect Puget Sound Chinook salmon. Intake screening at Samish, Lummi Bay, Whatcom hatcheries, and McKinnon acclimation ponds complies with NMFS recommendations, thus minimizing effects on ESA-listed species. Although the intake screens at Glenwood Springs and Kendall Creek hatcheries are not compliant, there are no listed species in those areas. The Skookum Creek Hatchery intake will be upgraded to meet NMFS standards. Proposed construction at Skookum Creek Hatchery involves temporary dewatering and increased turbidity, but these are short-term impacts and work will be conducted during work windows when fish are less likely to be present. While there may be some minor, temporary adverse effects to a few fish during the construction work, long-term benefits include habitat improvement through boulder weir installation, increased aquatic habitat, and better fish passage conditions. Impacts to water quantity and quality are also very limited, as water is returned to the source after use in the hatchery, and effluents are the same water used to raise fish and are discharged consistent with the requirements of NPDES permits.

Effects from RM&E are expected to be low and the information gained from conducting the work is essential for understanding the effects of the hatchery programs on natural-origin Chinook salmon populations.

As discussed above, some minor negative effects to ESA-listed Chinook salmon are expected, however, none of those are expected to rise to the level at which they would cause more than extremely minor adverse effects to, limit, or delay achievement of population viability. Therefore, we do not expect adverse effects to ESU survival and recovery. Measures implemented to reduce hatchery-related ecological and demographic effects on Chinook salmon are based on best management practices that are expected to adequately reduce negative effects to levels that do not adversely impact ESU survival or recovery. The two integrated programs are expected to benefit the NF and SF Nooksack populations and thus the ESU. Added to the Species' Status, environmental baseline, and effects of the Proposed Action are the effects of future state, private, or tribal activities, not involving Federal activities, within the Action Area. The recovery plan for this ESU describes the on-going and proposed state, tribal, and local government actions that are targeted to reduce known threats to ESA-listed Chinook salmon. Such actions include improving habitat conditions, and hatchery and harvest practices to protect natural-origin Chinook salmon, and NMFS expects this trend to continue, potentially leading to increases in abundance, productivity, spatial structure and diversity.

2.7.2. Puget Sound Steelhead

The best available information indicates that the Puget Sound Steelhead ESU remains threatened. Although increases in abundance have been observed in some DIPs over the most recent five year period, many DIPs are unmonitored and most are at demographic risk due to low abundance levels (NWFSC 2015; Ford 2022). Within the North Cascade MPG, the Samish and Bellingham Bay tributaries winter-run DIP has significantly increased in abundance recently while abundance of the Nooksack winter-run DIP has increased slightly. Abundance information is not available for summer-run steelhead populations in the Nooksack or Samish and Bellingham Bay DIPs but available data indicates abundance is low (Ford 2022). Our environmental baseline considers the effects of dams, habitat condition, fisheries, and hatcheries on Puget Sound steelhead. Although all may have contributed to the listing of Puget Sound steelhead, there have been improvements in the way these factors are managed or operated. As the climate continues to change, management of these factors may also alleviate some of the potential adverse effects.

Steelhead populations in the Puget Sound DPS may be adversely affected by climate change (see Section 2.4.4). Predictions of rapid changes over a geological scale in climate conditions in the PNW would be expected to reduce spring and summer flows, impairing water quantity and water quality in primary fish rearing habitat, including those located in the Nooksack River. Predicted increases in rain events would increase the frequency and intensity of floods in mainstem river areas, leading to scouring flows that would threaten the survival and productivity of natural- and hatchery-origin ESA-listed fish species.

Hatchery-origin salmon from the proposed action and their progeny on the spawning grounds are not expected to affect Nooksack steelhead. Adult salmon spawn before steelhead arrive on the Nooksack spawning grounds. Juvenile salmon emerge and migrate towards the estuary before juvenile steelhead emerge. As discussed above, steelhead are not encountered during in-river coho salmon broodstock collection and do not volunteer to collection facilities. The broodstock collection by the programs considered here is not expected to affect Puget Sound steelhead as steelhead do not enter the hatchery traps.

Ecological effects to steelhead from the Nooksack-Samish hatchery programs releases are equivalent to an estimated loss of 1.2% to 3.4% of steelhead adults. Juvenile steelhead will be handled as part of RM&E activities and this is expected to provide information necessary to better estimate the abundance and productivity of the DIPs, especially the summer-run DIPs. The majority of juvenile steelhead will be released unharmed so these activities are not expected to affect the abundance and productivity of the DPS, but may provide information needed to guide management actions.

Puget Sound steelhead populations experience very high mortality during their brief stay in Puget Sound, primarily due to predation, especially by harbor seals, rather than their time in the Pacific Ocean. Hatchery fish may contribute to reduced fitness and mortality, but these impacts are likely minor due to the rapid migration of juvenile steelhead through Puget Sound and the Strait of Juan de Fuca. Studies suggest that competition and foraging opportunities are not significant factors in steelhead survival. Hatchery Chinook salmon might even benefit steelhead survival, as evidenced by positive correlations in survival rates. Along the continental shelf, steelhead rapidly transit to open ocean areas, minimizing potential interactions with predators or competitors. In the open ocean, steelhead and Nooksack-Samish hatchery Chinook salmon likely do not overlap significantly in time or space to cause detectable effects. Predation by hatchery Chinook salmon on juvenile steelhead is rare, and overall, the risk of predation from these hatchery programs is low in Puget Sound and very low in other areas.

The operations of the hatchery facilities and anticipated upgrades are not expected to negatively affect Puget Sound steelhead. Intake screening at Samish, Lummi Bay, Whatcom hatcheries, and McKinnon acclimation ponds complies with NMFS recommendations, thus minimizing effects on ESA-listed species. Although the intake screens at Glenwood Springs and Kendall Creek hatcheries are not compliant, there are no listed species in those areas. The Skookum Creek Hatchery intake will be upgraded to meet NMFS standards. Proposed construction at Skookum Creek Hatchery involves temporary dewatering and increased turbidity, but these are short-term impacts. Long-term benefits include habitat improvement through boulder weir installation, increased aquatic habitat, and better fish passage conditions.

Fisheries in the action area not part of this Proposed Action, but rather are subject to separate consultation on an annual or multi-year basis, depending on the duration of the Puget Sound fishery management plan submitted by the co-managers

In summary, the effects of the proposed hatchery programs on listed Puget Sound steelhead are very small, given that the programs do not produce steelhead and thus don’t use them for broodstock, there are no intraspecific effects, and steelhead generally do not overlap in time and space with the hatchery fish released from these programs. The effects on steelhead are not likely to affect the status or trends of the affected population, and thus the DPS. Added to the Species’ Status, environmental baseline, and effects of the Proposed Action are the effects of future state, private, or tribal activities, not involving Federal activities, within the Action Area. The recovery plan for this DPS describes the on-going and proposed state, tribal, and local government actions that are targeted to reduce known threats to ESA-listed steelhead. Such actions include improving habitat conditions, and hatchery and harvest practices to protect natural-origin steelhead, and NMFS expects this trend to continue, potentially leading to increases in abundance, productivity, spatial structure and diversity.

2.7.3. Critical Habitat

Critical habitat for ESA-listed Puget Sound Chinook salmon and Puget Sound steelhead is described in Sections 2.2.1.2 and 2.2.1.4 of this Opinion. In reviewing the Proposed Action and evaluating its effects, NMFS has determined that the Proposed Action will not degrade habitat designated as critical for listed fish. The existing hatchery facilities have not led to altered channel morphology and stability, reduced or degraded floodplain connectivity, excessive sediment input, or the loss of habitat diversity, and the effects of proposed changes to existing facilities are not expected to alter the conservation value of the habitat for PS chinook and PS steelhead. The Proposed Actions include compliance with limits and strict criteria for withdrawing and discharging water used for fish rearing, and the actions will not result in any adverse effects to critical habitat.

Water withdrawals by the hatchery facilities are considered low-risk for ESA-listed Chinook salmon and steelhead Critical Habitat due to their non-consumptive use, short diversion distances, and low withdrawal proportions. Effluent discharge is regulated under NPDES permits to ensure compliance with water quality standards. Hatchery effluent from facilities like Samish, Whatcom, and Kendall Creek passes through pollution abatement ponds, minimizing its impact on the environment. The effluent contains therapeutic chemicals, but these are used periodically, dilute rapidly, and degrade quickly, further reducing any potential negative effects on ESA-listed species.

Steelhead and Chinook salmon populations in the Nooksack River basin may be adversely affected by climate change (see Section 2.4.4). Predictions of rapid changes over a geological scale in climate conditions in the PNW would be expected to reduce spring and summer flows, impairing water quantity and water quality in primary fish rearing habitat located in the Nooksack River. Predicted increases in rain events would increase the frequency and intensity of floods in mainstem river areas, leading to scouring flows that would threaten the survival and productivity of natural- and hatchery-origin ESA-listed fish species. The proposed NF and SF Nooksack Chinook salmon hatchery programs are expected to help attenuate climate change impacts over the short term by providing a refuge for the listed population from risks affecting critical life stages for naturally produced fish through circumvention of potentially adverse natural spawning, incubation, and rearing conditions. The adverse effects of the proposed construction at Skookum Creek Hatchery are predominantly short-term, and the beneficial effects although slight, are long-term. Even when cumulative effects are considered, the project effects on PBFs are insufficient to alter the conservation value of the habitat for Puget Sound Chinook salmon and Puget Sound steelhead.

Overall, the combination of regulatory compliance and operational practices ensures that hatchery operations pose minimal risk to the surrounding aquatic ecosystems and designated critical habitat, taking into consideration the environmental baseline, status of critical habitat, and cumulative effects.

2.8. Conclusion

After reviewing and analyzing the current status of the listed species and critical habitat, the environmental baseline within the action area, the effects of the Proposed Action and the cumulative effects, it is NMFS' Biological Opinion that the Proposed Action is not likely to jeopardize the continued existence of Puget Sound Chinook salmon or steelhead or destroy 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 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 ITS.

2.9.1. Amount or Extent of Take

In the Biological Opinion, NMFS determined that incidental take is reasonably certain to occur as follows:

The primary form of take of ESA-listed Chinook salmon is direct take, authorized under the 4(d) rule. However, NMFS also expects incidental take of ESA-listed salmon and steelhead will occur as a result of the Proposed Action for the following factors. The take pathways discussed below are:

- Handling of adults at adult collection facilities
- Genetic and ecological effects of hatchery adults on the spawning grounds
- Ecological effects of juveniles during emigration
- Increased ocean abundance of hatchery origin salmon
- Research, Monitoring, and Evaluation
- Facility effects of water intake structures

Handling of adults at adult collection facilities

Natural-origin Chinook salmon will be collected for use as broodstock at Skookum Creek and Kendall Creek hatcheries as described in Table 3 to allow for gene flow between the hatchery and naturally spawning populations while ensuring the naturally spawning population does not fall below the critical escapement threshold. We do not expect the number of natural-origin Chinook salmon used to exceed the levels described in Table 3. ESA-listed steelhead have not been encountered at salmon broodstock collection activities and facilities but would be released unharmed in the unlikely event they were encountered. It is not possible to count actual numbers of ESA-listed fish that die as a result of this activity, as natural-origin fish are not distinguishable from non-ESA-listed strays to the facility or from unmarked hatchery steelhead simultaneously encountered. Therefore, we will use encounters as a surrogate to measure for the extent of take. The numbers of encounters and mortality level are directly related to the amount of take NMFS has analyzed and expects in our Opinion, as released encounters will result in many of the fish surviving. Given the location of broodstock collection activities, no more than 100 steelhead collectively are expected to be encountered during broodstock collection annually at Samish, Skookum Creek, Glenwood Springs, Whatcom Creek, and Lummi Bay hatcheries. Co-managers will report annually the numbers of adults handled at each funded location and any mortalities incidental to adult collection of broodstock.

Genetic and ecological effects of hatchery adults on the spawning grounds

It is not possible to ascertain the exact amount of take by genetic effects related to hatchery fish spawning naturally, because it is not possible to meaningfully observe and measure the number of interactions, nor their precise effects. It is not possible to measure the number of adult Chinook salmon that effectively spawn in natural spawning areas, however, the number of hatchery-origin spawners generally increases with the number of juveniles released. The pHOS for hatchery-origin spawners generally increases with the number of juveniles released and/or a reduction in natural-origin spawners. In this case, where there are integrated hatchery programs intended to increase the size of the NF and SF Nooksack Chinook populations, and also segregated fall Chinook programs, the size of both programs affects the pHOS for the fall programs. Increased production of fall Chinook is connected to the level of take through genetic effects, as is decreased production of spring Chinook, as either of these could affect pHOS.

Therefore, NMFS will rely on two surrogate take indicators for genetic effects. First, we rely on a surrogate that is related to the number of hatchery origin fall spawners, this surrogate is the number of Chinook salmon juveniles anticipated for release as described in Table 4. This surrogate is related to the genetic take pathway because the number of hatchery-origin fall Chinook spawners is directly related to the extent of genetic influence from the fall Chinook salmon programs on the two native populations. Releasing Chinook salmon in the amounts described in Table 4 with no more than a 10% exceedance of those releases for any of the fall Chinook hatchery programs in any given year was included in the analysis and would not be expected to result in effects beyond those considered here. Additionally, a five-year running average of fall Chinook releases should not exceed the amounts described in Table 4 by more than 5%, in order to avoid effects not considered here. Co-managers will report annually the numbers of juveniles released from the various locations described in the Proposed Action.

A second take surrogate addresses pHOS of hatchery fall Chinook salmon produced as part of these programs. pHOS should remain under 5% to protect the genetic variation of the SF and NF Nooksack Chinook salmon populations. The co-managers will monitor and report pHOS in their annual reports. In summary, the extent of take will be exceeded if 1) fall Chinook salmon releases exceed the amounts described in Table 4 by more than 10% in any one year or; 2) the five-year running average of fall Chinook salmon releases exceed the amounts described in Table 4 by more than 5%; or 3) pHOS for hatchery fall Chinook salmon exceeds 5%.

Ecological effects of juveniles during emigration

NMFS has determined that juvenile hatchery-origin Chinook and yearling coho salmon may compete with and prey upon rearing and migrating natural-origin Chinook salmon and steelhead in freshwater areas downstream of the release sites. As described in Section 2.5.2.3, hatchery-origin Chinook and coho salmon may overlap spatially and temporally with natural-origin Chinook salmon and steelhead juveniles as hatchery-origin fish exit the Nooksack River seaward; competition between natural-origin and hatchery-origin fish could occur for food and space, and predation could occur if listed Chinook salmon and steelhead juveniles are sizes vulnerable to predation while outmigrating.

It is not possible to quantify the take associated with competition in the action area, because it is not possible to meaningfully measure the number of interactions between hatchery-origin Chinook, coho, and chum salmon and natural-origin Chinook salmon and steelhead juveniles. Therefore, NMFS will rely on a surrogate take indicator that relates to the proportion of the total abundance of emigrating juvenile salmonids comprised of hatchery-origin Chinook, coho, and chum salmon in the lower Nooksack River after the hatchery fish are released. The surrogate take indicator is the proportion of all hatchery produced juvenile salmon emigrating seaward in the Nooksack River downstream of the hatchery release sites on or after the 21st day after release. In the effects analysis, we estimated that at least 90% of the juvenile salmon would likely migrate out of the river within 21 days post-release. Thus, the take surrogate will be exceeded if, at 21 days post-release, the proportion of hatchery-origin Chinook, coho, and chum salmon at the lower Nooksack River smolt trap, exceeds 10% of the total number of juvenile salmon outmigrants.

The proportion of hatchery-origin Chinook, coho, or chum salmon versus total juvenile fish abundance will be calculated by statistical week, commencing 10 days post-hatchery release and continuing until no hatchery-origin Chinook salmon and coho salmon are captured, as identified either through expanded estimates or CPUE. This standard has a rational connection to the amount of take expected from ecological effects, since the co-occurrence of hatchery-origin and natural-origin fish is a necessary pre-condition to competition, and the assumption that, the greater ratio of hatchery fish to natural-origin fish, the greater likelihood that competition will occur. This proportion of hatchery fish in the rearing areas will be monitored by standing co-manager juvenile out-migrant screw trap and beach seining monitoring activities and reported annually.

Increased ocean abundance of hatchery origin salmon

It is not possible to quantify the take associated with competition in the action area, because it is not possible to meaningfully measure the number of interactions between hatchery-origin Chinook, coho, and chum salmon and natural-origin Chinook salmon and steelhead juveniles. However, the amount of hatchery-origin fish in the ocean portion of the action area is directly related to the number of fish released from the hatchery programs. Therefore, NMFS will rely on a surrogate take indicator that relates to the expected increases in marine abundance due to the proposed action. Co-managers will limit production to no more than 110 percent of levels described in the HGMPs in any one year with a five-year running average of the total number of salmon released per program not to exceed 105% of the release target for that program.

Research, Monitoring, and Evaluation

The co-managers will conduct RM&E activities to monitor juvenile outmigration of hatchery and natural salmon in the Nooksack watershed, monitor adults returning to the spawning grounds, and to collect scales and tissues for genetic analysis. The co-managers will also lethally collect 15,000 hatchery-origin juvenile Chinook salmon annually for up to seven years as part of a redd box study. NMFS determined that the proposed RM&E activities described in the Proposed Action are expected to directly and incidentally take juvenile and adult ESA-listed Chinook salmon and steelhead (Section 1.4.2) which may be collected and handled incidentally. The Opinion evaluated RM&E activities as part of the Proposed Action, and the take expected to occur is described in Table 6. Co-managers will report annually the numbers of juveniles collected during RM&E activities from the various locations described in the Proposed Action. For the purposes of this statement, encounters and/ or mortalities will not exceed those identified above Table 6 and represent the quantified level of expected take associated with RM&E activities.

Facility effects of upgrades to water intake structures

In the Opinion, NMFS determined that incidental take is reasonably certain to occur as follows from the construction at Skookum Creek Hatchery:

- Harm among Puget Sound steelhead and Puget Sound Chinook salmon, from exposure to elevated turbidity levels in Skookum Creek caused by in-water work;
- Harm among Puget Sound steelhead and Puget Sound Chinook salmon, from exposure to ephemeral slight reductions in benthic forage levels in Skookum Creek caused by in-water work;
- Capture, injury or death of Puget Sound Chinook salmon and Puget Sound steelhead during fish exclusion and removal from dewatered areas during in-water construction;

Amount of Take for effects of upgrades to water intake structures

Take in the form of capture or handling for worksite isolation is expected to be no more than 150 juvenile Puget Sound Chinook salmon.

Take in the form of injury or death during handling, or from impingement in the bypass channel is expected to be no more than ten juvenile Puget Sound Chinook salmon.

Take in the form of capture or handling for worksite isolation is expected to be no more than 100 juvenile Puget Sound steelhead.

Take in the form of injury or death during handling, or from impingement in the bypass channel is expected to be no more than five juvenile Puget Sound steelhead.

Take in the form of harm resulting from turbidity and decreased habitat function is difficult to estimate because not all exposed fish, nor all responses can be observed and verified. When take cannot be estimated we provide a surrogate metric, based on affected habitat, which is causally related to the form of take. This surrogate metric is called an Extent of Take.

The surrogate for take resulting from turbidity during construction activities is the 300 foot mixing zone, where Washington Department of Ecology’s Water Quality Standards for Surface Waters of the State of Washington, Chapter 173-201A WAC, allows turbidity to exceed 5 NTU over background up to 300 feet downstream (turbidity mixing zone for a river over 100 cfs) of the turbidity source when the background is 50 NTU or less; or a 10 percent increase in turbidity over background for up to 300 feet downstream when the background turbidity is more than 50 NTU. If turbidity exceeds these levels, or extends beyond 300 feet downstream, this surrogate is exceeded. This surrogate for take is causally linked to the take resulting from turbidity because harm of fish from turbidity increases as the concentration of turbidity and as the area with elevated levels increases.

The take surrogate for harm resulting from decreased habitat function caused by the in-water work is measured by the amount of aquatic habitat that would be disturbed or reduced. Here, all elements below to be modified OHW, together, are ~5,200 sq. ft. This extent is causally related to take in the form of harm because instream habitat modification displaces fish as work occurs, and typically reduces prey availability in disturbed area with multiple weeks to re-establish prey communities; reduced prey can result in diminished growth or fitness of rearing or migrating juveniles.

2.9.2. Effect of Take

In the 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 the species or destruction or adverse modification of critical habitat.

The above take surrogates in Section 2.9.1 can be reliably measured and monitored through enumeration and tracking. Each surrogate represents an independent threshold, meaning that exceedance would result in the Proposed Action having exceeded the incidental take limits included in this Statement, likely necessitating the reinitiation of consultation.

2.9.3. Reasonable and Prudent Measures

“Reasonable and prudent measures” refer to those actions the Director considers necessary or appropriate to minimize the impact of the incidental take on the species (50 CFR 402.02).

1. Ensure that the effects on SF and NF Nooksack Chinook salmon genetic diversity associated with implementation of the Nooksack-Samish Hatchery Chinook salmon programs are minimized.
2. Ensure that smolt releases do not pose competition and predation threats to juvenile natural-origin Chinook salmon or steelhead.
3. Ensure that broodstock collection operations do not adversely impact natural-origin steelhead.
4. Implement the hatchery programs as described in the HGMPs and monitor their operation. Indicate the performance and effects of the salmon hatchery programs, including the Terms and Conditions set forth in this Opinion, through completion and submission of annual reports.
5. Minimize incidental take in the form of harm from habitat disruptions during construction of the Skookum Creek Hatchery intake and minimize incidental take in the form of capture, injury, or death from handling and worksite isolation and monitor amount and extent of take and report the results of such monitoring.

2.9.4. Terms and Conditions

In order to be exempt from the prohibitions of Section 9 of the ESA, the co-managers must comply with the following terms and conditions. The co-managers have 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.

1a. Conduct annual surveys to describe the migration timing, abundance, distribution, and origin (hatchery and natural-origin) of Chinook salmon escaping and spawning naturally in the Nooksack River. The co-managers shall submit any revisions of protocols described in the proposed HGMPs for annual spawning ground surveys and biological sampling for NMFS concurrence on or before June 1 of each year.
1b. Collect demographic, mark/tag, and/or genetic data, and conduct analyses necessary to indicate the total annual adult contribution, by origin, of Nooksack-Samish Chinook salmon to terminal fisheries, hatcheries, and escapements for inclusion in annual reports.
1c. Annually report estimates of adult escapement to natural spawning areas and basin hatcheries, adult fish contributions to terminal area fisheries by origin (hatchery and natural), estimates of total recruit per spawner levels for the SF and NF Nooksack Chinook salmon populations, potential factors (e.g., ocean productivity and freshwater habitat conditions) for hatchery-origin Chinook salmon escapement levels to natural spawning areas (pHOS) relative to natural-origin Chinook salmon escapement levels in the Nooksack River Basin.
1d. Monitor the escapement of hatchery-origin fall Chinook salmon produced as part of the Nooksack-Samish hatchery programs to ensure that Nooksack River basin wide pHOS does not exceed 5% from the fall Chinook salmon programs included in this Opinion. pHOS estimates will be included in annual reports.
1e. Determine methods to increase the collection of natural-origin SF and NF Nooksack adult Chinook salmon to integrate as broodstock when numbers of natural-origin Nooksack Chinook increase.

2a. Annually monitor through the juvenile salmonid outmigrant trapping program, the statistical week incidence of hatchery-origin Chinook salmon and coho salmon yearling smolts relative to the total number of Chinook salmon and coho salmon smolts released, respectively, in watershed areas downstream of Skookum Creek and Kendall Creek hatcheries for at least one month after release of juveniles from the facility.
2b. Collect data regarding the relative proportions, emigration timings, and individual fish sizes, for hatchery-origin yearling Chinook and coho salmon, and natural-origin juvenile Chinook salmon, encountered through trapping and seining in the Nooksack River.
2c. Use protocols for estimating individual fish release size and timing that are based on best available practices. To ensure this occurs, submit any revisions of individual fish release size and timing protocols described in the HGMPs for NMFS concurrence on or before January 1 of each year.
2d. Annually report results of monitoring and data collection activities described in 2a and 2b as well as a summary of the results of RM&E activities.

3a. Immediately release unharmed at the point of capture any natural-origin steelhead incidentally encountered in the course of salmon broodstock collection operations. Hatchery-origin steelhead, identifiable by a clipped adipose fin, that are collected during salmon broodstock collection operations at any hatchery facility except Kendall Creek Hatchery, shall be removed at the point of capture and not returned to waters accessible to ESA-listed steelhead to reduce the threat of genetic and ecological effects to the native steelhead populations.

3b. Annually monitor and report the number, location, and disposition of any steelhead encountered during salmon broodstock collection operations.

4a. Implement the hatchery programs as described in the HGMPs to promote achievement of fish production goals while minimizing impacts on listed Puget Sound Chinook salmon and steelhead. Manage the programs to stay within their self-prescribed production targets, and notify NMFS should they ever exceed either 110 percent of levels described in the HGMPs in any one year, or a five-year running average of the total number of salmon released per program that would result in exceeding by more than 5% the release target for that program, or if there is ever a release of hatchery salmon from locations other than those described in the HGMPs.

4b. WDFW will ensure the Salmon Conservation and Reporting Engine (SCoRE) is updated annually with accurate co-manager approved information regarding population escapement, juveniles released, composition of adults on spawning grounds, and smolt-to-adult return rates for hatchery salmon.

4c. Provide one comprehensive annual report to NMFS SFD on or before December 31st of each year that includes the RM&E for the previous year described in these Term and Conditions. The numbers of hatchery-origin salmon released, release dates and locations, and tag/mark information shall be included in the annual report. All reports, as well as all other notifications required in the permit, shall be submitted electronically to the SFD point of contact for this program:

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5a. Conduct a visual inspection before in water work begins on the Skookum Creek Hatchery intake to determine if juvenile Chinook salmon and steelhead are present.

5b. If present, attempt exclusion via block net herding to areas above or below the worksite to reduce exposure to turbid conditions and avoid modified instream habitat.

5c. If present, conduct all in-water work in as brief a period as possible between July 1 and September 15, to minimize duration of potential exposure of juvenile steelhead and Chinook salmon.

5d. Perform visual monitoring of the turbidity plume. If the plume is obvious beyond the 300-foot mixing zone, perform nephelometric readings at 300 feet from the source of the plume.

5e. If turbidity exceeds the criteria outlined in Ecology's Water Quality Standards for Surface Waters of the State of Washington, Chapter 173-201A WAC, stop work and identify/implement supplemental BMPs to reduce the level of suspended sediment.

5f. Keep a count of any fish that are injured or killed during handling, or by impingement. If more than 4 fish are killed, stop work and contact the NMFS consulting biologist for next steps.

5g. Provide a post project summary of monitoring to NMFS (projectreports.wcr@noaa.gov; include the WCRO number in the subject line: WCR-2024-00669) within 60 days of completion of in-water work each year that describes:

If additional BMPs were required to reduce turbidity;
What additional BMPs were employed; and
The number of fish injured or killed.

2.9.5. 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).

1. Update all intake structures supplying water for the Nooksack-Samish Hatchery programs to be in compliance with the NMFS Anadromous Salmonid Passage Facility Design criteria (NMFS 2011b).
2. Collect data to better understand the effects of the Nooksack-Samish hatchery releases on steelhead and increase understanding of steelhead populations in the Action Area.

2.10. Re-initiation of Consultation

This concludes formal consultation for the Nooksack River basin and Georgia Strait salmon hatchery programs.

Under 50 CFR 402.16(a): "Reinitiation of consultation is required and shall be requested by the Federal agency, where discretionary Federal involvement or control over the action has been retained or is authorized by law and: (1) If the amount or extent of taking specified in the incidental take statement is exceeded; (2) If new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not previously considered; (3) If 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 written concurrence; or (4) If a new species is listed or critical habitat designated that may be affected by the identified action."

2.11. Not Likely to Adversely Affect Determinations

2.11.1. Hood Canal Summer-run Chum Salmon ESU

On June 28, 2005, NMFS listed Hood Canal Summer-run chum salmon—both natural-origin and some artificially-propagated fish—as a threatened species (70 FR 37160). The effects of take associated with implementation of Puget Sound region hatchery salmon and steelhead production on the Hood Canal Summer-run Chum Salmon ESU were previously evaluated by NMFS (NMFS 2002b).

The species comprises all naturally spawned populations of summer-run chum salmon in Hood Canal and its tributaries as well as populations in Olympic Peninsula rivers between Hood Canal and Dungeness Bay, Washington. The ESU has two populations, each containing multiple stocks or spawning aggregations. Juveniles, typically as fry, emerge from the gravel and outmigrate almost immediately to seawater. For their first few weeks, they reside in the top two to three centimeters of estuarine surface waters while staying extremely close to the shoreline (WDFW/PNPTT 2000). Subadults and adults forage in coastal and offshore waters of the North

Pacific Ocean before returning to spawn in their natal streams. HCS chum salmon spawn from mid-September to mid-October in the mainstems and lower river basins.

Natural-origin spawner abundance has increased since their 1999 ESA-listing (64 FR 14508) and spawning abundance targets in both populations have been met in some years (Ford 2022). Productivity was quite low at the time of the last review (Ford 2011), though rates have increased in the last five years, and have been greater than replacement rates in the past two years for both populations. For each population, spatial structure and diversity viability parameters have increased and nearly meet the viability criteria. However, only two of eight individual spawning aggregates have viable performance. Despite substantive gains towards meeting viability criteria in the Hood Canal and Strait of Juan de Fuca summer chum salmon populations, the ESU still does not meet all of the recovery criteria for population viability at this time (Ford 2022).

HCS chum salmon would potentially be encountered by juvenile fish released from the hatchery programs that are the subject of the Proposed Action during their emigration to marine waters after release. Thus, the only anticipated effects on HCS chum salmon are likely to be competition and predation. Due to the vast number of fall chum salmon in the Puget Sound area, it is likely that releases of hatchery fish from the Proposed Action are more likely to encounter fall chum fry and adults than summer chum fry and adults in the marine environment. Also, summer chum are likely to emigrate to the marine area in March (Tynan 1997), earlier than most of the releases of hatchery fish from these programs considered here. Thus, it is NMFS' opinion that effects through competition and predation of the Proposed Action on HCS chum salmon are discountable.

Because the only anticipated effects of the Proposed Action on Hood Canal Summer-run Chum salmon are discountable, NMFS determines that the Proposed Action is not likely to adversely affect the ESU.

2.11.2. Ozette Lake Sockeye Salmon ESU

The Ozette Lake Sockeye Salmon ESU was listed as a threatened species in 1999 (64 FR 14528; March 25, 1999). The ESU includes all naturally spawned populations of sockeye salmon in Ozette Lake and streams and tributaries flowing into Ozette Lake, Washington. The PSTRT considers the Ozette Lake Sockeye Salmon ESU to comprise one historical population with multiple spawning aggregations. The primary existing spawning aggregations occur in two beach locations—Allen's and Olsen's Beaches—and in two tributaries—Umbrella Creek and Big River. The ESU also includes fish originating from two artificial propagation programs: the Umbrella Creek and Big River sockeye hatchery programs.

After hatching, most juveniles spend one winter in Ozette Lake rearing before outmigrating to the ocean as two-year-old fish during April and May (Dlugokenski et al. 1981). The fish typically spend two years in the northeast Pacific Ocean foraging on zooplankton, squid, and, infrequently, on small fishes (Scott and Crossman 1973). Migration of adult sockeye salmon up the Ozette River generally occurs from mid-April to mid-August (Washington Department of Fisheries et al. 1993).

From 1977 to 2011, the estimated natural spawners ranged from 699 to 5,313 (NWFSC 2015; Ford 2022), well below the 31,250 – 121,000 viable population range proposed in the recovery plan (NMFS 2009). Over the last few decades, productivity appears to have remained stable around 1. The Umbrella Creek Hatchery program has successfully introduced a tributary spawning aggregate, increasing the diversity of age at return. However, the beach spawning aggregate is considered the core group of interest for recovery; the current number of beach spawners is well below historical levels and restricted to a subset of historical spawning beaches (NWFSC 2015; Ford 2022).

Lake Ozette sockeye salmon would potentially be encountered by juvenile fish released from the hatchery programs addressed in the Proposed Action during their emigration to offshore marine waters after release. Thus, the only anticipated effects on Lake Ozette sockeye salmon are likely to be through competition and predation. Lake Ozette sockeye salmon emigrate to marine areas in April to May (Haggerty et al. 2009), and would likely reach marine areas earlier than most of the releases of hatchery fish in the Nooksack River basin and Georgia Strait because they are released during the same timeframe, but have a much greater distance to travel. The nearshore around the Ozette River is a productive, shallow sub-tidal environment (Haggerty et al. 2009), and it is assumed that very few if any of these fish move into Puget Sound marine areas. Thus, it is NMFS' opinion that the effects of competition and predation of the Proposed Action on Lake Ozette sockeye salmon are discountable.

Because the only anticipated effects of the Proposed Action on Lake Ozette sockeye salmon are discountable, NMFS determines that the Proposed Action is not likely to adversely affect the ESU.

2.11.3. Lower Columbia River Chinook Salmon ESU

On March 24, 1999, NMFS listed the Lower Columbia River Chinook Salmon ESU as a threatened species (64 FR 14308). The threatened status was reaffirmed on June 28, 2005 (70 FR 37159) and on April 14, 2014 (79 FR 20802). Critical habitat for Lower Columbia River Chinook salmon was designated on September 2, 2005 (70 FR 52706). In 2022, NMFS completed its most recent 5-year review for Lower Columbia River Chinook salmon (NMFS 2022a).

The Lower Columbia River Chinook Salmon ESU includes natural populations in Oregon and Washington from the ocean upstream to, and including, the White Salmon River (river mile 167.5) in Washington and Hood River (river mile 169.5) in Oregon, except for salmon in the Willamette River (which enters the Columbia River at river mile 101). Within the Willamette River Chinook salmon are listed separately as the Upper Willamette River Salmon ESU, and not as part of the Lower Columbia River Chinook Salmon ESU. This ESA is comprised of thirty-two historical populations, within six MPGs distributed through three ecological zones. A combination of life-history types, based on run timing and ecological zones, result in six MPGs, some of which are considered extirpated or nearly extirpated. The run timing distributions across the 32 historical populations are: nine spring populations, 21 early-fall populations, and two late-fall populations.

Out of the 32 populations that make up this ESU, only seven populations are at or near the recovery viability goals set in the recovery plan. Six of these seven populations were located in the Cascade stratum; most of the populations in the Coastal and Gorge strata are doing rather poorly (Ford 2022). Many of the populations in this ESU remain at “high risk,” with low natural-origin abundance levels. Although many of the populations in this ESU are at “high” risk, it is important to note that poor ocean and freshwater conditions existed during the 2015–19 period and, despite these conditions, the status of a number of populations improved, some remarkably so from the previous status review (Grays River Tule, Lower Cowlitz River Tule, and Kalama River Tule fall runs) (Ford 2022).

Lower Columbia River Chinook salmon would potentially be encountered by juvenile fish released from the hatchery programs addressed in the Proposed Action after their emigration to offshore marine waters. Thus, the only anticipated effects on Lower Columbia River Chinook salmon are likely to be through competition and predation in marine areas where Nooksack hatchery-origin salmon comprise a very small proportion of the overall abundance and occur at low densities. Thus, it is NMFS’ opinion that the effects of competition and predation of the Proposed Action on Lower Columbia Chinook salmon are discountable.

Because the only anticipated effects of the Proposed Action on Lower Columbia Chinook salmon are discountable, NMFS determines that the Proposed Action is not likely to adversely affect the ESU.

2.11.4. Upper Willamette River Chinook Salmon ESU

On March 24, 1999, NMFS listed the Upper Willamette River Chinook Salmon ESU as a threatened species (64 FR 14308). The threatened status was reaffirmed on June 28, 2005 (70 FR 37160) and again on April 14, 2014 (79 FR 20802). Critical habitat was designated on September 2, 2005 (70 FR 52629). In 2024, NMFS published the most recent 5-year status review for Upper Willamette River Chinook salmon (NMFS 2024a). The NWFSC finalized its updated biological viability assessment for Northwest Pacific salmon and steelhead listed under the ESA in 2022 (Ford 2022).

The ESU includes all naturally spawned populations of spring-run Chinook salmon in the Clackamas River, the Willamette River and its tributaries above Willamette Falls, Oregon. Critical habitat encompasses 60 watersheds within the range of this ESU as well as the lower Willamette/Columbia River rearing/migration corridor, occurring in the counties of Benton, Clackamas, Clatsop, Columbia, Lane, Linn, Marion, Multnomah, Polk, and Yamhill, in the State of Oregon, and Clark, Cowlitz, Pacific, and Wahkiakum in the State of Washington (70 FR 52629). The ESU contains seven historical populations, within a single MPG, as well as six artificial propagation programs.

According to the most recent viability assessment (Ford 2022), abundance levels for five of the seven natural-origin populations in this ESU decreased relative to the 2015 status review (NWFSC 2015). Chinook salmon counts at Willamette Falls have been undertaken since 1946, when 53,000 Chinook salmon were counted; however, not until 2002, with the return of the first cohort of mass-marked hatchery-reared fish, was it possible to inventory naturally produced fish with any accuracy. Cohorts returning from 2015–19 outmigration were strongly influenced by warmer-than-normal and less-productive ocean conditions, in addition to warmer- and drier-than-normal freshwater conditions. The five-year average abundance geomean for 2015–19 was

6,916 natural-origin (unmarked) adults, a 31% decrease from the previous period. Abundances, in terms of adult returns, in the Clackamas and McKenzie Rivers have risen since the 2015 viability review (Ford 2022). Improvements in the status of the Middle Fork Willamette River population is due to the sole return of natural-origin adults to Fall Creek basin. However, the capacity of the Fall Creek basin alone is insufficient to achieve the recovery goals for the Middle Fork Willamette River individual population.

While there was a substantial downward trend in total and natural-origin spring-run abundance at Willamette Falls from 2003 to just before 2010, there were some indications of improving abundance in 2019 and 2020. Improvements in abundance corresponded with improved ocean and freshwater conditions, as well as changes in pinniped predation. In recent years, counts of spring-run Chinook salmon at Willamette Falls have been impacted by pinniped predation at the base of the falls. For the return years 2014–18, pinnipeds were estimated to consume 6–10% of the unmarked Chinook salmon escapement; however, in 2019, when a pinniped removal program was initiated, the rate dropped to approximately 4% (Ford 2022). Over the last 15 years, the long-term trend for natural-origin returns was negative 4% (Ford 2022), suggesting an overall decline in those populations above Willamette Falls.

Upper Willamette River Chinook salmon would potentially be encountered by juvenile fish released from the hatchery programs addressed in the Proposed Action after their emigration to offshore marine waters. Thus, the only anticipated effects on Upper Willamette River Chinook salmon are likely to be through competition and predation in marine areas where Nooksack hatchery-origin salmon comprise a very small proportion of the overall abundance and occur at low densities. Thus, it is NMFS' opinion that the effects of competition and predation of the Proposed Action on Upper Willamette Chinook salmon are discountable.

Because the only anticipated effects of the Proposed Action on Upper Willamette River Chinook salmon are discountable, NMFS determines that the Proposed Action is not likely to adversely affect the ESU.

2.11.5. Snake River Fall-Run Chinook Salmon ESU

On April 22, 1992, NMFS listed the Snake River Fall-Run Chinook Salmon ESU as a threatened species (57 FR 14653). The threatened status was reaffirmed on June 28, 2005 (70 FR 37159) and on May 26, 2016 (81 FR 33468). Critical habitat was designated on December 28, 1993 (58 FR 68543). It includes spawning and rearing areas limited to the Snake River below Hells Canyon Dam, and within the Clearwater, Hells Canyon, Imnaha, Lower Grand Ronde, Lower North Fork Clearwater, Lower Salmon, Lower Snake, Lower Snake-Asotin, Lower Snake-Tucannon, and Palouse hydrologic units. However, this critical habitat designation includes all river reaches presently or historically accessible to this species (except reaches above impassable natural falls, and Dworshak and Hells Canyon Dams). On October 4, 2019 NMFS announced the initiation of a new 5-year status review process including review of the Snake River Fall-Run Chinook Salmon ESU (84 FR 53117), which it completed and published on August 16, 2022 (NMFS 2022g).

The Snake River Fall-Run Chinook Salmon ESU includes naturally spawned fish in the lower mainstem of the Snake River and the lower reaches of several of the associated major tributaries, including the Tucannon, the Grande Ronde, Clearwater, Salmon, and Imnaha Rivers, along with 4 artificial propagation programs (Ford 2022). The decline of this ESU was due to heavy fishing pressure beginning in the 1890s and loss of habitat with the construction of Swan Falls Dam in 1901. Additionally, construction of the Hells Canyon Complex from 1958 to 1967 led to the extirpation of one of the historical populations. Hatcheries mitigating for losses caused by the dams have played a major role in the production of Snake River Fall-Run Chinook salmon since the 1980s.

In 2013, adult spawner abundance reached over 20,000 fish. From 2012–15, natural-origin returns were over 10,000 adults. Spawner abundance has declined since 2016 to 4,998 adult natural-origin spawners in 2019. In 2018, natural-origin spawner abundance was 4,916, a quarter of the return in 2013. This appears as a high negative percent change in the five-year geometric mean, but, when looking at the trend in longer time frames, across more than one brood cycle, it shows an increase in the ten-year geometric mean relative to the 2015 viability review (NWFSC 2015), and a near-zero population change for the 15-year trend in abundance (Ford 2022). The geometric mean natural adult abundance for the most recent ten years (2010–2019) is 9,034, higher than the ten-year geomean reported in the NWFSC (2015) status review. While the population has not been able to maintain the higher returns it achieved in 2010 and 2013–15, abundance has maintained at or above the ICTRT defined Minimum Abundance Threshold (3,000) during climate challenges in the ocean and rivers. Escapements have been increasing since 2020 and have continued through 2022 (WDFW and ODFW 2022).

Snake River Fall-Run Chinook salmon would potentially be encountered by juvenile fish released from the hatchery programs addressed in the Proposed Action after their emigration to offshore marine waters. Thus, the only anticipated effects on Snake River Fall-Run Chinook salmon are likely to be through competition and predation in marine areas where Nooksack hatchery-origin salmon comprise a very small proportion of the overall abundance and occur at low densities. Thus, it is NMFS' opinion that the effects of competition and predation of the Proposed Action on Snake River Fall-Run Chinook salmon are discountable.

Because the only anticipated effects of the Proposed Action on Snake River Fall-Run Chinook salmon are discountable, NMFS determines that the Proposed Action is not likely to adversely affect the ESU.

2.11.6. Snake River Spring/Summer-Run Chinook salmon ESU

On June 3, 1992, NMFS listed the Snake River Spring/Summer-Run Chinook Salmon ESU as a threatened species (57 FR 23458). More recently, the threatened status was reaffirmed on June 28, 2005 (70 FR 37160) and on April 14, 2014 (79 FR 20802). Critical habitat was originally designated on December 28, 1993 (58 FR 68543) but updated most recently on October 25, 1999 (65 FR 57399). In 2022, NMFS completed its most recent 5-year review for Snake River Spring/Summer-Run Chinook salmon (NMFS 2022k).

The Snake River Spring/Summer-Run Chinook Salmon ESU includes all naturally spawned populations of Spring/Summer-Run Chinook salmon in the mainstem Snake River and the Tucannon River, Grande Ronde River, Imnaha River, and Salmon River subbasins, as well as 13 artificial propagation programs (NMFS 2022b). However, inside the geographic range of the

ESU, there are a total of 18 hatchery spring/summer-run Chinook salmon programs currently operational (NMFS 2022b). Twenty-eight historical populations (four extirpated) within five MPGs comprise the Snake River Spring/Summer-Run Chinook Salmon ESU. The natural populations are aggregated into the five extant MPGs based on genetic, environmental, and life-history characteristics.

The majority of populations in the Snake River Spring/Summer-Run Chinook salmon ESU remain at high overall risk, with three populations (Minam River, Bear Valley Creek, and Marsh Creek) improving from the previous status review (NMFS 2016f) to an overall rating of maintained due to an increase in abundance/productivity. However, natural-origin abundance has generally decreased from the levels reported in the prior review for most populations in this ESU, in many cases sharply. The most recent 5-year geometric mean abundance estimates for 26 out of the 27 populations are lower than the corresponding estimates for the previous 5-year period by varying degrees; the estimate for the 27th population was a slight increase from a very low abundance in the prior 5-year period (Ford 2022). The entire ESU abundance data shows a consistent and marked pattern of declining population size, with the recent 5-year abundance levels for the 27 populations declining by an average of 55%. Medium-term (15-year) population trends in total spawner abundance were positive over the period 1990 to 2005 for all of the population natural-origin abundance series, but are all declining over the more recent time interval (20042019; Table 12 and Figure 21 in Ford 2022). The consistent and sharp declines for all populations in the ESU are concerning, with the abundance levels for some populations approaching similar levels to those of the early 1990s when the ESU was listed.
Snake River Spring/Summer-Run Chinook salmon would potentially be encountered by juvenile fish released from the hatchery programs addressed in the Proposed Action after their emigration to offshore marine waters. Thus, the only anticipated effects on Snake River Spring/Summer-Run Chinook salmon are likely to be through competition and predation in marine areas where Nooksack hatchery-origin salmon comprise a very small proportion of the overall abundance and occur at low densities. Thus, it is NMFS' opinion that the effects of competition and predation of the Proposed Action on Snake River Spring/Summer-Run Chinook salmon are discountable.

Because the only anticipated effects of the Proposed Action on Snake River Spring/Summer-Run Chinook salmon are discountable, NMFS determines that the Proposed Action is not likely to adversely affect the ESU.

2.11.7. Upper Columbia River Spring-Run Chinook Salmon ESU

On March 24, 1999, NMFS listed the Upper Columbia River Spring-run Chinook Salmon ESU as an endangered species (64 FR 14308). The endangered status was reaffirmed on June 28, 2005 (70 FR 37160) and most recently on April 14, 2014 (70 FR 20816). Critical habitat for the Upper Columbia River Spring-Run Chinook salmon was designated on September 2, 2005 (70 FR 2732). In 2022, NMFS completed its most recent 5-year review for Upper Columbia River Spring-Run Chinook salmon (NMFS 2022b).

Inside the geographic range of this ESU, eight natural populations within three MPGs have historically comprised the Upper Columbia River Spring-Run Chinook Salmon ESU, but the ESU is currently limited to one MPG (North Cascades MPG) and three extant populations (Wenatchee, Entiat, and Methow populations). Ten hatchery spring-run Chinook salmon programs are currently operational, but only seven are included in the ESU (NMFS 2022b). Approximately half of the area that originally produced spring-run Chinook salmon in this ESU is now blocked by dams. What remains of the ESU includes all naturally spawned fish upstream of Rock Island Dam and downstream of Chief Joseph Dam in Washington State, excluding the Okanogan River (64 FR 14208, March 24, 1999).

All three populations in the Upper Columbia River Spring-Run Chinook Salmon ESU remain at high overall risk. Natural origin abundance has decreased over the levels reported in the prior review (NMFS 2016W) for all populations in this ESU, in many cases sharply. The abundance data for the entire ESU show a downward trend over the last 5 years, with the recent 5-year abundance levels for all three populations declining by an average of 48% (NMFS 2022m). The consistent and sharp declines for all populations in the ESU are concerning. Relatively low ocean survivals in recent years were a major factor in recent abundance patterns. Given the high degree of year-to-year variability in life stage survivals and the time lags resulting from the 5-year life cycle of the populations, it is not possible to detect incremental gains from habitat actions implemented to date in population level measures of adult abundance or productivity (NMFS 2022M). Efforts are underway to develop life stage specific estimates of performance (survival and capacities) and to use a life cycle model framework to evaluate progress (Zabel and Jordan 2020). Based on the information available for the 2022 review (Ford 2022), the risk category for the Upper Columbia River Spring-run Chinook Salmon ESU remains unchanged from the prior review (NWFSC 2015). Although the recent decline of population abundances is concerning, each population remains well above the abundance levels of when they were listed. All three populations remain at high risk.

Upper Columbia River Spring-Run Chinook salmon would potentially be encountered by juvenile fish released from the hatchery programs addressed in the Proposed Action after their emigration to offshore marine waters. Thus, the only anticipated effects on Upper Columbia River Spring-Run Chinook salmon are likely to be through competition and predation in marine areas where Nooksack hatchery-origin salmon comprise a very small proportion of the overall abundance and occur at low densities. Thus, it is NMFS' opinion that the effects of competition and predation of the Proposed Action on Upper Columbia River Spring-Run Chinook salmon are discountable.

Because the only anticipated effects of the Proposed Action on Upper Columbia River Spring-Run Chinook salmon are discountable, NMFS determines that the Proposed Action is not likely to adversely affect the ESU.

2.11.8. Lower Columbia River Coho Salmon ESU

On June 28, 2005, NMFS listed the listed the Lower Columbia River coho Salmon ESU as a threatened species (70 FR 37160). The threatened status was reaffirmed on April 14, 2014 (79 FR 20802). Critical Habitat was originally proposed January 14, 2013 and was finalized on February 24, 2016 (81 FR 9251). In 2022, NMFS completed its most recent 5-year review for Lower Columbia River coho salmon (NMFS 2022a).

Inside the geographic range of the ESU, 23 hatchery coho salmon programs are currently operational. Twenty-one hatchery programs are currently included in the ESU (NMFS 2022a).

Lower Columbia River coho salmon are primarily limited to the tributaries downstream of Bonneville Dam. Twenty-four historical populations within three MPGs comprise the Lower Columbia River Coho Salmon ESU with generally low baseline persistence probabilities (Ford 2022). The ESU includes all naturally spawned populations of coho salmon in the Columbia River and its tributaries from the mouth of the Columbia River up to and including the White Salmon and Hood Rivers, and including the Willamette River to Willamette Falls, Oregon. Coho salmon in the Willamette River spawning above Willamette Falls are not considered part of the Lower Columbia River Coho Salmon ESU (70 FR 37160).

NMFS conducted viability status reviews of the Lower Columbia River coho Salmon ESU in 1996 , in 2001 (NMFS 2001), in 2005 (Good et al. 2005), in 2011 (Ford et al. 2011), in 2015 (NWFSC 2015), and most recently in 2022 (Ford 2022). In contrast to the previous 5-year review (NWFSC 2015), which occurred at a time of near record returns for several populations, the ESU abundance has declined during the last five years. Only 6 of the 23 populations for which we have data appear to be above their recovery goals (Ford 2022). This includes the Youngs Bay demographically independent population and Big Creek demographically independent population, which have very low recovery goals, and the Salmon Creek demographically independent population and Tilton River demographically independent population, which were not assigned goals but have relatively high abundances (Ford 2022). Of the remaining demographically independent populations in the ESU, three are at 50–99% of their recovery goals, seven are at 10–50% of their recovery goals, and seven are at less than 10% of their recovery goals (this includes the Lower Gorge demographically independent population for which there are no data, but it is assumed that the abundance is low) (Ford 2022).

Lower Columbia River coho salmon would potentially be encountered by juvenile fish released from the hatchery programs addressed in the Proposed Action after their emigration to offshore marine waters. Thus, the only anticipated effects on Lower Columbia River coho salmon are likely to be through competition and predation in marine areas where Nooksack hatchery-origin salmon comprise a very small proportion of the overall abundance and occur at low densities. Thus, it is NMFS' opinion that the effects of competition and predation of the Proposed Action on Lower Columbia River coho salmon are discountable.

Because the only anticipated effects of the Proposed Action on Lower Columbia River coho salmon are discountable, NMFS determines that the Proposed Action is not likely to adversely affect the ESU.

2.11.9. Columbia River Chum Salmon ESU

On March 25, 1999, NMFS listed the Columbia River Chum Salmon ESU as a threatened species (64 FR 14508). The threatened status was most recently reaffirmed on April 14, 2014 (79 FR 20802). Critical habitat was designated on September 2, 2005 (70 FR 52746). In 2022, NMFS published its most recent 5-year review for Columbia River chum salmon (NMFS 2022a).

The ESU includes all naturally spawning populations of chum salmon in the Columbia River and its tributaries in Washington and Oregon, along with the hatchery chum salmon. This ESU is comprised of three MPGs and has 17 natural populations. Chum salmon are primarily limited to the tributaries downstream of Bonneville Dam and the majority of the fish spawn in Washington tributaries of the Columbia River. Inside the geographic range of the ESU, three hatchery chum salmon programs are currently operational and are all included in the ESU (NMFS 2022a).

Over the last century, Columbia River chum salmon returns have collapsed from hundreds of thousands to just a few thousand per year (NMFS 2013c). Of the 17 natural populations that historically made up this ESU, 15 of them (six in Oregon and nine in Washington) are so depleted that either their baseline probability of persistence is very low, extirpated, or nearly so (Ford et al. 2011; NMFS 2013c; NWFSC 2015). The Grays River and Lower Gorge populations showed a sharp increase in 2002 for several years, but have since declined back to relatively low abundance levels in the range of variation observed over the last several decades.

It is notable that during this most recent review period, the three populations (Grays River, Washougal, and Lower Gorge demographically independent populations) improved markedly in abundance. Improvements in productivity were observed in almost every year during the 2015–19 interval (Ford 2022). This is somewhat surprising, given that the majority of chum salmon emigrate to the ocean as subyearlings after only a few weeks, and one would expect the poor ocean conditions to have a strong negative influence on the survival of juveniles (as with many of the other ESUs in this region). In contrast to these three demographically independent populations, the remaining populations in this ESU have not exhibited any detectable improvement in status (Ford 2022). Abundances for these populations are assumed to be at or near zero, and straying from nearby healthy populations does not seems sufficient to reestablish self-sustaining populations. It may be that the chum salmon life-history strategy of emigrating post-emergence en masse (possibly as a predator swamping mechanism) requires a critical number of spawners to be effective (Ford 2022).

Of the risk factors considered, freshwater habitat conditions may be negatively influencing spawning and early rearing success in some basins, and contributing to the overall low productivity of the ESU. Recent studies also suggest that a freshwater parasite, *Ceratonova shasta*, may be limiting the survival of juvenile chum salmon (WDFW and ODFW 2019). The prevalence of this parasite may increase with warmer water temperatures from flow modification or climatic change. Land development, especially in the low-gradient reaches that chum salmon prefer, will continue to be a threat to most chum populations due to projected increases in the population of the greater Vancouver–Portland area and the lower Columbia River overall (Metro 2014). The viability of this ESU is relatively unchanged since the prior review, and the improvements in some populations do not warrant a change in risk category, especially given the uncertainty regarding climatic effects in the near future. The Lower Columbia River chum salmon ESU therefore remains at "moderate" risk of extinction, and the viability is largely unchanged from the prior review.

Columbia River chum salmon would potentially be encountered by juvenile fish released from the hatchery programs addressed in the Proposed Action after their emigration to offshore marine waters. Thus, the only anticipated effects on Columbia River chum salmon are likely to be through competition and predation in marine areas where Nooksack hatchery-origin salmon comprise a very small proportion of the overall abundance and occur at low densities. Thus, it is NMFS' opinion that the effects of competition and predation of the Proposed Action on Columbia River chum salmon are discountable.

Because the only anticipated effects of the Proposed Action on Columbia River chum salmon are discountable, NMFS determines that the Proposed Action is not likely to adversely affect the ESU.

2.11.10. Snake River Sockeye Salmon ESU

On November 20, 1991, NMFS listed the Snake River Sockeye Salmon ESU as an endangered species (56 FR 58619) under the ESA. This listing was affirmed in 2005 (70 FR 37160), and again on April 14, 2014 (79 FR 20802). Critical habitat was designated on December 28, 1993 (58 FR 68543). In 2022, NMFS published the most recent 5-year status review for Snake River sockeye salmon (NMFS 2022d).

The ESU includes naturally spawned anadromous and residual sockeye salmon originating from the Snake River Basin in Idaho, as well as two artificially propagated sockeye salmon programs. The ICTRT treats Sawtooth Valley sockeye salmon as the single MPG within the Snake River Sockeye Salmon ESU. The MPG contains one extant population (Redfish Lake) and two to four historical populations (NMFS 2015c). At the time of listing in 1991, the only confirmed extant population included in this ESU was the beach-spawning population of sockeye salmon from Redfish Lake, with about 10 fish returning per year (NMFS 2015c). Historical records indicate that sockeye salmon once occurred in several other lakes in the Stanley Basin, but no adults were observed in these lakes for many decades; once residual sockeye salmon were observed, their relationship to the Redfish Lake population was uncertain (McClure et al. 2005). Since ESA-listing, progeny of the Redfish Lake sockeye salmon population have been outplanted to Pettit and Alturas lakes within the Sawtooth Valley for recolonization purposes (NMFS 2011a).

Prior to the turn of the 20th century (ca. 1880), around 150,000 sockeye salmon ascended the Snake River to the Wallowa, Payette, and Salmon River basins to spawn in natural lakes (Chapman et al. 1990). The Wallowa River sockeye salmon run was considered extinct by 1905, the Payette River run was blocked by Black Canyon Dam on the Payette River in 1924, and anadromous Warm Lake sockeye salmon in the South Fork Salmon River basin may have been trapped in Warm Lake by a land upheaval in the early 20th century (ICTRT 2003). In the Sawtooth Valley, the Idaho Department of Fish and Game eradicated sockeye salmon from Yellowbelly, Pettit, and Stanley Lakes in favor of other species in the 1950s and 1960s, and irrigation diversions led to the extirpation of sockeye salmon in Alturas Lake in the early 1900s (ICTRT 2003), leaving only the Redfish Lake sockeye salmon population. From 1991 to 1998, a total of just 16 wild adult anadromous sockeye salmon returned to Redfish Lake. These 16 wild fish were incorporated into a captive broodstock program that began in 1992 and has since expanded. The program currently releases hundreds of thousands of juvenile fish each year in the Sawtooth Valley (Ford et al. 2011).

The increased abundance of hatchery reared Snake River sockeye salmon reduces the risk of extinction over the short-term, but levels of naturally produced sockeye salmon returns are variable and remain extremely low (Ford 2022). The ICTRT's viability target is at least 1,000 naturally produced spawners per year in each of Redfish and Alturas Lakes and at least 500 in Pettit Lake (ICBTRT 2007). The highest adult returns since the captive broodstock program began were in 2014, with a total of 1,579 counted in the Stanley Basin (Ford 2022). The general increases observed in the number of adult returns during 2008–2014 were likely due to a number of factors, including increases in hatchery production and favorable marine conditions. The 5-year geometric mean of natural-origin adult returns was 137 for 2010–2014. Since then, natural-origin adult returns have declined with a 2015–2019 5-year geometric mean of 16 (Ford 2022). Adult returns crashed in 2015 due to a combination of low flows and warm water temperatures in the migration corridor. There was also high in-basin mortality of smolts released in 2015–2017 due to water chemistry shock between hatchery waters and the water of Redfish Lake (Ford 2022). Poor survival and growth in the ocean also play a role in low returns. The total number of returning adults documented in the Sawtooth Valley in 2020, 2021 and 2022 was 152, 55, and 749, respectively.

Snake River sockeye salmon would potentially be encountered by juvenile fish released from the hatchery programs addressed in the Proposed Action after their emigration to offshore marine waters. Thus, the only anticipated effects on Snake River sockeye salmon are likely to be through competition and predation in marine areas where Nooksack hatchery-origin salmon comprise a very small proportion of the overall abundance and occur at low densities. Thus, it is NMFS' opinion that the effects of competition and predation of the Proposed Action on Snake River sockeye salmon are discountable.

Because the only anticipated effects of the Proposed Action on Snake River sockeye salmon are discountable, NMFS determines that the Proposed Action is not likely to adversely affect the ESU.

2.11.11. Lower Columbia River Steelhead DPS

On March 19, 1998, NMFS listed the Lower Columbia River Steelhead DPS as a threatened species (63 FR 13347). The threatened status was reaffirmed on January 5, 2006 (71 FR 834) and most recently on April 14, 2014 (79 FR 20802). Critical habitat for Lower Columbia River steelhead was designated on September 2, 2005 (70 FR 52833). The most recent 5-year review for Lower Columbia River steelhead was released in 2022 (NMFS 2022a).

The DPS includes all naturally spawned anadromous steelhead populations below natural and manmade impassable barriers in streams and tributaries to the Columbia River between the Cowlitz and Wind Rivers, Washington (inclusive), and the Willamette and Hood Rivers, Oregon (inclusive), as well as multiple artificial propagation programs (Ford 2022; NMFS 2022a). Inside the geographic range of the DPS, 25 hatchery programs are currently operational, of which only 9 are considered part of the ESA-listed DPS description. The Lower Columbia River Steelhead DPS is composed of 23 historical populations, split by summer or winter life history, resulting in four MPGs. There are six summer populations and seventeen winter populations.

The majority of winter-run steelhead demographically independent populations in this DPS continue to persist at low abundance levels (hundreds of fish), with the exception of the Clackamas and Sandy River populations, which have abundances in the low 1,000s. Although the five-year geometric abundance means are near recovery plan goals for many populations, the recent trends are negative (Ford 2022). Summer-run steelhead demographically independent populations were similarly stable, but also at low abundance levels (Ford 2022). Summer-run demographically independent populations in the Kalama, East Fork Lewis, and Washougal River demographically independent populations are near their recovery plan goals; however, it is unclear how hatchery-origin fish contribute to this abundance. The decline in the Wind River summer-run demographically independent population is a source of concern, given that this population has been considered one of the healthiest of the summer runs (Ford 2022). It is not clear whether the declines observed represent a short-term oceanic cycle, longer-term climatic change, or other systematic issue. While other species in the Lower Columbia River steelhead DPS have a coastal-oriented distribution, steelhead are wide-ranging, and it is more difficult to predict the effects of changes in ocean productivity. Alternatively, most steelhead juveniles remain in freshwater for two years prior to emigration, making them more susceptible to climatic changes in temperature and precipitation (Ford 2022).

Spatial structure and abundances are limited due to migrational blockages in the Cowlitz and Lewis River basins (Ford 2022). The efficiency of adult passage and juvenile collection programs remain an issue. Recent studies indicate that there have been improvements in juvenile collection efficiency in the Cowlitz River, but these have not been reflected yet in adult abundance (Ford 2022).

The juvenile collection facilities at North Fork Dam in the Clackamas River appear to be successful enough to support increases in abundance. It is not possible to determine the risk status of this DPS given the uncertainty in abundance estimates for nearly half of the demographically independent populations (Ford 2022). Additionally, nearly all of the demographically independent populations for which there are abundance data exhibited negative abundance trends in 2018 and 2019.

Lower Columbia River steelhead would potentially be encountered by juvenile fish released from the hatchery programs addressed in the Proposed Action after their emigration to offshore marine waters. Thus, the only anticipated effects on Lower Columbia River steelhead are likely to be through competition and predation in marine areas where Nooksack hatchery-origin salmon comprise a very small proportion of the overall abundance and occur at low densities. Thus, it is NMFS' opinion that the effects of competition and predation of the Proposed Action on Lower Columbia River steelhead are discountable.

Because the only anticipated effects of the Proposed Action on Lower Columbia River steelhead are discountable, NMFS determines that the Proposed Action is not likely to adversely affect the ESU.

2.11.12. Upper Willamette River Steelhead DPS

On March 25, 1999, NMFS listed the Upper Willamette River Steelhead DPS as a threatened species (64 FR 14517). The threatened status was reaffirmed in 2006 and most recently on April 14, 2014 (79 FR 20802). Critical habitat for the DPS was designated on September 2, 2005 (70 FR 52848). NMFS' most recent five-year review for Upper Willamette River Steelhead was completed in 2024 (NMFS 2024a). The NWFSC finalized its updated biological viability assessment for Northwest Pacific salmon and steelhead listed under the ESA in January 2022 (Ford 2022).

The Upper Willamette River Steelhead DPS includes all naturally spawned anadromous winter-run steelhead originating below natural and manmade impassable barriers in the Willamette River, Oregon, and its tributaries upstream from Willamette Falls to the Calapooia River (Ford 2022). One MPG, composed of four historical populations, comprises the Upper Willamette River Steelhead DPS. Inside the geographic range of the DPS, 1 hatchery program is currently operational, though it is not included in the DPS (Ford 2022; NMFS 2024a). Hatchery summer-run steelhead also occur in the Willamette River Basin but are an out-of-basin stock that is not included as part of this DPS (Ford 2022).

Before the construction of a fish ladder at Willamette Falls in the early 1900s, flow conditions allowed steelhead to ascend Willamette Falls only during the late winter and spring. Presently, the majority of the Upper Willamette River winter steelhead run return to freshwater from January through April, pass Willamette Falls from mid-February to mid-May, and spawn from March through June (with peak spawning in late April and early May). Upper Willamette River steelhead currently exhibit a stream-type life-history with individuals exhibiting yearling life-history strategy. Juvenile steelhead rear in headwater tributaries and upper portions of the subbasins from one to four years (average of two years), then as smoltification occurs in April through May, they migrate downstream through the mainstem Willamette and Columbia River estuaries and into the ocean. The downstream migration speed depends on factors including river flow, temperature, turbidity, and others, with the quickest migration occurring with high river flows. Upper Willamette River steelhead can forage in the ocean for one to two years (average of two years) and during this time period, are thought to migrate north to waters off Canada and Alaska and into the North Pacific including the Alaska Gyre (Myers et al. 2006; ODFW and NMFS 2011). This species may spawn more than once; however, the frequency of repeat spawning is relatively low. The repeat spawners are typically females that spend more than one year post spawning in the ocean and spawn again the following spring (ODFW and NMFS 2011).

Abundance and life history data for steelhead in the Upper Willamette River steelhead DPS are very limited. Consistent redd counts are available for some index reaches, primarily in Thomas and Crabtree Creeks, but these do not provide population-level indicators of abundance (Ford 2022). Specific research projects have been undertaken to estimate steelhead spawning abundance and distribution (Mapes et al. 2017), but only in specific basins and for a limited number of years (Ford 2022). Adult counts were also available from observations at Willamette Falls, Bennett Dam, the Minto Dam fish facility (North Santiam River), and Foster Dam (South Santiam River). While steelhead counts at Willamette Falls provide a DPS-wide estimate of abundance, there is some uncertainty in distinguishing native late-winter steelhead from non-native early-winter steelhead and unmarked non-native summer steelhead (Johnson et al. 2018; Weigel et al. 2019). Counts of steelhead in eastside tributaries provide more population-specific information on abundance (Ford 2022). Winter steelhead counts at Willamette Falls provide a complete count of fish returning to the DPS (Ford 2022).

Populations in this DPS have experienced long-term declines in spawner abundance. The underlying cause(s) of these declines is not well understood. Returning adult winter steelhead do not experience the same deleterious water temperatures as the spring-run Chinook salmon, and prespawn mortalities are not likely to be significant (Ford 2022). Although the recent magnitude of these declines is relatively moderate, continued declines would be a cause for concern. Improvements to Bennett Dam fish passage and operational temperature control at Detroit Dam may be providing some stability in abundance in the North Santiam River demographically independent population (Ford 2022). It is unclear if sufficient high-quality habitat is available below Detroit Dam to support the population reaching its VSP recovery goal, or if some form of access to the upper watershed is necessary to sustain a "recovered" population (Ford 2022). Similarly, the South Santiam River basin may not be able to achieve its recovery goal status without access to historical spawning and rearing habitat above Green Peter Dam (Quartzville Creek and the Middle Santiam River) and/or improved juvenile downstream passage at Foster Dam (Ford 2022).

Upper Willamette River steelhead would potentially be encountered by juvenile fish released from the hatchery programs addressed Proposed Action after their emigration to offshore marine waters. Thus, the only anticipated effects on Upper Willamette River steelhead are likely to be through competition and predation in marine areas where Nooksack hatchery-origin salmon comprise a very small proportion of the overall abundance and occur at low densities. Thus, it is NMFS' opinion that the effects of competition and predation of the Proposed Action on Upper Willamette River steelhead are discountable.

Because the only anticipated effects of the Proposed Action on Upper Willamette River steelhead are discountable, NMFS determines that the Proposed Action is not likely to adversely affect the ESU.

2.11.13. Middle Columbia River Steelhead DPS

On March 25, 1999, NMFS listed the Middle Columbia River Steelhead DPS as a threatened species (64 FR 14517). The threatened status was reaffirmed in 2006 and most recently on April 14, 2014 (79 FR 20802). Critical habitat for the Middle Columbia River steelhead was designated on September 2, 2005 (70 FR 52808). The most recent 5-year review for Middle Columbia River steelhead was released in 2022 (NMFS 2022h).

The Middle Columbia River Steelhead DPS includes naturally spawned anadromous *O. mykiss* originating from below natural and manmade impassable barriers from the Columbia River and its tributaries upstream of the Wind River (Washington) and Hood River (Oregon) to and including the Yakima River, excluding the Upper Columbia River tributaries (upstream of Priest Rapids Dam) and the Snake River. Four MPGs, composed of 19 historical populations (2 extirpated), comprise the Middle Columbia River Steelhead DPS. Inside the geographic range of the DPS, six hatchery steelhead programs are currently operational. Four of these artificial programs are included in the DPS. The Middle Columbia River Steelhead DPS includes the only populations of inland winter steelhead in the Columbia River (those populations in the Lower Columbia River Steelhead DPS and Upper Willamette River Steelhead DPS that are classified as "winter" are geographically close enough to the Pacific Ocean so as not to be considered inland steelhead). Variations in the migration timing exist between populations.

Spawner abundance estimates for the most recent five years decreased relative to the prior review for all five populations. The 15-year trend in natural-origin spawners was strongly negative for the Deschutes River Eastside population, and essentially zero for the Fifteenmile

Creek and Deschutes River Westside runs. Preliminary estimates of escapements into Rock Creek were recently developed, and a high proportion of the observed steelhead in that system were out-of-basin strays (Ford 2022). Total escapement and natural-origin escapements declined relative to the prior five-year review (NWFSC 2015) for all five of the John Day MPG populations (Ford 2022). Only two of the five populations in this group had a positive 15-year trend in natural-origin abundance, driven largely by peak returns in the early 2000s, despite the strong declines over the most recent five-year period.

Five-year geometric mean natural-origin and total abundance estimates for each of the four populations in the Yakima MPG also decreased sharply relative to the previous review (NWFSC 2015). All four populations in this group have exhibited increases since the early 1990s, with similar peak return years as other DPS populations, but, given recent declines, the 15-year trend for all populations was essentially zero. Total spawning escapements have decreased in the most recent brood cycle for all three populations in the Umatilla/Walla Walla MPG as well. The 15-year trend in natural-origin abundance was positive for the Umatilla River population and slightly negative for Touchet River, though the trends are shallow (Ford 2022). Population productivity was cyclical, with most populations following a similar pattern of growth and decline (Ford 2022).

Middle Columbia River steelhead would potentially be encountered by juvenile fish released from the hatchery programs addressed in the Proposed Action after their emigration to offshore marine waters. Thus, the only anticipated effects on Middle Columbia River steelhead are likely to be through competition and predation in marine areas where Nooksack hatchery-origin salmon comprise a very small proportion of the overall abundance and occur at low densities. Thus, it is NMFS' opinion that the effects of competition and predation of the Proposed Action on Middle Columbia River steelhead are discountable.

Because the only anticipated effects of the Proposed Action on Middle Columbia River steelhead are discountable, NMFS determines that the Proposed Action is not likely to adversely affect the ESU.

2.11.14. Upper Columbia River Steelhead DPS

On August 18, 1997, NMFS listed the Upper Columbia River Steelhead DPS as an endangered species (62 FR 43937). The Upper Columbia River steelhead was then listed as a threatened species as of January 5, 2006 (71 FR 834). This DPS was re-classified as endangered on January 13, 2007 (74 FR 42605). However, the status was changed to threatened again in 2009 (74 FR 42605) and was reaffirmed on April 14, 2014 (79 FR 20802). Critical habitat for the Upper Columbia River Steelhead DPS was designated on September 2, 2005 (70 FR 52630). The most recent five-year review for Upper Columbia River Steelhead was released in 2022 (NMFS 2022b).

The Upper Columbia River Steelhead DPS includes all naturally spawned anadromous *O. mykiss* (steelhead) populations below natural and manmade impassable barriers in streams in the Columbia River Basin upstream from the Yakima River, Washington, to the U.S.-Canada border, as well as six artificial propagation programs (Ford 2022, NMFS2002m). As with other Steelhead DPSs, NMFS has defined the Upper Columbia River Steelhead DPS to include only the anadromous members of this species (70 FR 67130). The Upper Columbia River Steelhead DPS is composed of one extant MPG with four extant populations.

All four populations in the Upper Columbia River steelhead DPS remain at high overall risk (NMFS 2022m). Natural origin abundance has decreased over the levels reported in the prior review for all populations in this DPS, in many cases sharply. The abundance data for the entire DPS show a downward trend over the last 5 years, with the recent 5-year abundance levels for all four populations declining by an average of 48%. The consistent and sharp declines for all populations in the DPS are concerning. Relatively low ocean survivals in recent years were a major factor in recent abundance patterns.

Spatial structure ratings remain unchanged from the prior review and continue to be rated at low risk for the Wenatchee and Methow populations, moderate risk for the Entiat population, and high risk for the Okanogan population. The overall diversity ratings remain unchanged at high risk. The high-risk ratings for diversity are largely driven by high levels of hatchery spawners within natural spawning areas and lack of genetic diversity among the populations (NMFS 2022m). Under the current recovery plan, habitat protection and restoration actions are being implemented that are directed at key limiting factors.

Upper Columbia River steelhead would potentially be encountered by juvenile fish released from the hatchery programs addressed in the Proposed Action after their emigration to offshore marine waters. Thus, the only anticipated effects on Upper Columbia River steelhead are likely to be through competition and predation in marine areas where Nooksack hatchery-origin salmon comprise a very small proportion of the overall abundance and occur at low densities. Thus, it is NMFS' opinion that the effects of competition and predation of the Proposed Action on Upper Columbia River steelhead are discountable.

Because the only anticipated effects of the Proposed Action on Upper Columbia River steelhead are discountable, NMFS determines that the Proposed Action is not likely to adversely affect the ESU.

2.11.15. Snake River Basin Steelhead DPS

On August 18, 1997, NMFS listed the Snake River Basin Steelhead DPS as a threatened species (62 FR 43937). The threatened status was reaffirmed in 2006 and most recently on April 14, 2014 (79 FR 20802). Critical habitat for the DPS was designated on September 2, 2005 (70 FR 52769). The most recent 5-year status review for Snake River Basin steelhead was released in 2022 (NMFS 2022m).

The Snake River Basin Steelhead DPS includes all naturally spawned anadromous *O. mykiss* originating below natural and manmade impassable barriers in streams in the Snake River Basin of southeast Washington, northeast Oregon, and Idaho (Ford 2022). Twenty-seven historical populations within six MPGs comprise the Snake River Basin Steelhead DPS. Inside the geographic range of the DPS, 13 hatchery steelhead programs are currently operational. Six of these artificial programs are included in the DPS (NMFS 2002a). This DPS consists of A-Index steelhead, which primarily return to spawning areas beginning in the summer, and B-Index steelhead, which exhibit a larger body size and begin their migration in the fall (NMFS 2011a).

Based on the updated viability information available for this review, none of the five MPGs meet the viability criteria set forth in the 2017 recovery plan, and the viability of many individual populations remains uncertain (Ford 2022; NMFS 2022h). Of particular note, the updated, population-level abundance estimates have made very clear the recent (last 5 years) sharp declines that are extremely worrisome, were they to continue (Ford 2022; NMFS 2022h). The most recent 5-year metric indicates that each population has decreased by about 50%. The viability metrics used in these analyses (standardized PNW-wide and ICTRT) are intentionally based on long-time periods (10–20 year geometric means) to buffer against the rapid swings in abundance that salmon and steelhead populations are known to exhibit (Ford 2022).

Based on 20-year geometric means, productivity for all populations remains above replacement (Ford 2022; NMFS 2022m). Cyclical spawner-to-spawner ratios, which reflect combined impacts of habitat, climate, and density dependence, have been strongly below replacement since 2010. Productivity is also expected to decline in the coming years due to recent declines in abundance (Ford 2022; NMFS 2022m).

Snake River Basin steelhead would potentially be encountered by juvenile fish released from the hatchery programs addressed in the Proposed Action after their emigration to offshore marine waters. Thus, the only anticipated effects on Snake River Basin steelhead are likely to be through competition and predation in marine areas where Nooksack hatchery-origin salmon comprise a very small proportion of the overall abundance and occur at low densities. Thus, it is NMFS' opinion that the effects of competition and predation of the Proposed Action on Snake River Basin steelhead are discountable.

Because the only anticipated effects of the Proposed Action on Snake River Basin steelhead are discountable, NMFS determines that the Proposed Action is not likely to adversely affect the ESU.

3. Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation

Section 305(b) of the MSA directs Federal agencies to consult with NMFS on all actions or Proposed Actions that may adversely affect EFH. Under the MSA, this consultation is intended to promote the conservation of EFH as necessary to support sustainable fisheries and the managed species' contribution to a healthy ecosystem. For the purposes of the MSA, EFH means "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity", and includes the associated physical, chemical, and biological 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 may result from actions occurring within EFH or outside of it and may include direct, indirect, site-specific or habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810). Section 305(b) of the MSA 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 (50 CFR 600.905(b))].

This analysis is based, in part, on descriptions of EFH for Pacific coast salmon (PFMC 2023) contained in the fishery management plans developed by the Pacific Fishery Management Council (PFMC) and approved by the Secretary of Commerce.

3.1. Essential Fish Habitat Affected by the Project

The Proposed Action and action area for this consultation are described in Sections 1.3 and 2.3, respectively. The action area includes areas designated as EFH for various life stages of Pacific Coast salmon: Chinook salmon, Coho salmon (*O. kisutch*), and pink salmon (*O. gorbuscha*). The effects of the Proposed Action on EFH are the same as those described above in the ESA portion of this document (Section 2.5), as the EFH species share the same habitats as ESA listed Puget Sound chinook salmon, and Puget Sound steelhead.

3.2. Adverse Effects on Essential Fish Habitat

The adverse effects, described more fully in Section 2.5.2.5, include temporary reductions in water quality, temporary reductions in benthic prey communities, and temporary reduction in riparian vegetation for freshwater rearing and migrating.

3.3. Essential Fish Habitat Conservation Recommendations

NMFS determined that the following conservation recommendations are necessary to avoid, minimize, mitigate, or otherwise offset the impact of the Proposed Action on EFH. We offer one EFH conservation recommendations:

1. Where riprap is placed along banks, add a mix of gravel to fill interstitial voids, and encourage colonization by invertebrates to improve forage.

Fully implementing these EFH conservation recommendations would protect, by avoiding or minimizing the adverse effects described in Section 3.2, above, for Pacific Coast salmon.

3.4. Statutory Response Requirement

As required by Section 305(b)(4)(B) of the MSA, the Federal agency must provide a detailed response in writing to NMFS within 30 days after receiving an EFH Conservation Recommendation. 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 the 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)).

3.5. Supplemental Consultation

The NMFS 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)).

The ACOE 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

4.1. Utility

Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable, and beneficial to the intended users. NMFS has determined, through this ESA Section 7 consultation, that operation of the twelve hatchery programs in the Nooksack River basin and Georgia Strait as proposed will not jeopardize ESA-listed species, will not destroy or adversely modify designated critical habitat, and will adversely affect essential fish habitat. Therefore, NMFS can issue an ITS. The intended users of this Opinion are the Lummi Nation and WDFW (operators); Nooksack Indian Tribe (co-manager); NMFS and ACOE (regulatory agencies); USFWS and BIA (funders). The scientific community, resource managers, and stakeholders benefit from the consultation through adult returns of program-origin salmon to the Nooksack River basin, Georgia Strait, and Puget Sound, and through the collection of data indicating the potential effects of the hatchery programs on the viability of natural populations of Puget Sound Chinook salmon and Puget Sound steelhead. This information will improve scientific understanding of hatchery-origin salmon effects on natural populations that can be applied broadly within the Pacific Northwest area for managing benefits and risks associated with hatchery operations. The document will be available through the NOAA Institutional Repository approximately two weeks after signature. 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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6. Appendix A

Effects of Hatchery Programs on Salmon and Steelhead Populations: Reference Document for NMFS ESA Hatchery Consultations (Revised February 2022)[8]

NMFS applies available scientific information, identifies the types of circumstances and conditions that are unique to individual hatchery programs, then refines the range in effects for a specific hatchery program. Our analysis of a Proposed Action addresses six factors:

(1) The hatchery program does or does not remove fish from the natural population and use them for hatchery broodstock
(2) Hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds and encounters with natural-origin and hatchery fish at adult collection facilities
(3) Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas, the migration corridor, estuary, and ocean
(4) Research, monitoring, and evaluation (RM&E) that exist because of the hatchery program
(5) Operation, maintenance, and construction of hatchery facilities that exist because of the hatchery program
(6) Fisheries that would not exist but for the hatchery program, including terminal fisheries intended to reduce the escapement of hatchery-origin fish to spawning grounds

Because the purpose of biological opinions is to evaluate whether proposed actions pose unacceptable risk (jeopardy) to listed species, much of the language in this appendix addresses risk. However, we also consider that hatcheries can be valuable tools for conservation or recovery, for example when used to prevent extinction or conserve genetic diversity in a small population, or to produce fish for reintroduction.

The following sections describe each factor in detail, including as appropriate, the scientific basis for and our analytical approach to assessment of effects. The material presented in this appendix is only scientific support for our approach; social, cultural, and economic considerations are not included. The scientific literature on effects of salmonid hatcheries is large and growing rapidly. This appendix is thus not intended to be a comprehensive literature review, but rather a periodically updated overview of key relevant literature we use to guide our approach to effects analysis. Because this appendix can be updated only periodically, it may sometimes omit very recent findings, but should always reflect the scientific basis for our analyses. Relevant new information not cited in the appendix will be cited in the other sections of the opinion that detail our analyses of effects.

In choosing the literature we cite in this appendix, our overriding concern is our mandate to use "best available science". Generally, "best available science" means recent peer-reviewed journal articles and books. However, as appropriate we cite older peer-reviewed literature that is still relevant, as well as "gray" literature. Although peer-review is typically considered the "gold standard" for scientific information, occasionally there are well-known and popular papers in the peer-reviewed literature we do not cite because we question the methodology, results, or

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[8] This version of the appendix supersedes all earlier dated versions and the NMFS (2012a) standalone document of the same name.

conclusions. In citing sources, we also consider availability, and try to avoid sources that are difficult to access. For this reason, we generally avoid citing master's theses and doctoral dissertations, unless they provide unique information.

1.1 Factor 1. The hatchery program does or does not remove fish from the natural population and use them for hatchery broodstock

A primary consideration in analyzing and assessing effects for broodstock collection is the origin and number of fish collected. The analysis considers whether broodstock are of local origin and the biological benefits and risks of using ESA-listed fish (natural or hatchery-origin) for hatchery broodstock. It considers the maximum number of fish proposed for collection and the proportion of the donor population collected for hatchery broodstock. "Mining" a natural population to supply hatchery broodstock can reduce population abundance and spatial structure

1.2 Factor 2. Hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds and encounters with natural and hatchery fish at adult collection facilities.

There are three aspects to the analysis of this factor: genetic effects, ecological effects, and encounters at adult collection facilities. We present genetic effects first. For the sake of simplicity, we discuss genetic effects on all life stages under factor 2.

1.2.1. Genetic effects

1.2.1.1. Overview

Based on currently available scientific information, artificial breeding and rearing is likely to result in some degree of change of genetic diversity and fitness reduction in hatchery-origin. Hatchery-origin fish can thus pose a risk to diversity and to salmon population rebuilding and recovery when they spawn in the wild. However, conservation hatchery programs may prevent extinction or accelerate recovery of a target population by increasing abundance faster than may occur naturally (Waples 1999). Hatchery programs can also be used to create genetic reserves for a population to prevent the loss of its unique traits due to catastrophes (Ford et al. 2011).

We recognize that there is considerable debate regarding aspects of genetic risk. The extent and duration of genetic change and fitness loss and the short- and long-term implications and consequences for different species (i.e., for species with multiple life-history types and species subjected to different hatchery practices and protocols) remain unclear and should be the subject of further scientific investigation. We expect the scientific uncertainty surrounding genetic risks to be reduced considerably in the next decade due to the rapidly increasing power of genomic analysis (Waples et al. 2020).

Four general processes determine the genetic composition of populations of any plant or animal species (e.g., Falconer and MacKay 1996):

- Selection- changes in genetic composition over time due to some genotypes being more successful at survival or reproduction (i.e., more fit) than others

- Migration- individuals, and thus their genes, moving from one population to another
- Genetic drift- random loss of genetic material due to finite population size
- Mutation- generation of new genetic diversity through changes in DNA

Mutations are changes in DNA sequences that are generally so rare[9] that they can be ignored for relatively short-term evaluation of genetic change, but the other three processes are considerations in evaluating the effects of hatchery programs on the productivity and genetic diversity of natural salmon and steelhead populations. Although there is considerable biological interdependence among them, we consider three major areas of genetic effects of hatchery programs in our analyses (Figure 1):

- Within-population genetic diversity
- Among-population genetic diversity/outbreeding
- Hatchery-influenced selection

The first two areas are well-known major concerns of conservation biology (e.g., Frankham et al. 2010; Allendorf et al. 2013), but our emphasis on hatchery-influenced selection— what conservation geneticists would likely call "adaptation to captivity" (Allendorf et al. 2013, pp. 408-409)— reflects the fairly unique position of salmon and steelhead among ESA-listed species. In the case of ESA-listed Pacific salmon and steelhead, artificial propagation in hatcheries has been used as a routine management tool for many decades, and in some cases the size and scope of hatchery programs has been a factor in listing decisions.

In the sections below we discuss these three major areas of risk, but preface this with an explanation of some key terms relevant to genetic risk. Although these terms may also be listed in a glossary in the biological opinion to which this appendix accompanies, we felt that it was important to include them here, as this appendix may at times be used as a stand-alone document.

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[9] For example, the probability of a random base substitution in a DNA molecule in coho salmon is .000000008 (Rougemont et al. 2020).

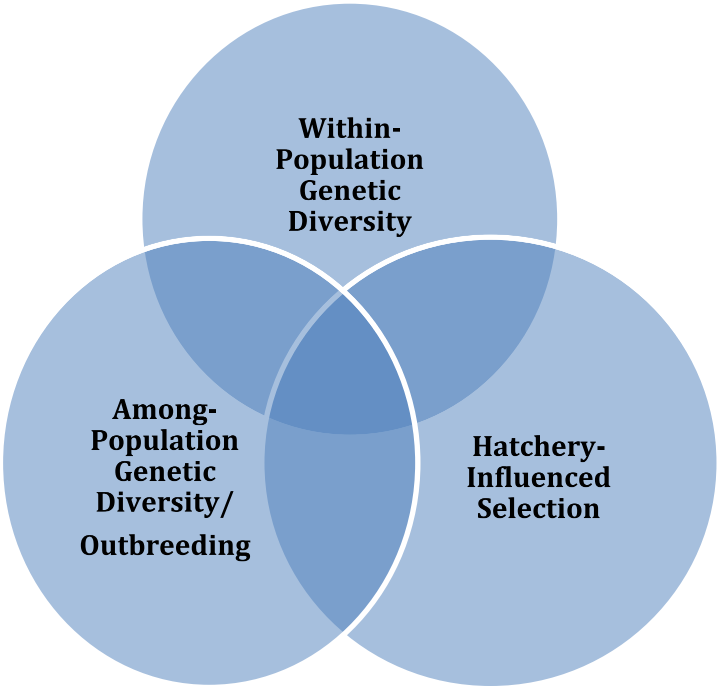

Figure A-13. Major categories of hatchery program genetic effects analyzed by NMFS.

1.2.1.1.1. Key Terms

The terms “wild fish” and “hatchery fish” are commonly used by the public, management biologists, and regulatory biologists, but their meaning can vary depending on context. For genetic risk assessment, more precise terminology is needed. Much of this terminology, and further derivatives of it, is commonly attributed to the Hatchery Scientific Review Group (HSRG), but were developed in 2004 technical discussions between the HSRG and scientists from the Washington Department of Fish and Wildlife (WDFW) and the Northwest Indian Fisheries Commission (HSRG 2009a).

- **Hatchery-origin (HO)**- refers to fish that have been reared and released by a hatchery program, regardless of the origin (i.e., from a hatchery or from spawning in nature) of their parents. A series of acronyms has been developed for subclasses of HO fish:
  - **Hatchery-origin recruits (HOR)** – HO fish returning to freshwater as adults or jacks. Usage varies, but typically the term refers to post-harvest fish that will either spawn in nature, used for hatchery broodstock, or surplused.
  - **Hatchery-origin spawners (HOS)**- hatchery-origin fish spawning in nature. A very important derivative term, used both in genetic and ecological risk, is **pHOS,** the proportion of fish on the spawning grounds of a population consisting of HO fish. pHOS is the expected maximum genetic contribution of HO spawners to the naturally spawning population.
  - **Hatchery-origin broodstock (HOB)**- hatchery-origin fish that are spawned in the hatchery (i.e., are used as broodstock). This term is rarely used.

- **Natural-origin (NO)**- refers to fish that have resulted from spawning in nature, regardless of the origin of their parents. A series of acronyms parallel to those for HO fish has been developed for subclasses of NO fish:

    - **Natural-origin recruits (NOR)** – NO fish returning to freshwater as adults or jacks. Usage varies, but typically the term refers to post-harvest fish that will either spawn in nature or used for hatchery broodstock.

    - **Natural-origin spawners (NOS)**- natural-origin fish spawning in nature.

    - **Natural-origin broodstock (NOB)**- natural-origin fish that are spawned in the hatchery (i.e., are used as broodstock). An important derivative term is **pNOB**, the proportion of a hatchery program's broodstock consisting of NO fish.

Hatchery programs are designated as either as "integrated" or "segregated". In the past these terms have been described in various ways, based on purpose (e.g., conservation or harvest) or intent with respect to the genetic relationship between the hatchery fish and the natural population they interact with. For purposes of genetic risk, we use simple functional definitions based on use of natural-origin broodstock:

- **Integrated hatchery programs**- programs that intentionally incorporate natural-origin fish into the broodstock at some level (i.e., pNOB > 0)

- **Segregated hatchery programs**- programs that do not intentionally incorporate natural-origin fish into the broodstock (i.e., pNOB = 0)

1.2.1.2. Within-population diversity effects

Within-population genetic diversity is a general term for the quantity, variety, and combinations of genetic material in a population (Busack and Currens 1995). Within-population diversity is gained through mutations or gene flow from other populations (described below under outbreeding effects) and is lost primarily due to genetic drift. In hatchery programs diversity may also be lost through biased or nonrepresentational sampling incurred during hatchery operations, particularly broodstock collection and spawning protocols.

1.2.1.2.1. Genetic drift

Genetic drift is random loss of diversity due to population size. The rate of drift is determined not by the census population size (N_c), but rather by the effective population size (N_e). The effective size of a population is the size of a genetically "ideal" population (i.e., equal numbers of males and females, each with equal opportunity to contribute to the next generation) that will display as much genetic drift as the population being examined (e.g., Falconer and MacKay 1996; Allendorf et al. 2013)[10].

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[10] There are technically two subcategories of N_e: inbreeding effective size and variance effective size. The distinction between them is usually not a concern in our application of the concept.

As an example, a commonly used effective-size equation is $Ne = 4 * N_m * N_f / (N_m + N_f)$, where N_m and N_f are the number of male and female parents, respectively. Suppose a steelhead hatchery operation spawns 5 males with 29 females. According to the equation, although 34 fish were spawned, the skewed sex ratio made this equivalent to spawning 17 fish (half male and half female) in terms of conserving genetic diversity because half of the genetic material in the offspring came from only 5 fish.

Various guidelines have been proposed for what levels of N_e should be for conservation of genetic diversity. A long-standing guideline is the 50/500 rule (Franklin 1980; Lande and Barrowclough 1987): 50 for a few generations is sufficient to avoid inbreeding depression, and 500 is adequate to conserve diversity over the longer term. One recent review (Jamieson and Allendorf 2012) concluded the rule still provided valuable guidance; another (Frankham et al. 2014) concluded that larger values are more appropriate, basically suggesting a 100/1000 rule. See Frankham et al. (2010) for a more thorough discussion of these guidelines.

Although Ne can be estimated from genetic or demographic data, often-insufficient information is available to do this, so for conservation purposes it is useful to estimate effective size from census size. As illustrated by the example above, N_e can be considerably smaller than N_c. This is typically the case. Frankham et al. (2014) suggested a N_e/N_c range of ~0.1-0.2 based on a large review of the literature on effective size. For Pacific salmon populations over a generation, Waples (2004) arrived at a similar range of 0.05-0.3.

In salmon and steelhead management, effective size concerns are typically dealt with using the term effective number of breeders (N_b) in a single spawning season, with per-generation N_e equal to the generation time (average age of spawners) times the average N_b (Waples 2004). We will use N_b rather than N_e where appropriate in the following discussion.

Hatchery programs, simply by virtue of being able to create more progeny than natural spawners are able to, can increase N_b in a fish population. In very small populations, this increase can be a benefit, making selection more effective and reducing other small-population risks (e.g., Lacy 1987; Whitlock 2000; Willi et al. 2006). Conservation hatchery programs can thus serve to protect genetic diversity; several programs, such as the Snake River sockeye salmon program, are important genetic reserves. However, hatchery programs can also directly depress N_b by three principal pathways:

- Removal of fish from the naturally spawning population for use as hatchery broodstock. If a substantial portion of the population is taken into a hatchery, the hatchery becomes responsible for that portion of the effective size, and if the operation fails, the effective size of the population will be reduced (Waples and Do 1994).

- Mating strategy used in the hatchery. N_b is reduced considerably below the census number of broodstock by using a skewed sex ratio, spawning males multiple times (Busack 2007), and by pooling gametes. Pooling milt is especially problematic because when milt of several males is mixed and applied to eggs, a large portion of the eggs may be fertilized by a single male (Gharrett and Shirley 1985; Withler 1988). This problem can be avoided by more structured mating schemes such as 1-to-1 mating. Factorial mating schemes, in which fish are systematically mated multiple times, can be used to increase N_b (Fiumera et al. 2004; Busack and Knudsen 2007) over what would be achievable with less structured designs. Considerable benefit in N_b increase over what is achievable by 1-to-1 mating can be achieved through a factorial design as simple as a 2 x 2 (Busack and Knudsen 2007).

- Ryman-Laikre effect. On a per-capita basis, a hatchery broodstock fish can often contribute many more progeny to a naturally spawning population than a naturally spawning fish can contribute This difference in reproductive contribution causes the composite N_b to be reduced, which is called a Ryman-Laikre (R-L) effect (Ryman and Laikre 1991; Ryman et al. 1995). The key factors determining the magnitude of the effect are the numbers of hatchery and natural spawners, and the proportion of natural spawners consisting of hatchery returnees.

The initial papers on the R-L effect required knowledge of N_b in the two spawning components of the population. Waples et al. (2016) have developed R-L equations suitable for a wide variety of situations in terms of knowledge base. A serious limitation of any R-L calculation however, is that it is a snapshot in time. What happens in subsequent generations depends on gene flow between the hatchery broodstock and the natural spawners. If a substantial portion of the broodstock are NO fish, the long-term effective size depression can be considerably less than would be expected from the calculated per-generation N_b.

Duchesne and Bernatchez (2002), Tufto and Hindar (2003), and Wang and Ryman (2001) have developed analytical approaches to deal with the effective-size consequences of multiple generations of interbreeding between HO and NO fish. One interesting result of these models is that effective size reductions caused by a hatchery program can easily be countered by low levels of gene flow from other populations. Tufto (2017) recently provided us with R code (R Core Team 2019) updates to the Tufto and Hindar (2003) method that yield identical answers to the Duchesne and Bernatchez (2002) method, and we use an R (R Core Team 2019) program incorporating them to analyze the effects of hatchery programs on effective size.

Inbreeding depression, another N_e-related phenomenon, is a reduction in fitness and survival caused by the mating of closely related individuals (e.g., siblings, half-siblings, cousins). Related individuals are genetically similar and produce offspring characterized by low genetic variation, low heterozygosity, lower survival, and increased expression of recessive deleterious mutations (Frankham et al. 2010; Allendorf et al. 2013; Rollinson et al. 2014; Hedrick and Garcia-Dorado 2016). Lowered fitness due to inbreeding depression exacerbates genetic risk relating to small population size and low genetic variation which further shifts a small population toward extinction (Nonaka et al. 2019). The protective hatchery environment masks the effects of inbreeding which becomes apparent when fish are released into the natural environment and experience decreased survival (Thrower and Hard 2009). Inbreeding concerns in salmonids related to hatcheries have been reviewed by Wang et al. (2002) and Naish et al. (2007).

N_e affects the level of inbreeding in a population, as the likelihood of matings between close relatives is increased in populations with low numbers of spawners. Populations exhibiting high levels of inbreeding are generally found to have low N_e (Dowell Beer et al. 2019). Small populations are at increased risk of both inbreeding depression and genetic drift (e.g., Willi et al. 2006). Genetic drift is the stochastic loss of genetic variation, which is most often observed in populations with low numbers of breeders. Inbreeding exacerbates the loss of genetic variation by increasing genetic drift when related individuals with similar allelic diversity interbreed (Willoughby et al. 2015).

Hatchery populations should be managed to avoid inbreeding depression. If hatcheries produce inbred fish which return to spawn in natural spawning areas the low genetic variation and increased deleterious mutations can lower the fitness, productivity, and survival of the natural population (Christie et al. 2014). A captive population, which has been managed so genetic variation is maximized and inbreeding is minimized, may be used for a genetic rescue of a natural population characterized by low genetic variation and low Ne.

1.2.1.2.2. Biased/nonrepresentational sampling

Even if effective size is large, the genetic diversity of a population can be negatively affected by hatchery operations. Although many operations aspire to randomly use fish for spawning with respect to size, age, and other characteristics, this is difficult to do. For example, male Chinook salmon that mature precociously in freshwater are rarely if ever used as broodstock because they are not captured at hatchery weirs. Pressure to meet egg take goals is likely responsible for advancing run/spawn timing in at least some coho and Chinook salmon hatcheries (Quinn et al. 2002; Ford et al. 2006). Ironically, random mating, a common spawning guideline for conservation of genetic diversity has been hypothesized to be effectively selecting for younger, smaller fish (Hankin et al. 2009).

The sampling examples mentioned thus far are more or less unintentional actions. There are also established hatchery practices with possible diversity consequences that are clearly intentional. A classic example is use of jacks in spawning, where carefully considered guidelines range from random usage to near exclusion of jacks (e.g., Seidel 1983; IDFG et al. 2020). Another is the deliberate artificial selection in the hatchery of summer and winter steelhead to smolt at one year of age, which has resulted in early spawning stocks of both ecotypes (Crawford 1979).

Another source of biased sampling is non-inclusion of precocious males in broodstock. Precociousness, or early male maturation, is an alternative reproductive tactic employed by Atlantic salmon (Baglinière and Maisse 1985; Myers et al. 1986), Chinook salmon (Bernier et al. 1993; Larsen et al. 2004), coho salmon (Iwamoto et al. 1984; Silverstein and Hershberger 1992), steelhead (Schmidt and House 1979; McMillan et al. 2012) , sockeye salmon (Ricker 1959), as well as several salmonid species in Asia and Europe (Dellefors and Faremo 1988; Kato 1991; Munakata et al. 2001; Morita et al. 2009).

Unlike anadromous males and females that migrate to the ocean to grow for a year or more before returning to their natal stream, precocious males generally stay in headwater reaches or migrate shorter distances downstream (Larsen et al. 2010) before spawning. They are orders of magnitude smaller than anadromous adults and use a ‘sneaker’ strategy to spawn with full size anadromous females (Fleming 1996). Precocious males are typically not subject to collection as broodstock, because of either size or location. Thus, to the extent this life history is genetically determined, hatchery programs culturing species that display precociousness unintentionally select against it.

The examples above illustrate the overlap between diversity effects and selection. Selection, natural or artificial, affects diversity, so could be regarded as a subcategory of within-population diversity. Analytically, here we consider specific effects of sampling or selection on genetic diversity. Broodstock collection or spawning guidelines that include specifications about non-random use of fish with respect to age or size, spawn timing, etc. (e.g., Crawford 1979) are of special interest. We consider general non-specific effects of unintentional selection due to the hatchery that are not related to individual traits in Section 1.2.1.4.

1.2.1.3. Among-population diversity/ Outbreeding effects

Outbreeding effects result from gene flow from other populations into the population of interest. Gene flow occurs naturally among salmon and steelhead populations, a process referred to as straying (Quinn 1997; Keefer and Caudill 2012; Westley et al. 2013). Natural straying serves a valuable function in preserving diversity that would otherwise be lost through genetic drift and in re-colonizing vacant habitat, and straying is considered a risk only when it occurs at unnatural levels or from unnatural sources.

Hatchery fish may exhibit reduced homing fidelity relative to NO fish (Grant 1997; Quinn 1997; Jonsson et al. 2003; Goodman 2005), resulting in unnatural levels of gene flow into recipient populations from strays, either in terms of sources or rates. Based on thousands of coded-wire tag (CWT) recoveries, Westley et al. (2013) concluded that species propagated in hatcheries vary in terms of straying tendency: Chinook salmon > coho salmon > steelhead. Also, within Chinook salmon, “ocean-type” fish stray more than “stream-type” fish. However, even if hatchery fish home at the same level of fidelity as NO fish, their higher abundance relative to NO fish can cause unnaturally high gene flow into recipient populations.

Rearing and release practices and ancestral origin of the hatchery fish can all play a role in straying (Quinn 1997). Based on fundamental population genetic principles, a 1995 scientific workgroup convened by NMFS concluded that aggregate gene flow from non-native HO fish from all programs combined should be kept below 5 percent (Grant 1997), and this is the recommendation NMFS uses as a reference in hatchery consultations. It is important to note that this 5% criterion was developed independently and for a different purpose than the HSRG’s 5% pHOS criterion that is presented in Section 1.2.1.4.

Gene flow from other populations can increase genetic diversity (e.g., Ayllon et al. 2006), which can be a benefit in small populations, but it can also alter established allele frequencies (and co-adapted gene complexes) and reduce the population’s level of adaptation, 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 (ICBTRT 2007), and the greater potential for outbreeding depression. For this reason, NMFS advises hatchery action agencies to develop locally derived hatchery broodstock.

In addition, unusual high rates of straying into other populations within or beyond the population's MPG, salmon ESU, or a steelhead DPS, can have a homogenizing effect, decreasing intra-population genetic variability (e.g., Vasemagi et al. 2005), and increasing risk to population diversity, one of the four attributes measured to determine population viability (McElhany et al. 2000). The practice of backfilling — using eggs collected at one hatchery to compensate for egg shortages at another—has historically a key source of intentional large-scale "straying". Although it now is generally considered an unwise practice, it still occurs but is usually limited to local sources.

There is a growing appreciation of the extent to which among-population diversity contributes to a "portfolio" effect (Schindler et al. 2010), and lack of among-population genetic diversity is considered a contributing factor to the depressed status of California Chinook salmon populations (Carlson et al. 2011; Satterthwaite and Carlson 2015). Eldridge et al. (2009) found that among-population genetic diversity had decreased in Puget Sound coho salmon populations during several decades of intensive hatchery culture.

As discussed in Section 1.2.1.4, pHOS[11] is often used as a surrogate measure of gene flow. Appropriate cautions and qualifications should be considered when using this proportion to analyze outbreeding effects.

- Adult salmon may wander on their return migration, entering and then leaving tributary streams before spawning (Pastor 2004). These "dip-in" fish may be detected and 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). On the other hand, "dip-ins" can also be captured by hatchery traps and become part of the broodstock.

- Strays may not 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 (e.g., Saisa et al. 2003; Blankenship et al. 2007). The causes of poor reproductive success of strays are likely similar to those responsible for reduced productivity of HO fish in general, e.g., differences in run and spawn timing, spawning in less productive habitats, and reduced survival of their progeny (Reisenbichler and McIntyre 1977; Leider et al. 1990; Williamson et al. 2010).

1.2.1.3. Hatchery-influenced selection effects

Hatchery-influenced selection (often called domestication[12]), the third major area of genetic effects of hatchery programs that NMFS analyses, occurs when selection pressures imposed by

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[11] It is important to reiterate that as NMFS analyzes them, outbreeding effects are a risk only when the HO fish are from a *different* population than the NO fish.

[12] We prefer the term "hatchery-influenced selection" or "adaptation to captivity" (Fisch et al. 2015) to "domestication" because in discussions of genetic risk in salmon "domestication" is often taken as equivalence to species that have been under human management for thousands of years; e.g., perhaps 30,000 yrs for dogs (Larson and Fuller 2014), and show evidence of large-scale genetic change (e.g., Freedman et al. 2016). By this standard, the only domesticated fish species is the carp (*Cyprinus carpio*) (Larson and Fuller 2014). "Adaptation to captivity", a

hatchery spawning and rearing differ greatly from those imposed by the natural environment and causes genetic change that is passed on to natural populations through interbreeding with HO fish. These differing selection pressures can be a result of differences in environments or a consequence of protocols and practices used by a hatchery program.

Hatchery-influenced selection can range from relaxation of selection that would normally occur in nature, to selection for different characteristics in the hatchery and natural environments, to intentional selection for desired characteristics (Waples 1999), but in this section, for the most part, we consider hatchery-influenced selection effects that are general and unintentional. Concerns about these effects, often noted as performance differences between HO and NO fish have been recorded in the scientific literature for more than 60 years (Vincent 1960, and references therein).

Genetic change and fitness reduction in natural salmon and steelhead due to hatchery-influenced selection depends on:

- The difference in selection pressures presented by the hatchery and natural environments. Hatchery environments differ from natural environments in many ways (e.g., Thorpe 2004). Some obvious ones are food, density, flows, environmental complexity, and protection from predation.
- How long the fish are reared in the hatchery environment. This varies by species, program type, and by program objective. Steelhead, coho and "stream-type" Chinook salmon are usually released as yearlings, while "ocean-type" Chinook, pink, and chum salmon are usually released at younger ages.
- The rate of gene flow between HO and NO fish, which is usually expressed as pHOS for segregated programs and PNI for integrated programs.

All three factors should be considered in evaluating risks of hatchery programs. However, because gene flow is generally more readily managed than the selection strength of the hatchery environment, current efforts to control and evaluate the risk of hatchery-influenced selection are currently largely focused on gene flow between NO and HO fish[13]. Strong selective fish culture with low hatchery-wild interbreeding can pose less risk than relatively weaker selective fish culture with high levels of interbreeding.

1.2.1.4.1. Relative Reproductive Success Research

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term commonly used in conservation biology (e.g., Frankham 2008), and becoming more common in the fish literature (Christie et al. 2011; Allendorf et al. 2013; Fisch et al. 2015) is more precise for species that have been subjected to semi-captive rearing for a few decades. We feel "hatchery-influenced selection" is even more precise, and less subject to confusion.

[13] Gene flow between NO and HO fish is often interpreted as meaning actual matings between NO and HO fish. In some contexts, it can mean that. However, in this document, unless otherwise specified, gene flow means contributing to the same progeny population. For example, HO spawners in the wild will either spawn with other HO fish or with NO fish. NO spawners in the wild will either spawn with other NO fish or with HO fish. But all these matings, to the extent they are successful, will generate the next generation of NO fish. In other words, all will contribute to the NO gene pool.

Although hundreds of papers in the scientific literature document behavioral, morphological and physiological differences between NO and HO fish, the most frequently cited research has focused on RRS of HO fish compared to NO 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 produce progeny that will then return to sustain the population. The RRS study method is simple: genotyped NO and HO 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) for at least three reasons:

- RRS studies 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 HO:NO 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.

- 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 HO and NO fish was due to spawning location; the HO 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.

- The history of the natural population in terms of hatchery ancestry can bias RRS results. Only a small difference in reproductive success of HO and NO fish might be expected if the population had been subjected to many generations of high pHOS (Willoughby and Christie 2017).

For several years, the bulk of the empirical evidence of fitness depression due to hatchery-influenced selection came from studies of species that are reared in the hatchery environment for an extended period— one to two years—before release (Berejikian and Ford 2004). Researchers and managers wondered if these results were applicable to species and life-history types with shorter hatchery residence, as it seemed reasonable that the selective effect of the hatchery environment would be less on species with shorter hatchery residence times (e.g., RIST 2009). Especially lacking was RRS information on “ocean-type” Chinook. Recent RRS work on Alaskan pink salmon, the species with the shortest hatchery residence time has found very large differences in reproductive success between HO and NO fish (Lescak et al. 2019; Shedd et al. 2022). The RRS was 0.42 for females and 0.28 for males (Lescak et al. 2019). This research suggests the “less residence time, less effect” paradigm should be revisited.

Collectively, some RRS results are now available for all eastern Pacific salmon species except sockeye salmon. Note that this is not an exhaustive list of references:

- Coho salmon (Theriault et al. 2011; Neff et al. 2015)
- Chum salmon (Berejikian et al. 2009)

- “Ocean-type” Chinook salmon (Anderson et al. 2012; Sard et al. 2015; Evans et al. 2019)
- “Stream-type” Chinook salmon (Ford et al. 2009; Williamson et al. 2010; Ford et al. 2012; Hess et al. 2012; Ford et al. 2015; Janowitz-Koch et al. 2018)
- Steelhead (Araki et al. 2007; Araki et al. 2009; Berntson et al. 2011; Christie et al. 2011)
- Pink salmon (Lescak et al. 2019; Shedd et al. 2022)

Although the size of the effect may vary, and there may be year-to-year variation and lack of statistical significance, the general pattern is clear: HO fish have lower reproductive success than NO fish.

As mentioned above, few studies have been designed to detect unambiguously 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 (Ford et al. 2012; Janowitz-Koch et al. 2018) have not detected a statistically significant genetic component.

Detecting a genetic component of fitness loss in one species and not another suggests that perhaps the impacts of hatchery-influenced selection on fitness differs between Chinook salmon and steelhead.[14] The possibility that steelhead may be more affected by hatchery-influenced selection than Chinook salmon by no means suggest that effects on Chinook are trivial, however. A small decrement in fitness per generation can lead to large fitness loss.

1.2.1.4.2. Hatchery Scientific Review Group (HSRG) Guidelines

Concepts concerning the relationship of gene flow to hatchery-influenced selection were initially developed in Washington by state and tribal co-managers in the Artificial Production Plan sections of the Comprehensive Coho and the Comprehensive Chinook Salmon Management Plans (PSTT and WDFW 1998). Surrogate gene flow guidelines were further developed by the Hatchery Scientific Review Group (HSRG), a congressionally funded group of federal, state, tribal, academic, and unaffiliated scientists that existed from 2004 to 2020. Although this group included Federal, state, tribal, academic and unaffiliated members, many tribes and other resource management agencies have not accepted its guidelines. Nevertheless, HSRG concepts have been influential regionally and so we discuss them in the next few paragraphs.

The HSRG developed gene-flow guidelines based on mathematical models developed by Ford (2002) and by Lynch and O'Hely (2001). Guidelines for segregated programs are based on pHOS, but guidelines for integrated programs also include PNI, which is a function of pHOS and pNOB. PNI is, in theory, a reflection of the relative strength of selection in the hatchery and natural environments; a PNI value greater than 0.5 indicates dominance of natural selective forces.

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[14] 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 et al. 2012).

The HSRG gene-flow guidelines (HSRG 2009b) vary according to type of program and conservation importance of the population. The HSRG used conservation importance classifications that were developed by the Willamette/Lower Columbia Technical Recovery Team (McElhany et al. 2003).[15] (Table 1). In considering the guidelines, we equate "primary" with ESA recovery goal levels of "viable" or "highly viable", and "contributing" with a recovery goal of "maintain". We disagree with the HSRG guidelines for "stabilizing", because we feel they are inadequate for conservation guidance.

Table A-17. HSRG gene flow guidelines (HSRG 2009b).

	Program classification	
Population conservation importance	**Integrated**	**Segregated**
Primary	**PNI $\geq$ 0.67 and pHOS $\leq$ 0.30**	**pHOS $\leq$ 0.05**
Contributing	**PNI $\geq$ 0.50 and pHOS $\leq$ 0.30**	**pHOS $\leq$ 0.10**
Stabilizing	**Existing conditions**	**Existing conditions**

Although they are controversial, the HSRG gene flow guidelines have achieved a considerable level of regional acceptance. They were adopted for a time as policy by the Washington Fish and Wildlife Commission (WDFW 2009), and were recently reviewed and endorsed by a WDFW scientific panel, who noted that the "…HSRG is the primary, perhaps only entity providing guidance for operating hatcheries in a scientifically defensible manner…" (Anderson et al. 2020). In addition, HSRG principles are being considered the Canadian Department of Fisheries and Oceans, with very similar gene-flow guidelines for some situations (Withler et al. 2018)[16]. However, the 2009 WDFW policy is now under revision, with measures related to the HSRG gene-flow guidelines suspended.

The gene flow guidelines developed by the HSRG have been implemented in areas of the Pacific Northwest for at most 15 years, so there has been insufficient time to judge their effect. They have also not been applied consistently, which complicates evaluation. However, the benefits of high pNOB (in the following cases, 100 percent) has been credited with limiting genetic change and fitness loss in supplemented Chinook populations in the Yakima (Washington) (Waters et al. 2015) and Salmon (Idaho) (Hess et al. 2012; Janowitz-Koch et al. 2018) basins.

Little work toward developing guidelines beyond the HSRG work has taken place. The only notable effort along these lines has been the work of Baskett and Waples (2013) and (Baskett et al. 2013), who developed models similar to that of Ford (2002), but added the ability to impose density-dependent survival and selection at different life stages. Their qualitative results were similar to Ford's, but the model would require some revision to be used to develop guidelines comparable to the HSRG's.

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[15] Development of conservation importance classifications varied among technical recovery teams (TRTs); for more information, documents produced by the individual TRT's should be consulted.

[16] Withler et al. (2018) noted a non-genetic biological significance to a pHOS level of 30%. Assuming mating is random with respect to origin (HO or NO) in a spawning aggregation of HO and NO fish, NOxNO matings will comprise the majority of matings only if pHOS is less than 30%.

NMFS has not adopted the HSRG gene flow guidelines per se. However, at present the HSRG guidelines are the only scientifically based quantitative gene flow guidelines available for reducing the risk of hatchery-influenced selection. NMFS has considerable experience with the HSRG guidelines. They are based on a model (Ford 2002) developed by a NMFS geneticist, they have been evaluated by a NMFS-lead scientific team (RIST 2009), and NMFS scientists have extended the Ford model for more flexible application of the guidelines to complex situations (Busack 2015) (Section 1.2.1.4.3).

At minimum, we consider the HSRG guidelines a useful screening tool. For a particular program, based on specifics of the program, broodstock composition, and environment, we may consider a pHOS or PNI level to be a lower risk than the HSRG would but, generally, if a program meets HSRG guidelines, we will typically consider the risk levels to be acceptable. However, our approach to application of HSRG concepts varies somewhat from what is found in HSRG documents or in typical application of HSRG concepts. Key aspects of our approach warrant discussion here.

1.2.1.4.2.1. PNI and segregated hatchery programs

The PNI concept has created considerable confusion. Because it is usually estimated by a simple equation that is applicable to integrated programs, and applied in HSRG guidelines only to integrated programs, PNI is typically considered to be a concept that is relevant only to integrated programs. This in turn has caused a false distinction between segregated and integrated programs in terms of perceptions of risk. The simple equation for PNI is:

$PNI \approx pNOB / (pNOB + pHOS)$.

In a segregated program, pNOB equals zero, so by this equation PNI would also be zero. You could easily infer that PNI is zero in segregated programs, but this would be incorrect. The error comes from applying the equation to segregated programs. In integrated programs, PNI can be estimated accurately by the simple equation, and the simplicity of the equation makes it very easy to use. In segregated programs, however, a more complicated equation must be used to estimate PNI. A PNI equation applicable to both integrated and segregated programs was developed over a decade ago by the HSRG (HSRG 2009a, equation 9), but has been nearly completed ignored by parties dealing with the gene flow guidelines:

$$PNI \approx \frac{h^2 + (1.0 - h^2 + \omega^2) * pNOB}{h^2 + (1.0 - h^2 + \omega^2) * (pNOB + pHOS)},$$

where h^2 is heritability and ω^2 is the strength of selection in standard deviation units, squared. Ford (2002) used a range of values for the latter two variables. Substituting those values that created the strongest selection scenarios in his simulations (h^2 of 0.5 and ω^2 of 10), which is appropriate for risk assessment, results in:

$$PNI \approx \frac{0.5 + 10.5 * pNOB}{0.5 + 10.5 * (pNOB + pHOS)}$$

HSRG (2004b) offered additional guidance regarding isolated programs, stating that risk increases dramatically 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. More recently, the HSRG concluded that the guidelines for isolated programs may not provide as much protection from fitness loss as the corresponding guidelines for integrated programs (HSRG 2014). This can be easily demonstrated using the equation presented in the previous paragraph: a pHOS of 0.05, the standard for a primary population affected by a segregated program, yields a PNI of 0.49, whereas a pHOS of 0.024 yields a PNI of 0.66, virtually the same as the standard for a primary population affected by an integrated program.

1.2.1.4.2.2. The effective pHOS concept

The HSRG recognized that HO fish spawning naturally may on average produce fewer adult progeny than NO spawners, as described above. To account for this difference, the HSRG (2014) defined *effective* pHOS as:

$$\text{pHOS}_{\text{eff}} = (\text{RRS} * \text{HOS}_{\text{census}}) / (\text{NOS} + \text{RRS} * \text{HOS}_{\text{census}}),$$

where RRS is the reproductive success of HO fish relative to that of NO fish. They then recommend using this value in place of $\text{pHOS}_{\text{census}}$ in PNI calculations.

We feel that adjustment of census pHOS by RRS for this purpose should be done not nearly as freely as the HSRG document would suggest because the Ford (2002) model, which is the foundation of the HSRG gene-flow guidelines, implicitly includes a genetic component of RRS. In that model, hatchery fish are expected to have RRS < 1 (compared to natural fish) due to selection in the hatchery. A component of reduced RRS of hatchery fish is therefore already incorporated in the model and by extension the calculation of PNI. Therefore, reducing pHOS values by multiplying by RRS will result in underestimating the relevant pHOS and therefore overestimating PNI. Such adjustments would be particularly inappropriate for hatchery programs with low pNOB, as these programs may well have a substantial reduction in RRS due to genetic factors already incorporated in the model.

In some cases, adjusting pHOS downward may be appropriate, particularly if there is strong evidence of a non-genetic component to RRS. Wenatchee spring Chinook salmon (Williamson et al. 2010) is an example case with potentially justified adjustment by RRS, where the spatial distribution of NO and HO spawners differs, and the HO fish tend to spawn in poorer habitat. However, even in a situation like the Wenatchee spring Chinook salmon, it is unclear how much of an adjustment would be appropriate.

By the same logic, it might also be appropriate to adjust pNOB in some circumstances. For example, if hatchery juveniles produced from NO broodstock tend to mature early and residualize (due to non-genetic effects of rearing), as has been documented in some spring Chinook salmon and steelhead programs, the “effective” pNOB might be much lower than the census pNOB.

It is important to recognize that PNI is only an approximation of relative trait value, based on a model that is itself very simplistic. To the degree that PNI fails to capture important biological information, it would be better to work to include this biological information in the underlying models rather than make ad hoc adjustments to a statistic that was only intended to be a rough guideline to managers. We look forward to seeing this issue further clarified in the near future. In the meantime, except for cases in which an adjustment for RRS has strong justification, we feel that census pHOS, rather than effective pHOS, is the appropriate metric to use for genetic risk evaluation.

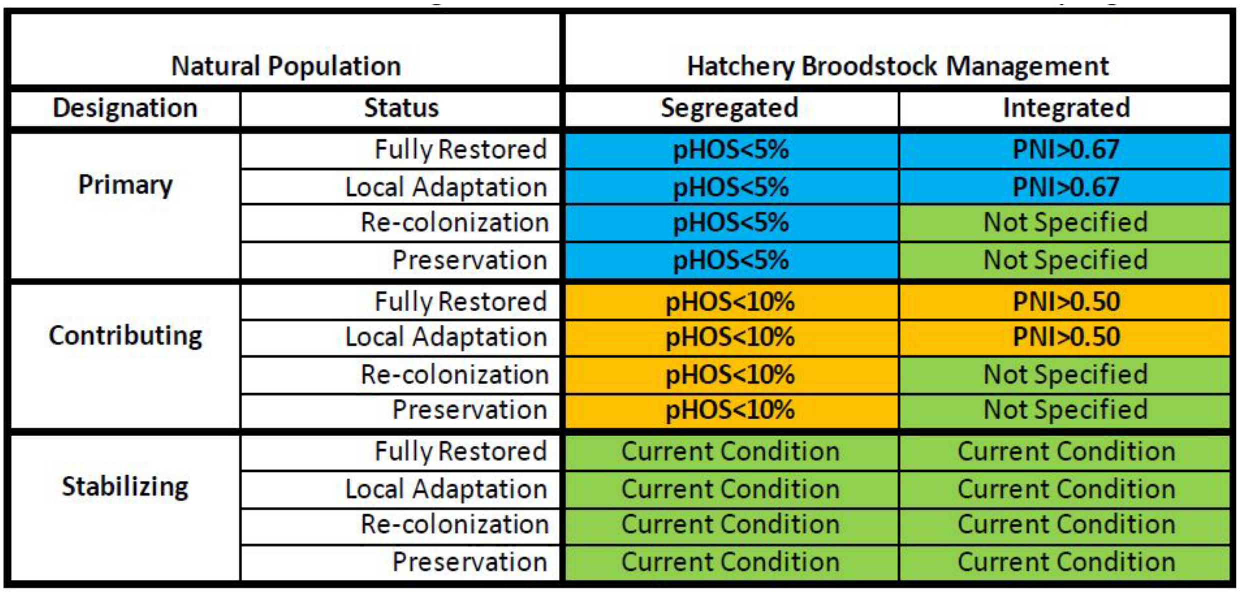
1.2.1.4.2.3. Gene flow guidelines in phases of recovery

In 2012 the HSRG expanded on the original gene flow guidelines/standards by introducing the concept of recovery phases for natural populations (HSRG 2012), and then refined the concept in later documents (HSRG 2014; 2015; 2017). They defined and described four phases:

1. Preservation
2. Re-colonization
3. Local adaptation
4. Fully restored

The HSRG provided guidance on development of quantitative "triggers" for determining when a population had moved (up or down) from one phase to another. As explained in HSRG (2015), in the preservation and re-colonization phase, no PNI levels were specified for integrated programs (Table 1). The emphasis in these phases was to "Retain genetic diversity and identity of the existing population". In the local adaptation phase, when PNI standards were to be applied, the emphasis shifted to "Increase fitness, reproductive success and life history diversity through local adaptation (e.g., by reducing hatchery influence by maximizing *PNI*)". The HSRG provided additional guidance in HSRG (2017), which encouraged managers to use pNOB to "…the extent possible…" during the preservation and recolonization phases.

Table A-18. HSRG gene flow guidelines/standards for conservation and harvest programs, based on recovery phase of impacted population (Table 2 from HSRG 2015).



Natural Population		Hatchery Broodstock Management	
Designation	**Status**	**Segregated**	**Integrated**
Primary	Fully Restored	pHOS<5%	PNI>0.67
	Local Adaptation	pHOS<5%	PNI>0.67
	Re-colonization	pHOS<5%	Not Specified
	Preservation	pHOS<5%	Not Specified
Contributing	Fully Restored	pHOS<10%	PNI>0.50
	Local Adaptation	pHOS<10%	PNI>0.50
	Re-colonization	pHOS<10%	Not Specified
	Preservation	pHOS<10%	Not Specified
Stabilizing	Fully Restored	Current Condition	Current Condition
	Local Adaptation	Current Condition	Current Condition
	Re-colonization	Current Condition	Current Condition
	Preservation	Current Condition	Current Condition

We have two concerns regarding the phases of recovery approach. First, although the phase structure is intuitively appealing, no scientific evidence was presented the HSRG for existence of the phases. Second, while we agree that conservation of populations at perilously low abundance may require prioritization of demographic over genetic concerns, we are concerned that high pHOS/low PNI regimes imposed on small recovering populations may prevent them from advancing to higher recovery phases[17]. A WDFW scientific panel reviewing HSRG principles and guidelines reached the same conclusion (Anderson et al. 2020). In response, the HSRG in issued revised guidance for the preservation and recolonization phases (HSRG 2020):

1. *Preservation – No specific pHOS or PNI recommendations, but hatchery managers are encouraged to use as many NOR brood as possible. In some cases (e.g., very low R/S values at low spawner abundances or low intrinsic productivity), it may be preferable to use all available NORs in the hatchery brood and allow only extra hatchery-origin recruits (HORs) to spawn naturally.*

2. *Recolonization – No specific pHOS or PNI recommendations, but managers are encouraged to continue to use some NOR in broodstock (perhaps 10%-30% of NORs), while allowing the majority of NORs to spawn naturally.*

1.2.1.4.3. Extension of PNI modeling to more than two population components

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[17] According to Andy Appleby, past HSRG co-chair, the HSRG never intended this guidance to be interpreted as total disregard for pHOS/PNI standards in the preservation and recovery phases (Appleby 2020).

The Ford (2002) model considered a single population affected by a single hatchery program—basically two population units connected by gene flow—but the recursion equations underlying the model are easily expanded to more than two populations (Busack 2015). This has resulted in tremendous flexibility in applying the PNI concept to hatchery consultations.

A good example is a system of genetically linked hatchery programs, an integrated program in which in which returnees from a (typically smaller) integrated hatchery program are used as broodstock for a larger segregated program, and both programs contribute to pHOS (Figure 3). It seems logical that this would result in less impact to the natural population than if the segregated program used only its own returnees as broodstock, but because the two-population implementation of the Ford model did not apply, there was no way to calculate PNI for this system.

Extending Ford's recursion equations (equations 5 and 6) to three populations allowed us to calculate PNI for a system of this type. We successfully applied this approach to link two spring Chinook salmon hatchery programs: Winthrop NFH (segregated) and Methow FH (integrated). By using some level of Methow returnees as broodstock for the Winthrop program, PNI for the natural population could be increased significantly[18](Busack 2015). We have since used the multi-population PNI model in numerous hatchery program consultations in Puget Sound and the Columbia basin, and have extended to it to include as many as ten hatchery programs and natural production areas.

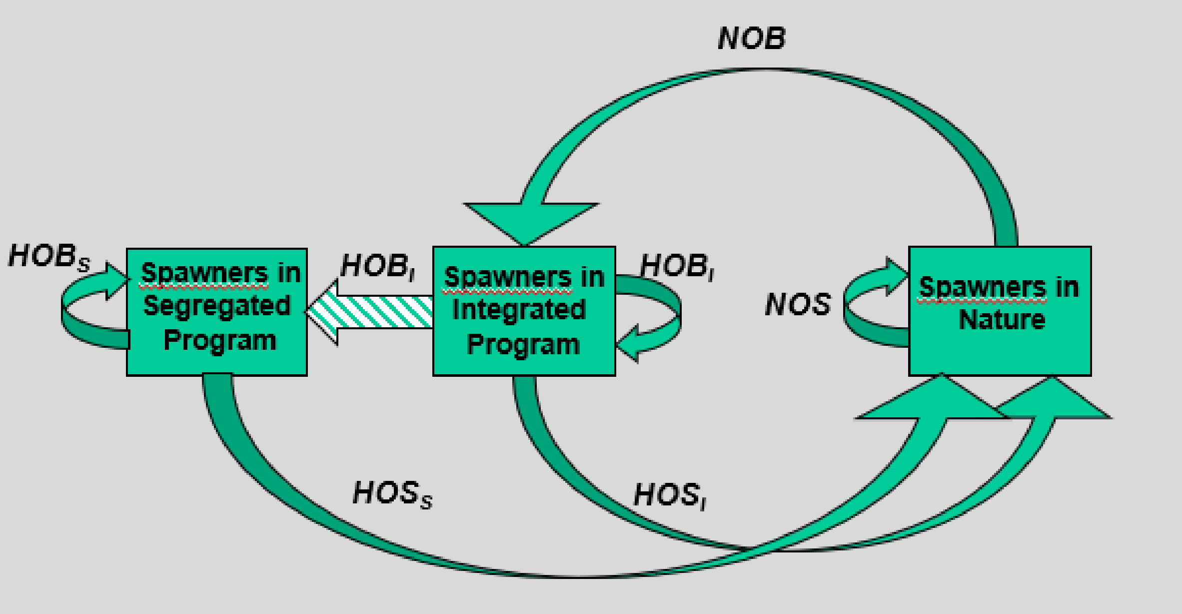

Figure A-14. Example of genetically linked hatchery programs. The natural population is influenced by hatchery-origin spawners from an integrated (HOS_I) and a segregated program (HOS_S). The integrated program uses a mix of natural-origin (NOB) and its own returnees (HOB_I) as broodstock, but the segregated uses returnees from the integrated program (HOB_I above striped arrow) as all or part of its broodstock, genetically linking the two programs. The system illustrated here is functionally

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[18] Such programs can lower the effective size of the system, but the model of Tufto (Section 1.2.1.4) can easily be applied to estimate this impact.

equivalent to the HSRG's (HSRG 2014)"stepping stone" concept.

1.2.1.4.4. California HSRG

Another scientific team was assembled to review hatchery programs in California and this group developed guidelines that differed somewhat from those developed by the "Northwest" HSRG (California HSRG 2012). The California team:

- Felt that truly isolated programs in which no HO returnees interact genetically with natural populations were impossible in California, and was "generally unsupportive" of the concept of segregated programs. However, if programs were to be managed as isolated, they recommend a pHOS of less than 5 percent.
-
- Rejected development of overall pHOS guidelines for integrated programs because the optimal pHOS will depend upon multiple factors, such as "the amount of spawning by NO fish in areas integrated with the hatchery, the value of pNOB, the importance of the integrated population to the larger stock, the fitness differences between HO and NO fish, and societal values, such as angling opportunity."
-
- Recommended that program-specific plans be developed with corresponding population-specific targets and thresholds for pHOS, pNOB, and PNI that reflect these factors. However, they did state that PNI should exceed 50 percent in most cases, although in supplementation or reintroduction programs the acceptable pHOS could be much higher than 5 percent, even approaching 100 percent at times.

- Recommended for conservation programs that pNOB approach 100 percent, but pNOB levels should not be so high they pose demographic risk to the natural population by taking too large a proportion of the population for broodstock.

1.2.2. Ecological effects

Ecological effects for this factor (i.e., hatchery fish and the progeny of naturally spawning hatchery fish on the spawning grounds) refer to effects from competition for spawning sites and redd superimposition, contributions to marine-derived nutrients, and the removal of fine sediments from spawning gravels. Ecological effects on the spawning grounds may be positive or negative.

To the extent that hatcheries contribute added fish to the ecosystem, there can be positive effects. For example, when anadromous salmonids return to spawn, hatchery-origin and natural-origin alike, they transport marine-derived nutrients stored in their bodies to freshwater and terrestrial ecosystems. Their carcasses provide a direct food source for juvenile salmonids and other fish, aquatic invertebrates, and terrestrial animals, and their decomposition supplies nutrients that may increase primary and secondary production (Kline et al. 1990; Piorkowski 1995; Larkin and Slaney 1996; Gresh et al. 2000; Murota 2003; Quamme and Slaney 2003; Wipfli et al. 2003). As a result, the growth and survival of juvenile salmonids may increase (Hager and Noble 1976; Bilton et al. 1982; Holtby 1988; Ward and Slaney 1988; Hartman and Scrivener 1990; Johnston et al. 1990; Larkin and Slaney 1996; Quinn and Peterson 1996; Bradford et al. 2000; Bell 2001; Brakensiek 2002).

Additionally, studies have demonstrated that perturbation of spawning gravels by spawning salmonids loosens cemented (compacted) gravel areas used by spawning salmon (e.g., (Montgomery et al. 1996). The act of spawning also coarsens gravel in spawning reaches, removing fine material that blocks interstitial gravel flow and reduces the survival of incubating eggs in egg pockets of redds.

The added spawner density resulting from hatchery-origin fish spawning in the wild can have negative consequences, such as increased competition, and potential for 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 overlap between natural-and hatchery-origin spawners, the potential exists for hatchery-derived 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).

1.2.3. Adult Collection Facilities

The analysis also considers the effects from encounters with natural-origin fish that are incidental to broodstock collection. Here, NMFS analyzes effects from sorting, holding, and handling natural-origin fish in the course of broodstock collection. Some programs collect their broodstock from fish voluntarily entering the hatchery, typically into a ladder and holding pond, while others sort through the run at large, usually at a weir, ladder, or sampling facility. The more a hatchery program accesses the run at large for hatchery broodstock – that is, the more fish that are handled or delayed during migration – the greater the negative effect on natural- and hatchery-origin fish that are intended to spawn naturally and on ESA-listed species. The information NMFS uses for this analysis includes a description of the facilities, practices, and protocols for collecting broodstock, the environmental conditions under which broodstock collection is conducted, and the encounter rate for ESA-listed fish.

NMFS also analyzes the effects of structures, either temporary or permanent, that are used to collect hatchery broodstock, and remove hatchery fish from the river or stream and prevent them from spawning naturally, on juvenile and adult fish from encounters with these structures. NMFS determines through the analysis, for example, whether the spatial structure, productivity, or abundance of a natural population is affected when fish encounter a structure used for broodstock collection, usually a weir or ladder.

1.3. Factor 3. Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas, the migratory corridor, estuary, and ocean (Revised June 1, 2020)

NMFS also analyzes the potential for competition, predation, and disease when the progeny of naturally spawning hatchery fish and hatchery releases share juvenile rearing areas.

1.3.1. Competition

Competition and a corresponding reduction in productivity and survival may result from direct or indirect interactions. Direct interactions occur when hatchery-origin fish interfere with the accessibility to limited resources by natural-origin fish, and indirect interactions occur when the utilization of a limited resource by hatchery fish reduces the amount available for fish from the natural population (Rensel et al. 1984). Natural-origin fish may be competitively displaced by hatchery fish early in life, especially when hatchery fish are more numerous, are of equal or greater size, take up residency before natural-origin fry emerge from redds, and residualize. Hatchery fish might alter natural-origin salmon behavioral patterns and habitat use, making natural-origin fish more susceptible to predators (Hillman and Mullan 1989; Steward and Bjornn 1990). Hatchery-origin fish may also alter natural-origin salmonid migratory responses or movement patterns, leading to a decrease in foraging success by the natural-origin fish (Hillman and Mullan 1989; Steward and Bjornn 1990). Actual impacts on natural-origin fish thus depend on the degree of dietary overlap, food availability, size-related differences in prey selection, foraging tactics, and differences in microhabitat use (Steward and Bjornn 1990).

Several studies suggest that salmonid species and migratory forms that spend longer periods of time in stream habitats (e.g., coho salmon and steelhead) are more aggressive than those that outmigrate at an earlier stage (Hutchison and Iwata 1997). The three least aggressive species generally outmigrate to marine (chum salmon) or lake (kokanee and sockeye salmon) habitats as post-emergent fry. The remaining (i.e., more aggressive) species all spend one year or more in stream habitats before outmigrating. Similarly, Hoar (1951) did not observe aggression or territoriality in fry of early migrants (chum and pink salmon), in contrast to fry of a later migrating species (coho salmon) which displayed high levels of both behaviors. Hoar (1954) rarely observed aggression in sockeye salmon fry, and observed considerably less aggression in sockeye than coho salmon smolts. Taylor (1990) found that Chinook salmon populations that outmigrate as fry are less aggressive than those that outmigrate as parr, which in turn are less aggressive than those that outmigrate as yearlings.

Although *intraspecific* interactions are expected to be more frequent/intense than *interspecific* interactions (e.g., Hartman 1965; Tatara and Berejikian 2012), this apparent relationship between aggression and stream residence appears to apply to *interspecific* interactions as well. For example, juvenile coho salmon are known to be highly aggressive toward other species (e.g., Stein et al. 1972; Taylor 1991). Taylor (1991) found that coho salmon were much more aggressive toward size-matched *ocean*-type Chinook salmon (early outmigrants), but only moderately more aggressive toward size-matched *stream*-type Chinook salmon (later outmigrants). Similarly, the findings of Hasegawa et al. (2014) indicate that masu salmon (*O. masou*), which spend 1 to 2 years in streams before outmigrating, dominate and outcompete the early-migrating chum salmon.

A few exceptions to this general stream residence-aggression pattern have been observed (e.g., Lahti et al. 2001; Young 2003; Hasegawa et al. 2004; Young 2004), but all the species and migratory forms evaluated in these studies spend one year or more in stream habitat before outmigrating. Other than the Taylor (1991) and Hasegawa et al. (2014) papers noted above, we are not aware of any other studies that have looked specifically at interspecific interactions between early-outmigrating species (e.g., sockeye, chum, and pink salmon) and those that rear longer in streams.

En masse hatchery salmon and steelhead smolt releases may cause displacement of rearing natural-origin juvenile salmonids from occupied stream areas, leading to abandonment of advantageous feeding stations, or to premature out-migration by natural-origin juveniles. Pearsons et al. (1994) reported small-scale displacement of naturally produced juvenile rainbow trout from stream sections by hatchery steelhead. Small-scale displacements and agonistic interactions observed between hatchery steelhead and natural-origin juvenile trout were most likely a result of size differences and not something inherently different about hatchery fish, such as behavior.

A proportion of the smolts released from a hatchery may not migrate to the ocean but rather reside for a time near the release point. These non-migratory smolts (residuals) may compete for food and space with natural-origin juvenile salmonids of similar age (Bachman 1984; Tatara and Berejikian 2012). Although this behavior has been studied and observed most frequently in hatchery steelhead, residualism has been reported as a potential issue for hatchery coho and Chinook salmon as well (Parkinson et al. 2017). Adverse impacts of residual hatchery Chinook and coho salmon on natural-origin salmonids can occur, especially given that the number of smolts per release is generally higher than for steelhead; however, residualism in these species has not been as widely investigated as it has in steelhead. Therefore, for all species, monitoring of natural stream areas near hatchery release points may be necessary to determine the potential effects of hatchery smolt residualism on natural-origin juvenile salmonids.

The risk of adverse competitive interactions between hatchery- and natural-origin fish can be minimized by:

- Releasing hatchery smolts that are physiologically ready to migrate. Hatchery fish released as smolts emigrate seaward soon after liberation, minimizing the potential for competition with juvenile natural-origin fish in freshwater (Steward and Bjornn 1990; California HSRG 2012)
- Rearing hatchery fish to a size sufficient to ensure that smoltification occurs
- Releasing hatchery smolts in lower river areas, below rearing areas used by natural-origin juveniles
- Monitoring the incidence of non-migratory smolts (residuals) after release and adjusting rearing strategies, release location, and release timing if substantial competition with natural-origin juveniles is likely

Critical information for analyzing competition risk is quality and quantity of spawning and rearing habitat in the action area,[19] including the distribution of spawning and rearing habitat by quality, and best estimates for spawning and rearing habitat capacity. Additional important information includes the abundance, distribution, and timing for naturally spawning hatchery fish and natural-origin fish; the timing of emergence; the distribution and estimated abundance for progeny from both hatchery and natural-origin natural spawners; the abundance, size,

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[19] "Action area," in ESA section 7 analysis documents, means all areas to be affected directly or indirectly by the action in which the effects of the action can be meaningfully detected and evaluated.

distribution, and timing for juvenile hatchery fish in the action area; and the size of hatchery fish relative to co-occurring natural-origin fish.

1.3.2. Predation

Predation is another potential ecological effect of hatchery releases. Predation, either direct (consumption by hatchery fish) or indirect (increases in predation by other predator species due to enhanced attraction), can result from hatchery fish released into the wild. Here we consider predation by hatchery-origin fish, by the progeny of naturally spawning hatchery fish, and by birds and other non-piscine predators attracted to the area by an abundance of hatchery fish.

Hatchery fish originating from egg boxes and fish planted as non-migrant fry or fingerlings can prey upon fish from the local natural population during juvenile rearing. Hatchery fish released at a later stage that are more likely to migrate quickly to the ocean, can still prey on fry and fingerlings that are encountered during the downstream migration. Some of these hatchery fish do not emigrate and instead take up residence in the stream where they can prey on stream-rearing juveniles over a more prolonged period, as discussed above. The progeny of naturally spawning hatchery fish also can prey on fish from a natural population and pose a threat.

Predation may be greatest when large numbers of hatchery smolts encounter newly emerged fry or fingerlings, or when hatchery fish are large relative to natural-origin fish (Rensel et al. 1984). Due to their location in the stream, size, and time of emergence, newly emerged salmonid fry are likely to be the most vulnerable to predation. Their vulnerability is greatest immediately upon emergence from the gravel and then decreases as they move into shallow, shoreline areas (USFWS 1994). Emigration out of important rearing areas and foraging inefficiency of newly released hatchery smolts may reduce the degree of predation on salmonid fry (USFWS 1994).

Some reports suggest that hatchery fish can prey on fish that are as large as 1/2 their length (Hargreaves and LeBrasseur 1986; Pearsons and Fritts 1999; HSRG 2004b and references therein), but other studies have concluded that salmonid predators prey on fish up to 1/3 their length (Horner 1978; Hillman and Mullan 1989; Beauchamp 1990; Cannamela 1992; CBFWA 1996; Daly et al. 2009). Hatchery fish may also be less efficient predators as compared to their natural-origin conspecifics, reducing the potential for predation impacts (Sosiak et al. 1979; Bachman 1984; Olla et al. 1998).

Size is an important determinant of how piscivorous hatchery-origin fish are. Keeley and Grant (2001) reviewed 93 reports detailing the relationship between size and piscivory in 17 species of stream-dwelling salmonids. *O. mykiss* and Pacific salmon were well represented in the reviewed reports. Although there is some variation between species, stream-dwelling salmonids become piscivorous at about 100 mm FL, and then piscivory rate increases with increasing size. For example:

- For 140 mm fish, 15% would be expected to have fish in their diet but would not be primarily piscivorous; 2% would be expected to be primarily piscivorous (> 60% fish in diet).
- For 200 mm fish, those figures go to 32% (fish in diet) and 11% (primarily piscivorous).

The implication for hatchery-origin fish is pretty clear: larger hatchery-origin fish present a greater predation risk because more of them eat fish, and more of them eat primarily fish.

There are two key measures that hatchery programs can implement to reduce or avoid the threat of predation:

- Ensuring that a high proportion of the hatchery fish are fully smolted. Juvenile salmon tend to migrate seaward rapidly when fully smolted, limiting the duration of interaction between hatchery- and natural-origin fish present within and downstream of release areas.
- Releasing hatchery smolts in lower river areas near river mouths and below upstream areas used for stream-rearing young-of-the-year naturally produced salmon fry, thereby reducing the likelihood for interaction between the hatchery and naturally produced fish.

The two measures just mentioned will reduce minimize residualism as well as predation. The following measures can also help minimize residualism:

- Allowing smolts to exit the hatchery facility volitionally rather than forcing them out
- Ensuring that hatchery rearing regimes and growth rates produce fish that meet the minimum size needed for smolting, but are not so large as to induce desmoltification or early maturation
- Removing potential residuals based on size or appearance before release. This is likely impractical in most cases

1.3.3. Disease

The release of hatchery fish, as well as hatchery effluent, into juvenile rearing areas can lead to pathogen transmission; and contact with chemicals, or altering environmental conditions (e.g., dissolved oxygen) can result in disease outbreaks. Fish diseases can be subdivided into two main categories:

- Infectious diseases are those caused by pathogens such as viruses, bacteria, and parasites.
- Noninfectious diseases are those that cannot be transmitted between fish and are typically caused by environmental factors (e.g., low dissolved oxygen), but can also have genetic causes.

Pathogens can be categorized as exotic or endemic. For our purposes, exotic pathogens are those that have little to no history of occurrence within the boundaries of the state where the hatchery program is located. For example, *Oncorhynchus masou* virus (OMV) would be considered an exotic pathogen if identified anywhere in Washington state because it is not known to occur there. Endemic pathogens are native to a state, but may not be present in all watersheds.

In natural fish populations, the risk of disease associated with hatchery programs may increase through a variety of mechanisms (Naish et al. 2007), discussed below:

- Introduction of exotic pathogens
- Introduction of endemic pathogens to a new watershed
- Intentional release of infected fish or fish carcasses
- Continual pathogen reservoir
- Pathogen amplification

The last two terms above require some explanation. A continual pathogen reservoir is created when a standing crop of susceptible hosts keeps the pathogen from burning itself out. For example, stocking certain susceptible strains of trout can ensure that the pathogen is always present. Pathogen amplification occurs when densities of pathogens that are already present increase beyond baseline levels due to hatchery activities. A good example is sea lice in British Columbia (e.g., Krkošek 2010). The pathogen is endemic to the area and is normally present in wild populations, but salmon net pens potentially allow for a whole lot more pathogen to be produced and added to the natural environment.

Continual pathogen reservoir and pathogen amplification can exist at the same time. For example, stocked rainbow trout can amplify a naturally occurring pathogen if they become infected, and if stocking occurs every year, the stocked animals also can act as a continual pathogen reservoir.

Pathogen transmission between hatchery and natural fish can occur indirectly through hatchery water influent/effluent or directly via contact with infected fish. Within a hatchery, the likelihood of transmission leading to an epizootic (i.e., disease outbreak) is increased compared to the natural environment because hatchery fish are reared at higher densities and closer proximity than would naturally occur. During an epizootic, hatchery fish can shed relatively large amounts of pathogen into the hatchery effluent and ultimately, the environment, amplifying pathogen numbers. However, few, if any, examples of hatcheries contributing to an increase in disease in natural populations have been reported (Steward and Bjornn 1990; Naish et al. 2007). This lack of reporting is because both hatchery and natural-origin salmon and trout are susceptible to the same pathogens (Noakes et al. 2000), which are often endemic and ubiquitous (e.g., *Renibacterium salmoninarum,* the cause of Bacterial Kidney Disease).

Several state, federal, and tribal fish health policies, in some cases combined with state law, limit the disease risks associated with hatchery programs (IHOT 1995; ODFW 2003; USFWS 2004; NWIFC and WDFW 2006). Specifically, the policies govern the transfer of fish, eggs, carcasses, and water to prevent the spread of exotic and endemic pathogens. For example, the policy for Washington (NWIFC and WDFW 2006) divides the state into 14 Fish Health Management Zones[20] (FHMZs), and specifies requirements for transfers within and across FHMZs. Washington state law lists pathogens for which monitoring and reporting is required (regulated pathogens), and the Washington Department of Fish and Wildlife typically requires monitoring and reporting for additional pathogens. Reportable pathogen occurrence at a Washington

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[20] Puget Sound consists of five FHMZs, the Columbia basin only 1.

hatchery is communicated to the state veterinarian, but also to fish health personnel at a variety of levels: local, tribal, state, and federal.

For all pathogens, both reportable and non-reportable, pathogen spread and amplification are minimized through regular monitoring (typically monthly) removing mortalities, and disinfecting all eggs. Vaccines may provide additional protection from certain pathogens when available (e.g., *Vibrio anguillarum*). If a pathogen is determined to be the cause of fish mortality, treatments (e.g., antibiotics) will be used to limit further pathogen transmission and amplification. Some pathogens, such as *infectious hematopoietic necrosis virus* (IHNV), have no known treatment. Thus, if an epizootic occurs for those pathogens, the only way to control pathogen amplification is to cull infected individuals or terminate all susceptible fish. In addition, current hatchery operations often rear hatchery fish on a timeline that mimics their natural life history, which limits the presence of fish susceptible to pathogen infection and prevents hatchery fish from becoming a pathogen reservoir when no natural fish hosts are present.

In addition to the state, federal, and tribal fish health policies, disease risks can be further minimized by preventing pathogens from entering the hatchery through the treatment of incoming water (e.g., by using ozone), or by leaving the hatchery through hatchery effluent (Naish et al. 2007). Although preventing the exposure of fish to any pathogens before their release into the natural environment may make the hatchery fish more susceptible to infection after release into the natural environment, reduced fish densities in the natural environment compared to hatcheries likely reduces the risk of fish encountering pathogens at infectious levels (Naish et al. 2007).

Treating the hatchery effluent reduces pathogen amplification, but does not reduce disease outbreaks within the hatchery caused by pathogens present in the incoming water supply. Another challenge with treating hatchery effluent is the lack of reliable, standardized guidelines for testing or a consistent practice of controlling pathogens in effluent (LaPatra 2003). However, hatchery facilities located near marine waters likely limit freshwater pathogen amplification downstream of the hatchery without human intervention because the pathogens are killed before transmission to fish when the effluent mixes with saltwater.

Noninfectious diseases are typically caused by environmental factors (e.g., low dissolved oxygen). Hatchery facilities routinely use a variety of chemicals for treatment and sanitation purposes. Chlorine levels in the hatchery effluent, specifically, are monitored with a National Pollutant Discharge Elimination System (NPDES) permit administered by the Environmental Protection Agency. Other chemicals are discharged in accordance with manufacturer instructions. The NPDES permit also requires regular monitoring of settleable and unsettleable solids, temperature, and dissolved oxygen in the hatchery effluent to ensure compliance with environmental standards and to prevent fish mortality.

In contrast to infectious diseases, which typically are manifest by a limited number of life stages and over a protracted time period, non-infectious diseases caused by environmental factors typically affect all life stages of fish indiscriminately and over a relatively short time period. Because of the vast literature available on rearing of salmon and trout in aquaculture, one group of non-infectious diseases that are expected to occur rarely in current hatchery operations are those caused by nutritional deficiencies

1.3.4. Ecological Modeling

While competition, predation, and disease are important effects to consider, they are events which can rarely, if ever, be observed and directly measured. However, these behaviors have been established to the point where NMFS can model these potential effects to the species based on known factors that lead to competition or predation occurring. In our Biological Opinions, we use the Predation, Competition, and Delayed Mortality (PCD) Risk model version 4.1.0 based on Pearsons and Busack (2012). PCD Risk is an individual-based model that simulates the potential number of ESA-listed natural-origin juveniles lost to competition, predation, and delayed mortality (from disease, starvation, etc.) due to the release of hatchery-origin juveniles in the freshwater environment.

The PCD Risk model has undergone considerable modification since 2012 to increase supportability, reliability, transparency, and ease of use. Notably, the current version no longer operates as a compiled FORTRAN program in a Windows environment. The current version of the PCD Risk model (Version 4.1.0) is an R package (R Core Team 2019). A macro-enabled Excel workbook is included as an interface to the model that is used as a template for creating model scenarios, running the model, and reporting results. Users with knowledge of the R programming language have flexibility to develop and run more complex scenarios than can be created by the Excel template. The current model version no longer has a probabilistic mode for defining input parameter values. We also further refined the model by allowing for multiple hatchery release groups of the same species to be included in a single run.

There have also been a few recent modifications to the logic and parameterization of the model. The first was the elimination of competition equivalents and replacement of the disease function with a delayed mortality parameter. The rationale behind this change was to make the model more realistic; competition rarely directly results in death in the model because it takes many competitive interactions to suffer enough weight loss to kill a fish. Weight loss is how adverse competitive interactions are captured in the model. However, fish that lose competitive interactions and suffer some degree of weight loss are likely more vulnerable to mortality from other factors such as disease or predation by other fauna such as birds or bull trout. Now, at the end of each run, the competitive impacts for each fish are assessed, and the fish has a probability of delayed mortality based on the competitive impacts. This function will be subject to refinement based on research. For now, the probability of delayed mortality is equal to the proportion of a fish's weight loss. For example, if a fish has lost 10% of its body weight due to competition and a 50% weight loss kills a fish, then it has a 20% probability of delayed death, (0.2 = 0.1/0.5).

Another change in logic was to the habitat segregation parameter to make it size-independent or size-dependent based on hatchery species. Some species, such as coho salmon, are more aggressive competitors than other species, such as chum and sockeye salmon. To represent this difference in behavior more accurately in the model, for less aggressive species such as chum and sockeye salmon, hatchery fish segregation is random, whereas for more aggressive species, segregation occurs based on size, with the largest fish eliminated from the model preferentially.

1.3.5. Acclimation

One factor that can affect hatchery fish distribution and the potential to spatially overlap with natural-origin spawners, and thus the potential for genetic and ecological impacts, is the acclimation (the process of allowing fish to adjust to the environment in which they will be released) of hatchery juveniles before release. Acclimation of hatchery juveniles before release increases the probability that hatchery adults will home back to the release location, reducing their potential to stray into natural spawning areas.

Acclimating fish for a time also allows them to recover from the stress caused by the transportation of the fish to the release location and by handling. Dittman and Quinn (2008) provide an extensive literature review and introduction to homing of Pacific salmon. They note that, as early as the 19th century, marking studies had shown that salmonids would home to the stream, or even the specific reach, where they originated. The ability to home to their home or "natal" stream is thought to be due to odors to which the juvenile salmonids were exposed while living in the stream (olfactory imprinting) and migrating from it years earlier (Dittman and Quinn 2008; Keefer and Caudill 2014). Fisheries managers use this innate ability of salmon and steelhead to home to specific streams by using acclimation ponds to support the reintroduction of species into newly accessible habitat or into areas where they have been extirpated (Quinn 1997; Dunnigan 1999; YKFP 2008).

Dittman and Quinn (2008) reference numerous experiments that indicated that a critical period for olfactory imprinting is during the parr-smolt transformation, which is the period when the salmonids go through changes in physiology, morphology, and behavior in preparation for transitioning from fresh water to the ocean (Hoar 1976; Beckman et al. 2000). Salmon species with more complex life histories (e.g., sockeye salmon) may imprint at multiple times from emergence to early migration (Dittman et al. 2010). Imprinting to a particular location, be it the hatchery, or an acclimation pond, through the acclimation and release of hatchery salmon and steelhead is employed by fisheries managers with the goal that the hatchery fish released from these locations will return to that particular site and not stray into other areas (Fulton and Pearson 1981; Quinn 1997; Hard and Heard 1999; Bentzen et al. 2001; Kostow 2009; Westley et al. 2013). However, this strategy may result in varying levels of success in regards to the proportion of the returning fish that stray outside of their natal stream. (e.g., (Kenaston et al. 2001; Clarke et al. 2011).

Increasing the likelihood that hatchery salmon and steelhead home to a particular location is one measure that can be taken to reduce the proportion of hatchery fish in the naturally spawning population. When the hatchery fish home to a particular location, those fish can be removed (e.g., through fisheries, use of a weir) or they can be isolated from primary spawning areas. Factors that can affect the success of acclimation as a tool to improve homing include:

- Timing acclimation so that a majority of the hatchery juveniles are going through the parr-smolt transformation during acclimation
- A water source distinct enough to attract returning adults

- Whether hatchery fish can access the stream reach where they were released
- Whether the water quantity and quality are such that returning hatchery fish will hold in that area before removal and/or their harvest in fisheries.

1.4. Factor 4. Research, monitoring, and evaluation that exists because of the hatchery program

NMFS also analyzes proposed research, monitoring, and evaluation (RM&E) for its effects on listed species and on designated critical habitat. Negative effects from RM&E are weighed against the value of new information, particularly information that tests key assumptions and that reduces uncertainty. RM&E actions that can cause harmful changes in behavior and reduced survival include, but are not limited to:

- Observation during surveying (in-water or from the bank)
- Collecting and handling (purposeful or inadvertent)
- Sampling (e.g., the removal of scales and tissues)
- Tagging and fin-clipping, and observing the fish (in-water or from the bank)

NMFS also considers the overall effectiveness of the RM&E program. There are five factors that we take into account when it assesses the beneficial and negative effects of hatchery RM&E:

- Status of the affected species and effects of the proposed RM&E on the species and on designated critical habitat
- Critical uncertainties concerning effects on the species
- Performance monitoring to determine the effectiveness of the hatchery program at achieving its goals and objectives
- Identifying and quantifying collateral effects
- Tracking compliance of the hatchery program with the terms and conditions for implementing the program.

After assessing the proposed hatchery RM&E, and before it makes any recommendations to the action agency(s) NMFS considers the benefit or usefulness of new or additional information, whether the desired information is available from another source, the effects on ESA-listed species, and cost.

1.4.1. Observing/Harassing

For some activities, listed fish are observed in-water (e.g., by snorkel surveys, wading surveys, or observation from the banks). Direct observation is the least disruptive method for determining a species' presence/absence and estimating its relative numbers. Effects of direct observation are also generally the shortest-lived and least harmful of the research activities discussed in this section because a cautious observer can effectively obtain data while only slightly disrupting fish behavior.

Fish frightened by the turbulence and sound created by observers are likely to seek temporary refuge in deeper water, or behind/under rocks or vegetation. In extreme cases, some individuals may leave a particular pool or habitat type and then return when observers leave the area. These avoidance behaviors are expected to be in the range of normal predator and disturbance behaviors.

1.4.2. Capturing/handling

Any physical handling or psychological disturbance is known to be stressful to fish (Sharpe et al. 1998). Primary contributing factors to stress and death from handling are excessive doses of anesthetic, differences in water temperatures (between the river and holding vessel), dissolved oxygen conditions, the amount of time fish are held out of the water, and physical trauma. Stress increases rapidly if the water temperature exceeds 18ºC or dissolved oxygen is below saturation. Fish transferred to holding tanks can experience trauma if care is not taken in the transfer process, and fish can experience stress and injury from overcrowding in traps if the traps are not emptied regularly. Decreased survival can result from high stress levels, and may also increase the potential for vulnerability to subsequent challenges (Sharpe et al. 1998).

NMFS has developed general guidelines to reduce impacts when collecting listed adult and juvenile salmonids (NMFS 2000b; 2008a) that have been incorporated as terms and conditions into section 7 opinions and section 10 permits for research and enhancement. Additional monitoring principles for supplementation programs have been developed by Galbreath et al. (2008).

1.4.3. Fin clipping and tagging

Many studies have examined the effects of fin clips on fish growth, survival, and behavior. Although the results of these studies vary somewhat, it appears that generally fin clips do not alter fish growth (Brynildson and Brynildson 1967; Gjerde and Refstie 1988). Mortality among fin-clipped fish is variable, but can be as high as 80 percent (Nicola and Cordone 1973). In some cases, though, no significant difference in mortality was found between clipped and un-clipped fish (Gjerde and Refstie 1988; Vincent-Lang 1993). The mortality rate typically depends on which fin is clipped. Recovery rates are generally higher for adipose- and pelvic-fin-clipped fish than for those that have clipped pectoral, dorsal, or anal fins (Nicola and Cordone 1973), probably because the adipose and pelvic fins are not as important as other fins for movement or balance (McNeil and Crossman 1979). However, some work has shown that fish without an adipose fin may have a more difficult time swimming through turbulent water (Reimchen and Temple 2003; Buckland-Nicks et al. 2011).

In addition to fin clipping, two commonly available tags are available to differentially mark fish: passive integrated transponder (PIT) tags, and coded-wire tags (CWTs). PIT tags consist of small radio transponders that transmit an ID number when interrogated by a reader device.[21] CWTs are small pieces of wire that are detected magnetically and may contain codes[22] that can be read visually once the tag is excised from the fish.

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[21] The same technology, more commonly called RFID (radio frequency identification), is widely used in inventory control and to tag pets.

[22] Tags without codes are called blank wire tags (BWTs).

PIT tags are inserted into the body cavity of the fish just in front of the pelvic girdle. The tagging procedure requires that the fish be captured and extensively handled. Thus, tagging needs to take place where there is cold water of high quality, a carefully controlled environment for administering anesthesia, sanitary conditions, quality control checking, and a recovery tank.

Most studies have concluded that PIT tags generally have very little effect on growth, mortality, or behavior. Early studies of PIT tags showed no long-term effect on growth or survival (Prentice and Park 1984; Prentice et al. 1987; Rondorf and Miller 1994). In a study between the tailraces of Lower Granite and McNary Dams (225 km), Hockersmith et al. (2000) concluded that the performance of yearling Chinook salmon was not adversely affected by orally or surgically implanted sham radio tags or PIT tags. However, (Knudsen et al. 2009) found that, over several brood years, PIT tag induced smolt-adult mortality in Yakima River spring Chinook salmon averaged 10.3 percent and was at times as high as 33.3 percent.

CWTs are made of magnetized, stainless-steel wire and are injected into the nasal cartilage of a salmon and thus cause little direct tissue damage (Bergman et al. 1968; Bordner et al. 1990). The conditions under which CWTs should be inserted are similar to those required for PIT tags. A major advantage to using CWTs is that they have a negligible effect on the biological condition or response of tagged salmon (Vander Haegen et al. 2005); however, if the tag is placed too deeply in the snout of a fish, it may kill the fish, reduce its growth, or damage olfactory tissue (Fletcher et al. 1987; Peltz and Miller 1990). This latter effect can create problems for species like salmon because they use olfactory clues to guide their spawning migrations (Morrison and Zajac 1987).

Mortality from tagging is both acute (occurring during or soon after tagging) and delayed (occurring long after the fish have been released into the environment). Acute mortality is caused by trauma induced during capture, tagging, and release—it can be reduced by handling fish as gently as possible. Delayed mortality occurs if the tag or the tagging procedure harms the animal. Tags may cause wounds that do not heal properly, may make swimming more difficult, or may make tagged animals more vulnerable to predation (Howe and Hoyt 1982; Matthews and Reavis 1990; Moring 1990). Tagging may also reduce fish growth by increasing the energetic costs of swimming and maintaining balance.

1.4.4. Masking

Hatchery actions also must be assessed for risk caused by masking effects, defined as when hatchery fish included in the Proposed Action are not distinguishable from other fish. Masking undermines and confuses RM&E, and status and trends monitoring. Both adult and juvenile hatchery fish can have masking effects. When presented with a proposed hatchery action, NMFS analyzes the nature and level of uncertainties caused by masking, and whether and to what extent listed salmon and steelhead are at increased risk as a result of misidentification in status evaluations. The analysis also takes into account the role of the affected salmon and steelhead population(s) in recovery and whether unidentifiable hatchery fish compromise important RM&E.

1.5. Factor 5. Construction, operation, and maintenance, of facilities that exist because of the hatchery program

The construction/installation, operation, and maintenance of hatchery facilities can alter fish behavior and can injure or kill eggs, juveniles, and adults. These actions can also degrade habitat function and reduce or block access to spawning and rearing habitats altogether. Here, NMFS analyzes changes to: riparian habitat, channel morphology, habitat complexity, in-stream substrates, and water quantity and quality attributable to operation, maintenance, and construction activities. NMFS also confirms whether water diversions and fish passage facilities are constructed and operated consistent with NMFS criteria.

1.6. Factor 6. Fisheries that exist because of the hatchery program

There are two aspects of fisheries that are potentially relevant to NMFS' analysis:

1) Fisheries that would not exist but for the program that is the subject of the Proposed Action, and listed species are inadvertently and incidentally taken in those fisheries.
2) Fisheries that are used as a tool to prevent the hatchery fish associated with the HGMP, including hatchery fish included in an ESA-listed salmon ESU or steelhead DPS, from spawning naturally.

"Many hatchery programs are capable of producing more fish than are immediately useful in the conservation and recovery of an ESU and can play an important role in fulfilling trust and treaty obligations with regard to harvest of some Pacific salmon and steelhead populations. For ESUs listed as threatened, NMFS will, where appropriate, exercise its authority under section 4(d) of the ESA to allow the harvest of listed hatchery fish that are surplus to the conservation and recovery needs of the ESU, in accordance with approved harvest plans" (NMFS 2005c). In any event, fisheries must be carefully evaluated and monitored based on the take, including catch and release effects, of ESA-listed species.