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 Four Hatchery and Genetic Management Plans for Salmon in the Stillaguamish River basin under Limit 6 of the Endangered Species Act Section 4(d) Rule

NMFS Consultation Number: WCR-2018-8876

Action Agencies: National Marine Fisheries Service (NMFS) Bureau of Indian Affairs (BIA)

Affected Species and Determinations:

ESA-Listed Species	Status	Is the Action Likely to Adversely Affect Species or Critical Habitat?	Is the Action Likely To Jeopardize the Species?	Is the Action Likely To Destroy or Adversely Modify Critical Habitat?
Puget Sound steelhead (*Oncorhynchus mykiss*)	Threatened	Yes	No	No
Puget Sound Chinook salmon (*O. tshawytscha*)	Threatened	Yes	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, Sustainable Fisheries Division

Issued By:

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Date: **June 20, 2019**

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1. INTRODUCTION

This document describes the anticipated effects of operating hatchery programs rearing and releasing salmon in the Stillaguamish River watershed, as described in four Hatchery and Genetic Management Plans (HGMPs). The programs release Chinook, coho, and fall chum salmon; the releases occur in habitat for Chinook salmon and steelhead listed under the Endangered Species Act (ESA).

The National Marine Fisheries Service (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 2008a). The operation and management of every hatchery program is unique in time, and specific to an identifiable stock and its native habitat (Flagg et al. 2004). NMFS defines integrated hatchery programs as those that are reproductively connected or "integrated" with a natural population, promote natural selection over selection in the hatchery, contain genetic resources that represent the ecological and genetic diversity of a species, and are included in a salmon ESU or steelhead DPS. When a hatchery program actively maintains distinctions or promotes differentiation between hatchery fish and fish from a native population, then NMFS refers to the program as "isolated." They promote domestication or selection in the hatchery over selection in the wild and culture a stock of fish with different phenotypes (e.g., different ocean migrations and spatial and temporal spawning distribution) compared to the natural population.

The Proposed Actions are:

(1) the National Marine Fisheries Service's (NMFS) determination under limit 6 (50 CFR § 223.203(b)(6)) of the Endangered Species Act (ESA) 4(d) rule for ESA-listed Puget Sound steelhead and ESA-listed Puget Sound Chinook salmon concerning the Stillaguamish Tribe of Indians' (STI) four salmon hatchery programs in the Stillaguamish River watershed and,

(2) the Bureau of Indian Affairs' (BIA) ongoing disbursement of funds for operation and maintenance of the tribal hatchery programs listed in Table 1.

The Stillaguamish Tribe of Indians proposes to operate four hatchery programs that release Chinook, coho, and fall chum salmon into the Stillaguamish River basin (Table 1). Chinook salmon propagated through the Stillaguamish hatchery programs are included as part of the ESA-listed Puget Sound Chinook Salmon ESU (70 FR 37160, June 28, 2005; 71 FR 20802, April 14, 2014). Chinook salmon are affected by the proposed action in a number of ways as discussed below; steelhead are primarily affected because the hatchery salmon are being released into, and return to, steelhead habitat. Coho and fall chum salmon produced through these programs are not part of species listed under the ESA. As described in section 1.8 of the Hatchery and Genetic Management Plans (Stillaguamish Tribe of Indians 2015; Stillaguamish Tribe of Indians 2016; Stillaguamish Tribe of Indians 2017a; Stillaguamish Tribe of Indians 2017b), all four of the hatchery programs are operated for conservation purposes. All four of these salmon programs are operated as integrated[1] programs. Fish produced through these integrated programs are

[1] These terms are defined in Section 2.4.1.

derived from stocks native to the Stillaguamish River watershed, and are reproductively integrated with the natural Chinook, chum, and coho salmon populations.

The underlying activities that drive the Proposed Actions by the federal agencies (see Section 1.3) are the operation and maintenance of four hatchery programs' rearing and releasing Stillaguamish River salmon in the Stillaguamish River watershed. Because the actions of the federal agencies are subsumed within the effects of the hatchery program operation, the details of each hatchery program are summarized in Section 1.3 of this biological opinion based on a HGMP, which was submitted to NMFS for review.

Collectively, NMFS and the BIA are the "Action Agencies," NMFS because of its proposed determination on the plans and the BIA because of its funding of the programs (see section 1.3, below). Pursuant to the letter received by NMFS from the BIA, NMFS is the designated lead agency for this consultation (BIA 2017a; BIA 2017b).

Table 1. Programs included in the Proposed Action under Section 7 and the Limit 6 of the 4(d) rule.

Program	HGMP Receipt	Program Operator*	Funding Agency	Program Type and Purpose
Stillaguamish Summer Chinook	June 23, 2017	STI	BIA	Integrated Recovery
Stillaguamish Fall Chinook	June 23, 2017	STI	PST[†], BIA	Integrated Recovery
Stillaguamish Coho	December 17, 2015	STI	BIA	Integrated Recovery
Stillaguamish Fall Chum	July 26, 2016	STI	BIA	Integrated Recovery

*Primary operators are listed, but all programs are coordinated with the Washington Department of Fish and Wildlife (WDFW).

[†]This program receives funding through the Pacific Salmon Treaty as part of the Puget Sound Critical Stock Program.

1.1. Background

NMFS prepared the Biological Opinion (opinion) and incidental take statement (ITS) portions of this document in accordance with section 7(b) of the ESA of 1973, as amended (16 U.S.C. 1531, et seq.), and implementing regulations at 50 CFR part 402. The opinion documents consultation on the action proposed by NMFS and the BIA.

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 (section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001, Public Law 106-554). The document will be available through the NOAA Institutional Repository (https://repository.library.noaa.gov/) approximately two weeks after signature. A complete record of this consultation is on file at the Sustainable Fisheries Division (SFD) of NMFS in Lacey, Washington.

1.2. Consultation History

The approach to, and conduct of, hatchery consultations in Puget Sound has been developed and refined since the ESA-listing of the Puget Sound Chinook Salmon ESU (64 FR 14308, March 24, 1999). Initially, the goal was to collect all the HGMPs proposed for implementation in Puget Sound by the Puget Sound Tribes and the Washington Department of Fish and Wildlife (WDFW) (hereafter, the "co-managers"), at that time totaling 114 HGMPs region-wide, and bundle them into two Resource Management Plans (RMP) for ESA consultation purposes. To meet National Environmental Policy Act (NEPA) requirements associated with NMFS's 4(d) determinations on the two RMPs, a draft Environmental Impact Statement (the "Puget Sound Hatcheries Draft EIS") was prepared to disclose the environmental effects of the proposed RMPs encompassing all Puget Sound region hatchery programs, and of alternative hatchery operation scenarios, including an alternative evaluating impacts if all hatchery programs were terminated (NMFS 2016b).

As the Puget Sound Hatcheries draft EIS was being prepared, the co-managers continued to update and make important changes in their hatchery operations, leading to revisions in the HGMPs originally submitted to NMFS. The revised HGMPs were then submitted in updated form for NMFS's consideration, supplanting the HGMPs and RMPs reviewed in the completed Puget Sound Hatcheries draft EIS.

After reviewing the pros and cons of analyzing all Puget Sound region HGMPs proposed by the co-managers in a single document, and considering public comments that NMFS received on the Puget Sound Hatcheries Draft EIS, NMFS decided to withdraw the Draft EIS (80 FR 15986, March 26, 2015). The process to review all Puget Sound region HGMPs through a single process was replaced with an approach whereby NEPA and ESA review to evaluate effects of the updated, resubmitted HGMPs would be conducted in bundles generally organized on a watershed basis. Under this watershed-scale approach, NMFS will evaluate the effects of hatchery programs that are unique to each watershed, including whether the programs address ESA 4(d) rule criteria for hatchery actions. Although the document has been withdrawn, relevant information and analysis included in Puget Sound Hatcheries Draft EIS, along with public comments received on the document, will continue to be considered by NMFS in subsequent NEPA reviews of the watershed-specific HGMPs.

Among the Puget Sound region HGMPs that have been submitted for NMFS' consideration under the ESA are four plans developed by the Stillaguamish Tribe of Indians and WDFW describing hatchery programs for Chinook salmon, coho salmon, and fall chum salmon in the

Stillaguamish River watershed. On September 17, 2015, NMFS received two HGMPs: one for the Harvey Creek Hatchery summer Chinook salmon and one for the Brenner Creek Hatchery fall Chinook salmon programs, with a request to process these HGMPs under limit 6 of the 4(d) rule as a joint co-manager plan. The Stillaguamish Tribe of Indians subsequently submitted two additional HGMPs for review under 4(d) rule, limit 6, one on December 17, 2015, describing a program for coho salmon, and one on July 26, 2016, describing a program for fall chum salmon (Stillaguamish Tribe of Indians 2015; Stillaguamish Tribe of Indians 2016). The Harvey Creek Hatchery summer Chinook salmon and Brenner Creek Hatchery fall Chinook salmon HGMPs were revised and resubmitted on June 23, 2017. This biological opinion is based on information provided in these four HGMPs (Stillaguamish Tribe of Indians 2015; Stillaguamish Tribe of Indians 2016; Stillaguamish Tribe of Indians 2017a; Stillaguamish Tribe of Indians 2017b).

1.3. Proposed Federal Action

"Action" means all activities, of any kind, authorized, funded, or carried out, in whole or in part, by Federal agencies (50 CFR 402.02). For EFH consultation, "Federal action" means any action authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken by a Federal Agency (50 CFR 600.910).

Typically, funding a program results in effects that are identical to the operation of the program. Therefore, unless otherwise stated, for the purposes of this Opinion, we will focus on the effects of operating the programs. However, it should be understood that those effects are ultimately attributable to both of the above-listed proposed actions.

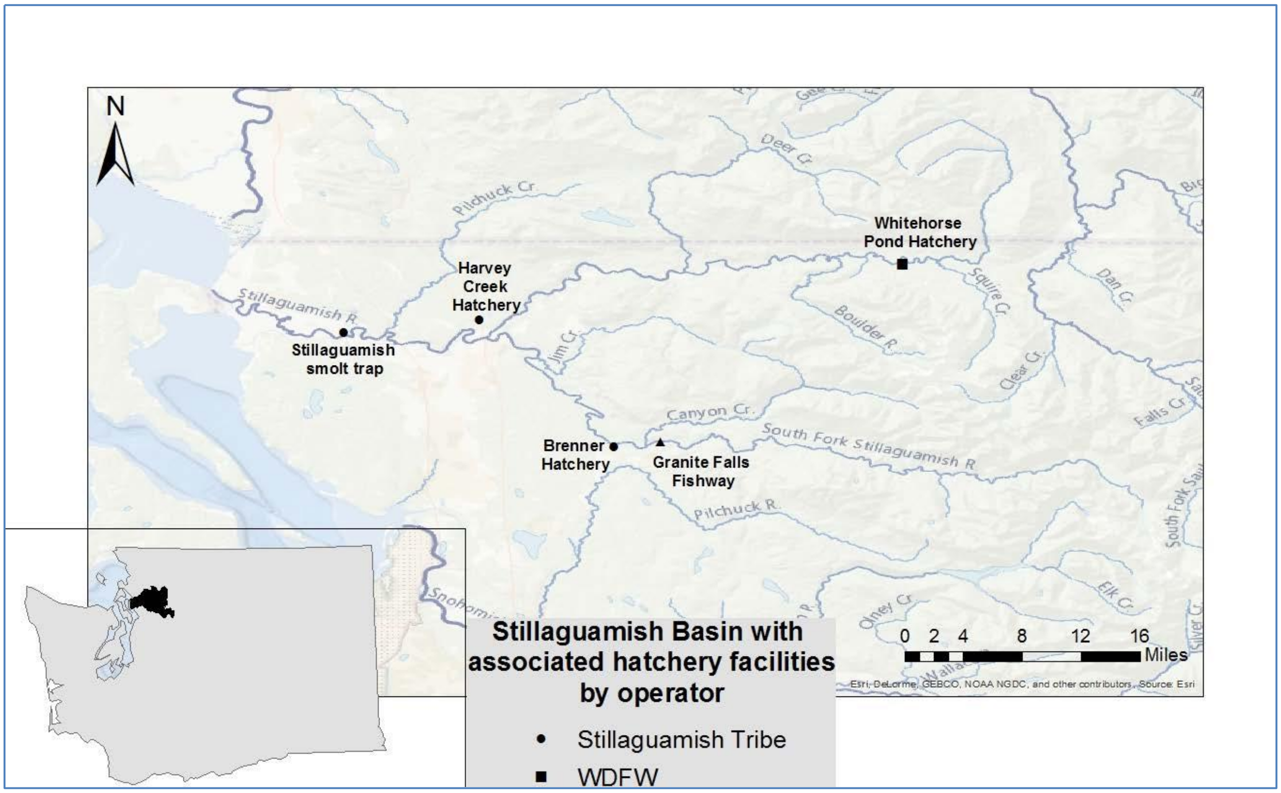

Figure 1. Location of facilities used in the Proposed Action.

1.3.1. Proposed hatchery broodstock collection and mating

Broodstock collection details and associated activities are described below in Table 2.

Table 2. Broodstock collection plans for the four Stillaguamish salmon hatchery programs.

Program	Origin[1]	Collection Location	Collection Method	Collection Number	Collection Duration	Proportion of Natural-Origin Brood (pNOB)	Spawning Approach[6]
North Fork Summer Chinook	Stillaguamish Summer	North Fork Stillaguamish River confluence of the mainstem (RM 0) and the mouth of Squire Creek (31.1)	Seining holding pools in the river	65 pairs, up to 150 adults total[3]	July – September[2]	The expected pNOB will represent the composition of the run at large in the river. Average over last twelve years of operations was 52 percent (range 32-65)	Pairwise (1:1) with use of a backup male
South Fork Fall Chinook	Stillaguamish Fall	South Fork Stillaguamish River confluence of the mainstem (RM 17.8) to the anadromous barrier of Granite Falls (RM 34.5)[7]	Seining river eddies[7]	900 smolts[4]	March-July	100 percent (smolts into captive brood). Use of acquired fall adults[3]	Pairwise (1:1) with use of a backup male
Fall Coho	Stillaguamish River	Fortson Creek, North Fork Stillaguamish River	Temporary box trap/Permanent fish ladder/adult holding pond	60 pairs	Late-October through mid-November	Up to 100 percent, 10-20% of broodstock has been hatchery-origin	Pairwise (1:1) with use of a backup male
Fall Chum	Stillaguamish River	North Fork Stillaguamish River (RM 15.3) at Harvey Creek Hatchery	Temporarily installed V trap	300 pairs	Mid-October through November	Mixture - pNOB > 2X Proportion of Hatchery-Origin Spawners (pHOS)[5]	Pairwise (1:1) with a backup male

[1] The PSTRT indicated there were two Chinook salmon populations in the Stillaguamish River, a North Fork and a South Fork population (Ruckelshaus et al. 2006). Subsequent genetic analyses of Chinook salmon collected in the Stillaguamish River indicate presence of both a unique summer and a unique fall run of Chinook, co-occurring in both forks of the river (Small et al. 2017a; Small et al. 2016; Stillaguamish Tribe of Indians 2017a; Stillaguamish Tribe of Indians 2017b).

[2] The operators end all adult broodstocking operations at noon daily to avoid warm water temperatures that may cause an increased stress response during pre-spawn holding and transport to the hatchery facilities.

[3] Adult broodstocking for both the summer and fall run programs takes place in the North Fork Stillaguamish River. Fish are genetically assigned to the summer or fall populations. Up to 30 adults annually might be genetically identified as belonging to the fall run, so the total adult removal includes the number of anticipated adult captures for the NF Stillaguamish summer-run chinook salmon program. Prioritizes natural-origin returns over hatchery-origin returns. Selected by maturation timing and necessity to equalize the sex ratio. Anadromous returning fall females are used, regardless of mark type due to the higher fecundity than captive brood reared females, per email and MS Excel file from Kate Konoski, STI, on May 15, 2018 (Konoski 2018).

[4] Smolts collected for the captive brood portion of the fall Chinook program are genetically assigned at the >90 percent likelihood. Smolts that assign as less than this threshold are released back into the river. The estimated proportion of fall assignment has been 50 percent of the smolts captured, so the intake goal is 450 fall run smolts, per email from Kate Konoski, STI, on May 15, 2018 (Konoski 2018).
[5] pNOB > 2X pHOS from ratio of natural escapement estimated by WDFW stream surveys to rack returns. Entire rack returns will be treated as part of pHOS as a conservative approach. PNI standard > 0.66 (Stillaguamish Tribe of Indians 2016). pHOS, pNOB and PNI are defined and discussed further in Section 2.4.1.2.
[6] Initial five-by-five spawning protocols were described in the submitted Chinook HGMPs (Stillaguamish Tribe of Indians 2017a; Stillaguamish Tribe of Indians 2017b). The spawning protocols for the Chinook programs were updated via personal communication with Kate Konoski, STI on October 2, 2017, to a one-to-one spawning protocol with the use of a backup male.
[7] Upon installation, anticipated fall of 2019, a temporary box V trap at Brenner Creek Hatchery will also be used to collect adult fall Chinook for broodstock.

Weirs and Traps

Currently, there are no weirs used for any of the four salmon hatchery programs. At Harvey Creek Hatchery, a ladder trap is opened annually from October-November for chum broodstock collection, with fish checked daily. At Fortson Creek mill pond fish ladder outlet, a temporary box trap is used to collect coho from October to January, with fish checked daily.

Planned 2018/2019 Trap Construction (Off-site) and Installation at Brenner Creek Hatchery

Plans for installing a temporary box V trap with the intent to collect Chinook salmon adult broodstock at Brenner Creek Hatchery have been drafted. Off-site construction and installation are anticipated to occur in order to begin trapping in the fall of 2019. The V trap will be installed over one day into either the lowest hatchery pond, or at the mouth of Brenner Creek. The V trap will be a stand-alone install, using a large excavator for placement. Trapping and installation is anticipated to occur in Mid-September of 2019, with trap removal in mid-November. As this is the first year of trap installation/operation, installation timing will depend on gathering of additional information, such as understanding of flows during this time, and expected entry timing of fall Chinook salmon for the 2019/2020 season.

1.3.2. Proposed hatchery egg incubation and juvenile release

The proposed procedures and goals for egg collection, incubation, rearing and release locations are summarized below in Table 3.

Table 3. Proposed annual release protocols for each program. CWT = coded-wire tag.

Program	Life Stage, Size and Number Released	Marking	Egg Incubation Location	Rearing Location	Acclimation Site; Duration	Volitional Release?	Release Location	Release Time
North Fork Summer Chinook	220,000 subyearlings; 90 fpp	100% ad clip; 100% CWT	Harvey Creek Hatchery	Harvey Creek Hatchery	Whitehorse Hatchery; 3-7 weeks	Yes	North Fork Stillaguamish River	April-June
South Fork Fall Chinook	Up to 200,000 subyearlings; 90 fpp	100% ad clip; 100% CWT	Brenner Creek Hatchery	Brenner Creek Hatchery	Brenner Creek Hatchery, egg to smolt	Yes	South Fork Stillaguamish River	April-June
Coho	60,000 yearlings; 18-20 fpp[1]	100% ad clip; 100% CWT	Harvey Creek Hatchery	Harvey Creek Hatchery	Harvey Creek Hatchery, egg to smolt	Yes	North Fork Stillaguamish River	April-June
Fall Chum	250,000 fry, 350-400 fpp	Unmarked	Harvey Creek Hatchery	Harvey Creek Hatchery	Harvey Creek Hatchery, egg to fry	Yes	North Fork Stillaguamish River	April - May
	50,000 eyed eggs	Unmarked	Church Creek	Harvey Creek Hatchery	Church Creek	No	Church Creek, Mainstem Stillaguamish Tributary	March

[1]Limited fry plants may occur in watershed tributaries by co-manager agreement (Stillaguamish Tribe of Indians 2016).

1.3.3. Fish Health Procedures

Fish health staff monitor the fish throughout their rearing cycle for signs of disease. Mortalities are checked daily and live samples are taken monthly. Fish are also tested prior to transfer to acclimation sites and before release. Sampling, testing, and treatment/control procedures are outlined in multiple documents (IHOT 1995; NWIFC and WDFW 2006; PNFHPC 1989).

Preventative care is also promoted through routine juvenile fish health monitoring. Northwest Indian Fisheries Commission (NWIFC) Pathologists conduct fish health exams at each of the tribal hatcheries on a monthly basis for all juveniles until they are released as smolts. Monthly monitoring exams include an evaluation of rearing conditions, as well as lethal sampling of small numbers of juvenile fish to assess the health status of the population and to detect pathogens of concern. Results are reported to hatchery managers along with any recommendations for improving or maintaining fish health. Vaccines may be used when appropriate to prevent the onset of two bacterial diseases (vibriosis or enteric redmouth disease (ERM), *Yersinia ruckerii*). In the event of disease epizootics or elevated mortality in a stock, fish pathologists are available to diagnose problems and provide treatment recommendations. Pathologists work with hatchery crews to ensure the proper use of drugs and chemicals for treatment. The entire health history for each hatchery release is stored in the AquaDoc database at the Northwest Indian Fisheries Commission.

Adult Chinook salmon seined from the North Fork Stillaguamish for broodstock are transferred to Harvey Creek Hatchery in a fish transport truck at low densities, and in water infused with oxygen. Fish health maintenance practices are applied during pre-spawn holding, including formalin treatments to control *Saprolegnia,* and antibiotic injections to reduce disease out-breaks reduce loss levels for Chinook salmon held at Harvey Creek Hatchery until spawn. Broodstock are tested for viral and bacterial pathogens. Female Chinook salmon entering the collection facility may be injected when they first arrive against bacterial diseases and prevention of vertical transmission. A broad-spectrum antibiotic is injected into all Chinook salmon during handling to treat furunculosis and columnaris (other typical diseases in salmonids). Adults are anesthetized prior to handling and injecting to reduce stress, and Poly Aqua added to help replace slime loss.
Juvenile Chinook and coho will be vaccinated against ERM and vibriosis at approximately 200 fpp, using the immersion method at the time of coded wire tag (CWT) application.

BKD testing occurs for the coho program, and strongly BKD positive eggs are culled.

For chum salmon, a NWIFC fish pathologist monitors fish health on a regular basis, with adult females sampled for disease. Rearing water is treated with formalin on a regular basis to control external fungus, with additional antibiotic injections given if conditions warrant.

1.3.4. Proposed adult management

Hatchery-origin returns produced by the two Chinook salmon programs are intended to spawn naturally so there are no proportion of hatchery-origin spawners (pHOS) standards proposed for these two programs. Adults originating from these programs are only removed from the river if captured during broodstock collection. All natural- and hatchery-origin adults collected are genetically assigned to either the North Fork or South Fork Stillaguamish population and then used as broodstock for the program propagating that genetic population. Those fish identified through an analysis of genetics or coded wire tags as non-Stillaguamish stock are culled. These non-Stillaguamish Chinook salmon may be used for human consumption. Carcasses injected with antibiotics are either given to the local wildlife rehab center or disposed of in a landfill.

Adult non-ESA listed coho and chum salmon produced through the proposed Stillaguamish hatchery programs are also intended to spawn naturally; however, the chum program does have standards for ensuring that the proportion of natural-origin brood (pNOB) remains at greater than twice the proportion of hatchery-origin spawners (pHOS), and the coho program targets 100% pNOB however 10-20% of the broodstock may consist of hatchery-origin volunteers (Table 2). After the adult broodstock goal has been met for two these programs, coho returning to Fortson Creek are passed above the ladder and trap to migrate to the spawning grounds, and chum returning to Harvey Creek are prevented from entering the trap so they may migrate to the spawning grounds. Coho and chum salmon captured at traps and hatcheries surplus to broodstock needs will be passed upstream to spawn, used for human consumption (e.g., distributed to tribal elders), or used for in-stream nutrient enhancement. Carcasses injected with antibiotics are either given to the local wildlife rehab center or disposed of in a landfill.

1.3.5. Proposed research, monitoring, and evaluation

Research, monitoring and evaluation (RM&E) activities are described below in Table 4.

Table 4. Research, monitoring, and evaluation associated with the four salmon hatchery programs and any existing ESA coverage.

Activity	Associated Program	ESA Coverage
Monitor adult collection, numbers, origin, length, age, genetic samples, marks/tags, and return timing in river using small mesh nets, traps, and hatchery facilities	All	This Opinion
Monitor proportion of hatchery- and natural-origin fish in natural production areas and collect basic life history information (i.e., length, maturity, migration status, marks/tags, sex, aging, (via scale samples), genetic identity, and condition)	All	This Opinion
Operate rotary screw traps to estimate the abundance, timing, and age composition of naturally produced migrants, and to collect tissue samples for pedigree analysis to determine parentage of migrants in the Stillaguamish River.	Summer and Fall Stillaguamish Chinook salmon	NMFS 4(d) research permit (WA2002-231-20784)
Smolt-to-adult survival, outmigration timing, and in season run forecasts using CWT data	All	This Opinion
Within-hatchery monitoring of fish health and survival	All	This Opinion

1.3.6. Proposed operation, maintenance, and construction of hatchery facilities

All programs return water to the diverted creek or river (minus any leakage and evaporation) along with any groundwater discharge. Water withdrawal at all facilities is in accordance with state-issued water rights. All facilities that rear over 20,000 pounds of fish operate under National Pollutant Discharge Elimination System (NPDES) through a general permit (Permit number 300J) issued by the Washington Department of Ecology (WDOE) (Table 5).

Table 5. Facility details for those facilities that divert water for hatchery operations.

Facilities	Program(s)	Surface Water (cfs)	Ground Water (Spring or Well) (cfs)	Water Diversion Distance (km)	Surface water source	Discharge Location	Instream Structures	Meet NMFS Screening Criteria?	NPDES Permit
Harvey Creek Hatchery	NF Summer Chinook, coho and fall chum	0.10-0.45 (permitted for up to 0.93 cfs S1-2314CWRIS)	0.33 (well)	0.01	Harvey Creek	Harvey Creek	3: Stream adjacent holding pond w/ v-trap at outfall	Yes	Not Applicable[1]
Brenner Creek Hatchery	SF Fall Chinook	N/A (spring water only)	0.67 (spring only)	0.2[2]	Brenner Creek	Brenner Creek	2: Intake, outfall[4]	N/A[2]	Not Applicable[1]
Whitehorse Ponds	NF Summer Chinook	5.0 #S1-00825CWRIS	1.74 (well) #G1-28153C	0.2	Whitehorse Spring Creek	Whitehorse Spring Creek	3: Stream adjacent holding pond w/ v-trap at outfall	N/A[3]	WAG 13-3008[1,3]

[1] The facility rears a total poundage that is below the level that requires an NPDES permit from the WDOE.
[2] Water diverted from a non-fish bearing spring water source.
[3] Whitehorse Ponds Hatchery facility uses well and surface water. Surface and well water rights are approved through Washington State trust water right permits #S1-00825CWRIS and G1-28153C. Fish rearing at the Whitehorse Ponds facility is implemented consistent with NPDES permit number WAG 13-3008, issued by WDOE. The intake screens at the Whitehorse Spring facility are in compliance with state and federal guidelines (NMFS 1995; NMFS 1996), but do not meet the current anadromous salmonid passage facility design and screening criteria (NMFS 2011a). The Whitehorse Ponds Hatchery screen has not been identified for replacement at this time since ESA-listed fish do not utilize Whitehorse Spring Creek (WDFW 2014).
[4] Operators anticipate the installation and use of a V trap at Brenner Creek Hatchery in the fall of 2019

Routine Maintenance

Several routine maintenance activities occur in or near water that could impact fish in the area including: sediment/gravel removal/relocation from intake and/or outfall structures, pond cleaning, pump maintenance, debris removal from intake and outfall structures, and maintenance and stabilization of existing bank protection and at the intake diversions, fish ladders, and effluent outfall. All in-water maintenance activities considered "routine" for the purposes of this action will occur within existing structures or the footprint of areas that have already been impacted. When maintenance activities occur within water, they will comply with the following guidance:

- In-water work will:
  - Be done during the allowable freshwater work times established for each location, or comply with an approved variance of the allowable freshwater work times with the appropriate state agencies
  - Follow a pollution and erosion control plan that addresses equipment and material storage sites, fueling operations, staging areas, cement mortars and bonding agents, hazardous materials, spill containment and notification, and debris management
  - Cease if fish are observed in distress at any time as a result of the activities
  - Include notification of NMFS staff
- Equipment will:
  - Be inspected daily, and be free of leaks before leaving the vehicle staging area
  - Work above ordinary high water or in the dry whenever possible

- Be sized correctly for the work to be performed and have approved oils / lubricants when working below the ordinary high water mark
- Be cleaned and free of vegetation before they are brought to the site and prior to removal from the project area
- Be staged and fueled in appropriate areas 150 feet from any water body

1.4. Action Area

The "action area" means all areas to be affected directly or indirectly by the Proposed Action, and not merely the immediate area involved in the action (50 CFR 402.02). The action area resulting from this analysis includes the places within or immediately adjacent to the Stillaguamish River watershed where salmon originating from the proposed hatchery programs would migrate to, or potentially stray to, and spawn naturally (Figure 2). The action area includes locations where fish are captured, reared, and released, as well as areas where they may be monitored, or stray.

NMFS considered whether the marine areas of Puget Sound outside of the Stillaguamish River watershed and the ocean should be included in the Action Area. The potential concern is a relationship between hatchery production and density-dependent interactions affecting salmon growth and survival. However, NMFS has determined that, based on best available science, it is not possible to establish a connection between hatchery production on the scale anticipated in the Proposed Action and the marine areas outside of the Stillaguamish River watershed. In addition, the four programs considered in this opinion contribute less than 0.5 percent of the estimated 165 million salmon and steelhead hatchery fish produced annually in Puget Sound (Haggerty 2018). Therefore, it is unlikely that there would be detectible effects in the marine environment beyond the Stillaguamish River watershed that could be attributable to the proposed action.

Presence of Stillaguamish Program Fish in the Skagit and Snohomish Watersheds

NMFS considered whether the Skagit and Snohomish watersheds should be included in the action area based on CWT recoveries in these watersheds indicating the presence of fish released from the two Stillaguamish Chinook salmon hatchery programs considered here. Between the return years 2006-2015, approximately 200 Stillaguamish CWT's were recovered from the natural spawning grounds in the Skagit Basin, accounting for 0.16% of natural spawners. In other words, out of the 127,661 natural spawners in the Skagit basin over these recovery years, 0.16% were identified as releases from Stillaguamish Chinook salmon programs.

In the Snohomish basin over the same return years, approximately 41 North Fork Stillaguamish CWT's were recovered, 5 in the Skykomish and 36 in the Snoqualmie. Out of the 13,380 natural spawners in the Snohomish basin, these recoveries represent 0.2 and 3.35 percent, respectively. It is important to note that these estimates are highly accurate, as compared to other programs recovered in these basins, which are tagged at much lower rates. Stillaguamish releases are 100% adipose clipped and coded wire tagged prior to release.

Because Chinook salmon released from Stillaguamish hatchery programs compromise a very low percentage of the total escapement to the Skagit and Snohomish escapement, the potential effects of straying into these adjacent basins, and genetic risks to the adjacent Skagit and Snohomish PRA tier 1, 2 and 3 natural populations, as assessed, are not meaningful or measurable. Therefore, this Opinion is not considering the Skagit and Snohomish watersheds as part of the Action Area for its analysis and these watersheds will not be discussed further.

Figure 2. Puget Sound Watersheds Map. The action area for the current proposed action is the entire Stillaguamish watershed. Source: (Puget Sound Partnership 2018).

1.5. Interrelated and Interdependent Actions

Interrelated actions are those that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration (50 CFR 402.02).

NMFS has considered whether there are any interrelated or independent actions related to the four Stillaguamish River watershed hatchery programs that are subject to analysis in this opinion. The proposed hatchery salmon programs analyzed in this opinion contribute to regional fisheries outside of the Stillaguamish River watershed and marine terminal areas. Fisheries outside of the action area support values associated with Treaty-reserved fishing rights recognized by the Federal courts, support *U.S. v. Washington* (1974) harvest sharing agreements between tribal and non-Indian fisheries, and help to meet Pacific Salmon Treaty (PST) salmon harvest agreements with Canada. There are no directed fisheries for salmon produced by the four salmon hatchery programs. The PST salmon-directed marine area fisheries, which occur outside of the action area, would occur regardless of whether the proposed action continues, and are therefore not interrelated or interdependent with the proposed action. The 2017-18 marine fisheries were evaluated and authorized through a separate NMFS ESA consultation (NMFS 2017a). They were determined not likely to jeopardize the continued existence of the Puget Sound Chinook Salmon ESU, the Hood Canal Summer Chum Salmon ESU, or the Puget Sound Steelhead DPS, or adversely modify designated critical habitat for these listed species (NMFS 2017a). A new Puget Sound fishery management plan for 2018-19 was submitted to NMFS for Section 7 consultation in December 2017 (PSIT and WDFW 2017). Past effects of these fisheries are described in the environmental baseline section (Section 2.3); future effects are described in the discussion of effects of the action.

Based on this, NMFS has not identified any interrelated/interdependent activities for this proposed action.

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. Section 7(a)(2) of the ESA requires Federal agencies to consult with the USFWS, NMFS, or both, to ensure that their actions are not likely to jeopardize the continued existence of endangered or threatened species or adversely modify or destroy their designated critical habitat. Section 7(b)(3) requires at the conclusion of the consultation, the Service provide an opinion stating how the agencies' actions will affect listed species and their critical habitat. 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 non-discretionary reasonable and prudent measures (RPMs) to minimize such impacts.

2.1. Analytical Approach

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

CFR 402.02). Therefore, the jeopardy analysis considers both survival and recovery of the species.

This biological opinion relies on the definition of "destruction or adverse modification," which "means a direct or indirect alteration that appreciably diminishes the value of critical habitat for the conservation of a listed species. Such alterations may include, but are not limited to, those that alter the physical or biological features essential to the conservation of a species or that preclude or significantly delay development of such features" (50 CFR 402.02).

The designations of critical habitat for the species considered in this opinion use the terms primary constituent element (PCE) or essential features. The new critical habitat regulations (81 FR 7414, February 11, 2016) replace this term with physical or biological features (PBFs). The shift in terminology does not change the approach used in conducting a "destruction or adverse modification" analysis, which is the same regardless of whether the original designation identified PCEs, PBFs, or essential features. In this biological opinion, we use the term PBF to mean PCE or essential feature, as appropriate for the specific critical habitat.

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

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 "viable salmonid populations" (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." 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.

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 2.3 of this opinion.

Effects of the Proposed Action
Consider how the Proposed Action would affect the species' abundance, productivity, spatial structure, and diversity (VSP parameters) and the Proposed Action's effects on critical habitat features in Section 2.4.

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 2.5 of this opinion.

Integration and synthesis
Integration and synthesis occurs in Section 2.6 of this opinion. In this step, NMFS adds the effects of the Proposed Action (Section 2.4) to the status of ESA-protected populations in the Action Area under the environmental baseline (Section 2.3) and to cumulative effects (Section 2.5). 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 2.6, the opinion determines whether the proposed action is likely to jeopardize ESA protected species or destroy or adversely modify designated critical habitat in Section 2.7.

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 a Reasonable and Prudent Alternative (RPA) or RPAs to the proposed action in Section 2.8.

Other species in action area
ESA-listed anadromous salmonid species in the action area (see Section 1.4) are described in Table 6. The effects of take associated with implementation of Puget Sound region hatchery salmon and steelhead production on the Hood Canal Summer Chum salmon ESU were previously evaluated and authorized by NMFS through a separate ESA section 7 consultation process (NMFS 2002a). An Environmental Assessment and FONSI were completed as part of the 2002 NMFS summer chum salmon consultation (NMFS 2002b). Effects on this ESA-listed

species associated with implementation of the six salmon HGMPs will therefore not be discussed 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, and 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 affect on any additional species based on the very small proportion of Stillaguamish River watershed hatchery-origin salmon produced by the proposed action in the Salish Sea and Pacific Ocean areas where these ESA-listed species occur. Based on this, these species will not be addressed further in this opinion.

In analyzing the effects of the proposed actions on listed Puget Sound Chinook salmon 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 (NMFS 2006a) (Figure 3). NMFS applies the PRA in ESA consultations for actions affecting ESA-listed Chinook salmon in Puget Sound (e.g., (NMFS 2011b; NMFS 2015). 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 of the Stillaguamish Chinook salmon populations are classified through the approach as Tier 2 populations (NMFS 2010). The classification for these two Chinook salmon populations that may be affected by the proposed actions are considered in NMFS's analysis with other factors (Section 2.6.1) to derive conclusions regarding Stillaguamish River watershed salmon hatchery-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 and designated critical habitat that would be affected by the Proposed Action. Status of the species is the level of risk that the listed species face based on parameters considered in documents such as recovery plans, status reviews, and

ESA listing determinations. The species status section informs the description of the species' likelihood of both survival and recovery. The species status section also helps to inform the description of the species' current "reproduction, numbers, or distribution" for jeopardy determination. The opinion also examines the condition of critical habitat in the designated area, evaluates the conservation value of the various watersheds and coastal and marine environments that make up the designated area, and discusses the current function of the essential PBFs that help to form that conservation value.

"Species" Definition: The ESA defines "species" to include "any distinct population segment (DPS) of any species of vertebrate fish or wildlife which interbreeds when mature" (16 U.S.C. 1532(16)). 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.

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 "viable salmonid population" (VSP) criteria therefore encompass the species' "reproduction, numbers, or distribution" needed to make a jeopardy determination. 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.

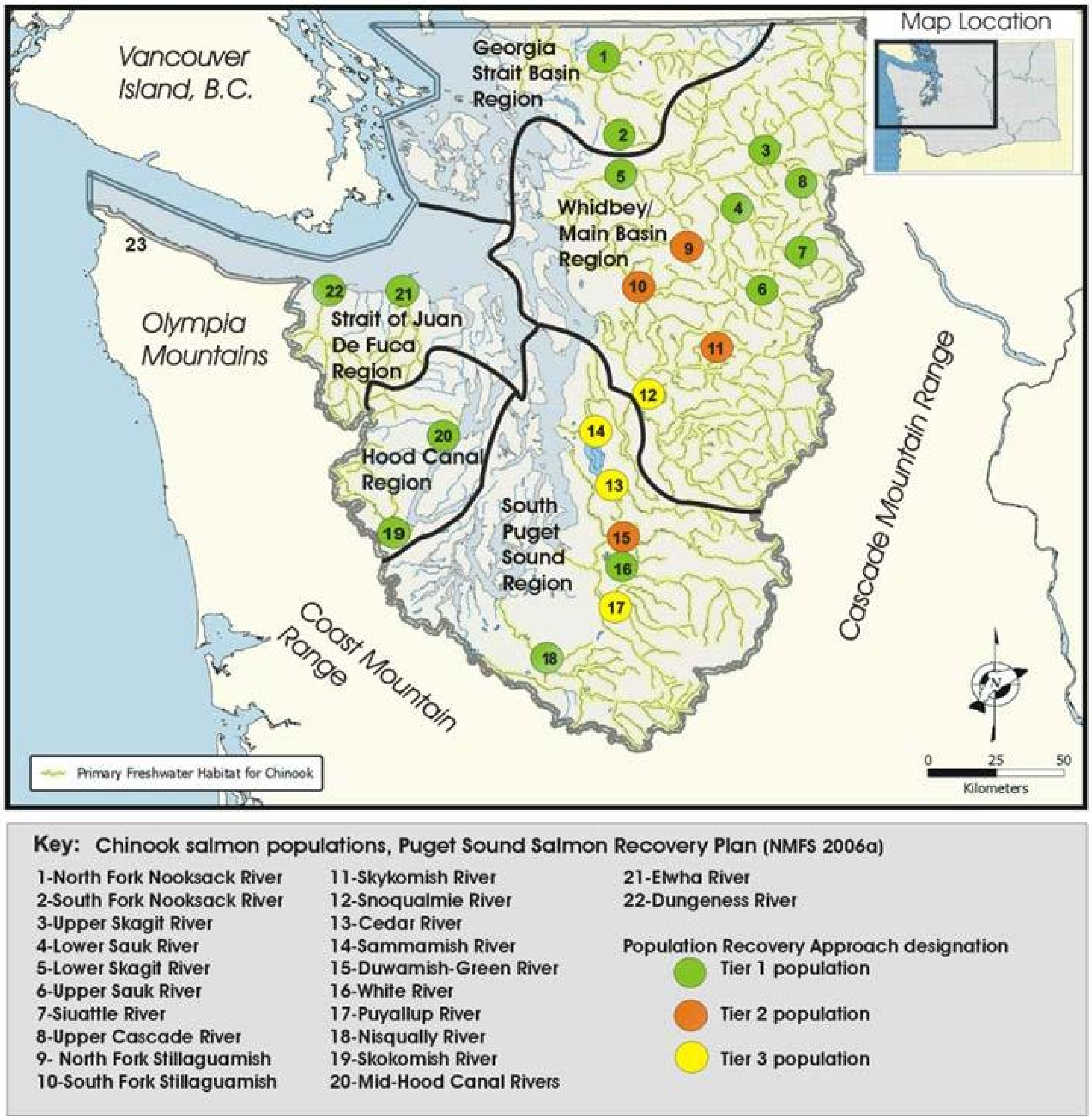

Figure 3. Populations delineated by NMFS for the Puget Sound Chinook salmon ESU (SSPS 2005) and their assigned Population Recovery Approach tier status (NMFS 2010). Note: Dosewallips, Duckabush, and Hamma Hamma River Chinook salmon are aggregated as the "Mid-Hood Canal Rivers" population.

Table 6. 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.

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

"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, NMFS relies on viability assessments and criteria in TRT documents and recovery plans, when available, that describe VSP parameters at the population, major population group (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. Puget Sound Chinook Salmon ESU

2.2.2. Life History and Status

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). The Proposed Action evaluates programs that produce "ocean-type" Chinook, which have very different characteristics compared to the "stream type". Ocean-type Chinook salmon reside in coastal ocean waters for 3 to 4 years compared to stream-type Chinook salmon that spend 2 to 3 years and exhibit extensive offshore ocean migrations. The ocean-type salmon also enter freshwater later (June through August), upon returning to spawn, compared to the stream-type (March through July) (Myers et al. 1998). Ocean-type Chinook salmon use different areas – they spawn and rear in lower elevation mainstem rivers and they typically reside in fresh water for no more than 3 months compared to spring Chinook salmon that spawn and rear high in the watershed and reside in freshwater for a year.

Status of the species is determined based on the abundance, productivity, spatial structure, and diversity of its constituent natural populations. Based on best available scientific information, including these parameters that are indicators of species viability, NMFS determined that the Puget Sound Chinook Salmon ESU was a threatened species in 1999 (64 FR 14508). Since the time of listing, only three complete generations of Chinook salmon have returned, and the ESU remains at high risk and threatened in status (Ford et al. 2011; NWFSC 2015).

The NMFS adopted the recovery plan for Puget Sound Chinook salmon on January 19, 2007 (72 FR 2493). The recovery plan consists of two documents: the Puget Sound Salmon Recovery Plan prepared by the Shared Strategy for Puget Sound and NMFS' Final Supplement to the Shared Strategy Plan (NMFS 2006b; SSPS 2007). 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. It adopts ESU and population level viability criteria recommended by the Puget Sound Technical Recovery Team (PSTRT) (Ruckelshaus et al. 2006). The PSTRT's Biological Recovery Criteria will be met when the following conditions are achieved:

1. All watersheds improve from current conditions, resulting in improved status for the species;

2. 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;

3. At least one or more populations from major diversity groups[2] historically present in each of the five Puget Sound regions attain a low risk status;

4. Tributaries to Puget Sound not identified as primary freshwater habitat for any of the 22 identified populations are functioning in a manner that is sufficient to support an ESU-wide recovery scenario;

5. 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.

Spatial Structure and Diversity. The PSTRT determined that 22 historical 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 (Figure 4) (Table 7). Based on genetic and historical evidence reported in the literature, the PSTRT also

[2] Major diversity groups of Chinook salmon are identified based on run timing, age distribution, and migration patterns. For example, early returning and late returning populations of adult Chinook salmon represent two types of major diversity groups that may be present within a biogeographical region.

determined that there were 16 additional spawning aggregations or populations in the Puget Sound Chinook Salmon ESU that are now putatively extinct[3] (Ruckelshaus et al. 2006). The Puget Sound Chinook salmon ESU includes all naturally spawned Chinook salmon originating 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. Per the Federal Register (79 FR 20802), Chinook salmon from the following 26 artificial propagation programs are also included in the listing: the Kendall Creek Hatchery Program; Marblemount Hatchery Program (spring subyearlings and summer-run); Harvey Creek Hatchery Program (summer-run); Whitehorse Springs Pond Program; Wallace River Hatchery Program (yearlings and subyearlings); Tulalip Bay Program; Issaquah Hatchery Program; Soos Creek Hatchery Program; Icy Creek Hatchery Program; Keta Creek Hatchery Program; White River Hatchery Program; White Acclimation Pond Program; Hupp Springs Hatchery Program; Voights Creek Hatchery Program; Diru Creek Program; Clear Creek Program; Kalama Creek Program; George Adams Hatchery Program; Rick's Pond Hatchery Program; Hamma Hamma Hatchery Program; Dungeness/Hurd Creek Hatchery Program; Elwha Channel Hatchery Program; and the Skookum Creek Hatchery Spring-run Program.

[3] It was not possible in most cases to determine whether these Chinook salmon spawning groups historically represented independent populations or were distinct spawning aggregations within larger populations.

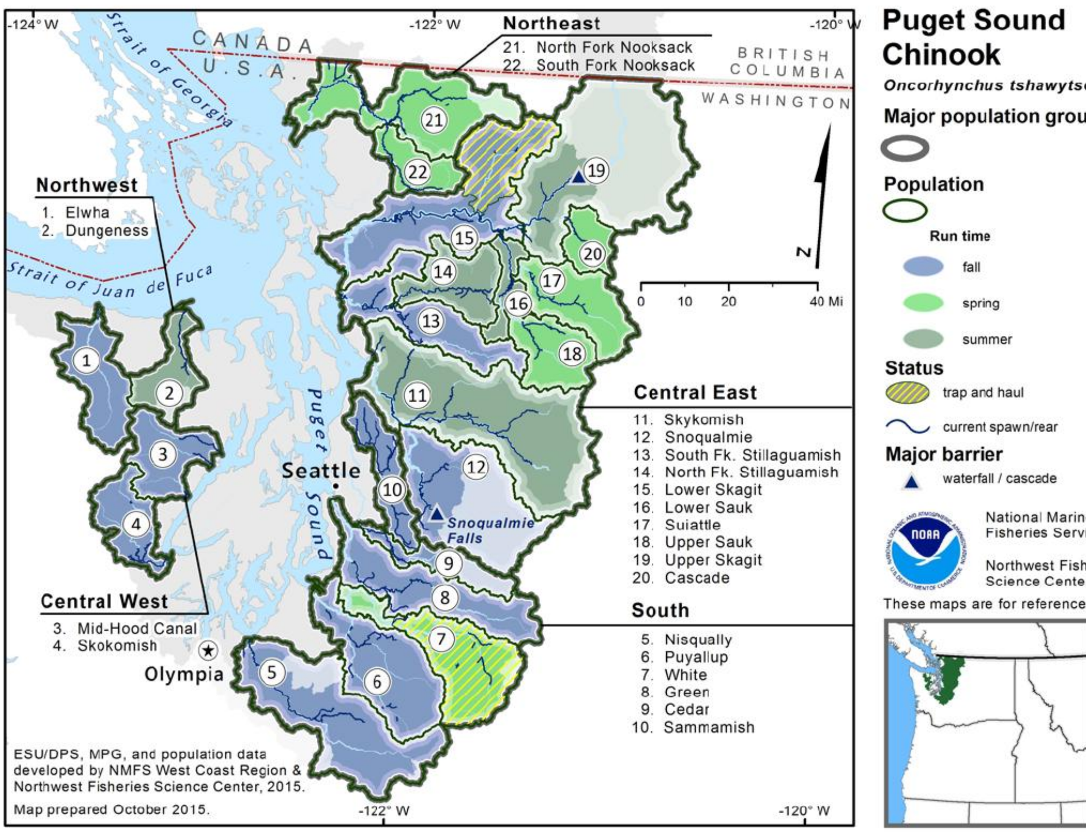

Figure 4. Map of the Puget Sound Chinook salmon ESU's spawning and rearing areas, illustrating populations and major population groups. Source: NWFSC 2015.

Table 7. Extant Puget Sound Chinook salmon populations by biogeographical region (NMFS 2006b).

Biogeographical Region	Population (Watershed)
Strait of Georgia	**North Fork Nooksack River**
	South Fork Nooksack River
Strait of Juan de Fuca	**Elwha River**
	Dungeness River
Hood Canal	**Skokomish River**
	Mid Hood Canal River
Whidbey Basin	Skykomish River (late)
	Snoqualmie River (late)
	North Fork Stillaguamish River (early)
	South Fork Stillaguamish River (moderately early)
	Upper Skagit River (moderately early)
	Lower Skagit River (late)
	Upper Sauk River (early)
	Lower Sauk River (moderately early)
	Suiattle River (very early)
	Upper Cascade River (moderately early)
Central/South Puget Sound Basin	Cedar River (late)
	Sammamish River (late)
	Green/Duwamish River (late)
	Puyallup River (late)
	White River (early)
	Nisqually River (late)

NOTE: NMFS has determined that the bolded populations in particular are essential to recovery of the Puget Sound ESU (NMFS 2006b). In addition, at least one other population of each race within the Whidbey Basin (one each of the early, moderately early and late spawn-timing) and Central/South Puget Sound Basin (one late spawn-timing) regions would need to be viable for recovery of the ESU.

Indices of spatial distribution and diversity have not been developed at the population level, though diversity at the ESU level is declining. Abundance is becoming more concentrated in fewer populations and regions within the ESU. The Whidbey Basin Region is the only region with consistently high fraction natural-origin spawner abundance, in six of the 10 populations within the Region. All other regions have moderate to high proportions of hatchery-origin spawners (Table 8).

In general, the Strait of Juan de Fuca, Georgia Basin, and Hood Canal regions are at greater risk than the other regions due to critically low natural abundance and/or declining growth rates of the populations in these regions. In addition, spatial structure, or geographic distribution, of the White, Skagit, Elwha and Skokomish populations has been substantially reduced or impeded by the loss of access to the upper portions of those tributary basins due to flood control activities and hydropower development. Habitat conditions conducive to salmon survival in most other watersheds have been reduced significantly by the effects of land use, including urbanization, forestry, agriculture, and development (NMFS 2005a; NMFS 2006a; NMFS 2008c; NMFS 2008e; SSPS 2007). It is likely that genetic and life history diversity has been substantially adversely affected by this habitat loss.

Abundance and Productivity

Most Puget Sound Chinook populations are well below escapement levels identified as required for recovery to low extinction risk (Table 8). All populations are consistently below productivity goals identified in the recovery plan (Table 8). Although trends vary for individual populations across the ESU, currently 20 populations exhibit a stable or increasing trend in natural escapement (Table 9). Fourteen of the 22 populations show a growth rate in the 17-year geometric mean natural-origin spawner abundances that is greater than or equal to 1.00. While the previous status review in 2015 (NWFSC 2015) concluded there was a widespread negative trend for the total ESU, with the addition of data through 2017, where available, there are now ESU-wide positive trends in natural-origin Chinook salmon spawner population abundances (Table 9).[4] This updated trend analysis is based on the addition of three years of escapement data including natural-origin escapement, which are only available for the more recent return years for several populations (Elwha, Dungeness, SF fall-run Stillaguamish, Lk Washington, Cedar, and Nisqually). With the addition of these data, natural-origin escapement trends indicate an improvement over the status as reported in the NWFSC 2015 status update. The NWFSC 2015 update was based on data through 2013 or 2014 when available, and was the best available information at the time of the completion of previous opinions (NMFS 2016b; NMFS 2017a).

Natural-origin escapements for eight populations are at or below their critical thresholds[5]. Both populations in three of the five biogeographical regions are below or near their critical threshold: Georgia Strait, Hood Canal, and Strait of Juan de Fuca (Table 8). When hatchery spawners are included, aggregate average escapement is over 1,000 for one of the two populations in each of these three regions. Nine populations are above their rebuilding thresholds,[6] with eight of those in the Whidbey/Main Basin Region. This appears to reflect modest improvements in population

[4] This is a synopsis of information provided in the recent five-year status review and supplemental data and complementary analysis from other sources, including the NWFCS Abundance and Productivity Tables. Differences in results reported in Tables 3 and 4 from those in the status review are related to the data source, method, and time period analyzed (e.g., 15 vs 25 years).

[5] After taking into account uncertainty, the critical threshold is defined as a point below which: (1) depensatory processes are likely to reduce the population below replacement; (2) the population is at risk from inbreeding depression or fixation of deleterious mutations; or (3) productivity variation due to demographic stochasticity becomes a substantial source of risk NMFS. 2006b. Final Supplement to the Shared Strategy's Puget Sound Salmon Recovery Plan. November 17, 2006. NMFS, Portland, Oregon. 47p..

[6] The rebuilding threshold is defined as the escapement that will achieve Maximum Sustainable Yield (MSY) under current environmental and habitat conditions ibid., and is based on an updated spawner-recruit assessment in the NMFS. 2018. Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response. Impacts of the Role of the BIA Under its Authority to Assist with the Development of the 2018-2019 Puget Sound Chinook Harvest Plan, Salmon Fishing Activities Authorized by the U.S. Fish and Wildlife Service, and Fisheries Authorized by the U.S. Fraser Panel in 2018. May 9, 2018. NMFS, West Coast Region. NMFS Consultation No.: WCR-2018-9134. 258p.. Thresholds were based on population-specific data, where available.

status since previous opinions (NMFS 2016b; NMFS 2017a) were completed. However, in 2017 NMFS updated the rebuilding thresholds, which are the Maximum Sustained Yield estimate of spawners based on available habitat. The new spawner-recruit analyses for several populations indicated a reduction in the number of spawners that can be supported by the available habitat. For example, the updated rebuilding escapement threshold for the Green River is 2,200 spawners compared to the previous rebuilding escapement threshold of 5,523 spawners. So, although several populations are above the updated rebuilding thresholds, indicating that escapement is sufficient for the available habitat in many cases, the overall abundance has declined.

Trends in 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 9). Since 1990, 14 populations show productivity that is at or above replacement for natural-origin escapement including populations in all regions. Ten populations in four of the five regions demonstrate positive growth rates in natural-origin recruitment (Table 9). Survival and recovery of the Puget Sound Chinook Salmon ESU will depend, over the long term, on remedial actions related to all harvest, hatchery, and habitat related activities. Many of the habitat and hatchery actions identified in the Puget Sound Salmon Recovery Plan are likely to take years or decades to be implemented and to produce important improvements in natural population attributes, and current trends are consistent with these expectations (NWFSC 2015).

Studies examining those variables responsible for influencing the fecundity of female salmonids indicate that as the average body size at maturation is reduced, the productivity of the population also exhibits a reduction. This reduction is related to the production of fewer and smaller eggs, and the reduced ability to dig redds deep enough to withstand scouring (Healey 1991; Healey and Heard 1984; Hixon et al. 2014). Puget Sound Chinook salmon populations are not exhibiting a reduction in body size at age of maturation (Ohlberger et al. 2018), which contributes to the observation that many of the populations continue to demonstrate stable levels of recruitment.

Table 8. 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**. For several populations, hatchery contribution to natural spawning data are limited or unavailable (NMFS 2018).

Region	Population	1999 to 2017 Geometric mean Escapement (Spawners)		NMFS Escapement Thresholds		Recovery Planning Abundance Target in Spawners (productivity)[2]	Average % hatchery fish in escapement 1999-2017 (min-max)[5]
		Natural [1]	Natural-Origin (Productivity[2])	Critical[3]	Rebuilding[4]		
Georgia Basin	Nooksack MU	2,233	262	400	500		
	NF Nooksack	1,537	**203**[9] (0.3)	*200*[6]	-	3,800 (3.4)	85 (63-94)
	SF Nooksack	43	**24**[9] (1.0)	*200*[6]	-	2,000 (3.6)	85 (62-96)
Whidbey/Main Basin	Skagit Summer/Fall MU						
	Upper Skagit River	9,390	8,188[9] (1.7)	738	5,836	5,380 (3.8)	3 (1-8)
	Lower Sauk River	572	504[9] (1.5)	*200*[6]	371	1,400 (3.0)	1 (0-10)
	Lower Skagit River	2,098	1,800[9] (1.6)	281	2,475	3,900 (3.0)	4 (2-8)
	Skagit Spring MU						
	Upper Sauk River	603	530[9] (2.4)	170	484	750 (3.0)	2 (0-5)
	Suiattle River	368	332[9] (2.1)	170	250	160 (2.8)	2 (0-7)
	Upper Cascade River	301	266[9] (1.5)	130	196	290 (3.0)	9 (0-50)
	Stillaguamish MU						
	NF Stillaguamish R.	1,147	565 (0.8)	300	550	4,000 (3.4)	48 (28-71)
	SF Stillaguamish R.	111	**98** (1.1)	*200*[6]	300	3,600 (3.3)	10 (0-49)
	Snohomish MU						
	Skykomish River	3,409	2,040[9] (1.3)	400	1,500	8,700 (3.4)	34 (17-62)
	Snoqualmie River	1,526	1,110[9] (1.1)	400	900	5,500 (3.6)	19 (8-35)
Central/South Sound	Cedar River	931	837[9] (1.8)	*200*[6]	*200-500*[7]	2,000 (3.1)	25 (10-46)
	Sammamish River	1,164	**183**[9] (0.6)	*200*[6]	*1,250*[6]	1,000 (3.0)	84 (66-95)
	Duwamish-Green R.	3,964	1,175[9] (1.2)	400	2,200	-	64 (36-79)
	White River[10]	1,778	720[9] (0.7)	*200*[6]	380[7]	-	53 (27-87)
	Puyallup River[11]	1,655	695[9] (1.1)	*200*[6]	797[7]	5,300 (2.3)	48 (18-76)
	Nisqually River	1,658	533[9] (1.3)	*200*[6]	1,200[8]	3,400 (3.0)	67 (43-87)

Hood Canal	Skokomish River	1,357	**312** (0.9)	452	1,160	-	68 (7-95)
	Mid-Hood Canal Rivers[12]	**179**		*200*[6]	*1,250*[6]	1,300 (3.0)	53 (5-90)
Strait of Juan de Fuca	Dungeness River	356	**99**[9] (0.6)	*200*[6]	925[8]	1,200 (3.0)	71 (39-96)
	Elwha River[13]	1,388	**101**[9]	*200*[6]	*1,250*[6]	6,900 (4.6)	92 (82-98)

[1] Includes naturally spawning hatchery fish.

[2] Source productivity is Abundance and Productivity Tables from NWFSC database; measured as the mean of observed recruits/observed spawners. 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 2008b); 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 2000).

[4] Rebuilding natural-origin escapement thresholds under current habitat and environmental conditions (McElhany et al. 2000; NMFS 2000).

[5] Estimates of the fraction of hatchery fish in natural spawning escapements are from the Abundance and Productivity Tables and co-manager postseason reports on the Puget Sound Chinook Harvest Management Plan (PSIT and WDFW 2013; PST and WDFW 2015; WDFW and PSTIT 2005; WDFW and PSTIT 2006; WDFW and PSTIT 2007; WDFW and PSTIT 2008; WDFW and PSTIT 2009; WDFW and PSTIT 2010; WDFW and PSTIT 2011; WDFW and PSTIT 2012; WDFW and PSTIT 2013; WDFW and PSTIT 2014; WDFW and PSTIT 2016), James and Dufault 2018 (preliminary data), and the 2010-2014 Puget Sound Chinook Harvest Management Plan (PSIT and WDFW 2010).

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

[7]Based on spawner-recruit assessment (NMFS 2018).

[8] Based on alternative habitat assessment.

[9] Estimates of natural-origin escapement for Nooksack available only for 1999-2015; Skagit springs, Skagit falls available only for 1999-2015; Snohomish for 1999-2001 and 2005-2017; Both Lake Washington populations (Cedar & Sammamish) for 2003-2016; White River 2005-2017; Puyallup for 2002-2017; Nisqually for 2005-2017; Dungeness for 2001-2017; Elwha for 2010-2017.

[10] 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.

[11] 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).

[12] The Puget Sound TRT 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; primarily based on returns to the Hamma Hamma River.

[13] Estimates of natural escapement do not include volitional returns to the hatchery or those fish gaffed or seined from spawning grounds for broodstock collection.

Table 9. Long-term trends in abundance and productivity for Puget Sound Chinook populations. Long-term, reliable data series for natural-origin contribution to escapement are limited in many areas (NMFS 2018).

Region	Population	Natural Escapement Trend[1] (1990-2017)		Natural Origin Growth Rate[2] (1990-2015)	
		NMFS		Recruitment (Recruits)	Escapement (Spawners)
Georgia Basin	NF Nooksack (early)	1.12	increasing	1.04	1.02
	SF Nooksack (early)	0.99	stable	1.00	0.98
Whidbey/Main Basin	Upper Skagit River (moderately early)	1.02	stable	0.99	1.02
	Lower Sauk River (moderately early)	1.00	stable	0.96	0.99
	Lower Skagit River (late)	1.02	stable	0.98	1.01
	Upper Sauk River (early)	1.05	increasing	1.03	1.03
	Suiattle River (very early)	1.01	stable	1.02	1.01
	Upper Cascade River (moderately early)	1.02	stable	1.01	1.02
	NF Stillaguamish R. (early)	0.99	stable	0.97	1.00
	SF Stillaguamish R[3] (moderately early)	0.96	**declining**	0.94	0.97
	Skykomish River (late)	1.00	stable	1.00	1.00
	Snoqualmie River (late)	1.01	stable	0.98	0.98
Central/South Sound	Cedar River (late)	1.05	increasing	1.01	1.04
	Sammamish River[4] (late)	1.01	stable	1.02	1.04
	Duwamish-Green R. (late)	0.97	stable	0.94	0.97
	White River[5] (early)	1.10	increasing	1.02	1.05
	Puyallup River (late)	0.98	**declining**	0.92	0.94
	Nisqually River (late)	1.05	increasing	0.93	1.00
Hood Canal	Skokomish River (late)	1.02	stable	0.90	0.99
	Mid-Hood Canal Rivers[3] (late)	1.04	stable	0.97	1.04
Strait of Juan de Fuca	Dungeness River (early)	1.05	increasing	1.03	1.06
	Elwha River[3] (late)	1.04	increasing	0.91	0.93

[1] 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.

[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] Estimate of the fraction of hatchery fish in time series is not available for use in λ calculation, so trend represents that in hatchery-origin + natural-origin spawners.

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

[5] 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.

Limiting factors

Limiting factors described in (SSPS 2007) and reiterated in (NMFS 2017a); NMFS (2017c) 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, impaired passage conditions and water quality have been degraded for adult spawning, embryo incubation, and rearing as a result of cumulative impacts of agriculture, forestry, and development. Some improvements have occurred over the last decade for water quality and removal of forest road barriers.
- Anadromous salmonid hatchery programs: Salmon and steelhead released from Puget Sound hatcheries operated for harvest augmentation purposes pose ecological, genetic, and demographic risks to natural-origin Chinook salmon populations. The risk to the species' persistence that may be attributable to hatchery-related effects has decreased since the last Status Review, based on hatchery risk reduction measures that have been implemented, and new scientific information regarding genetic effects noted above (NWFSC 2015). Improvements in hatchery operations associated with on-going ESA review and determination processes are expected to further reduce hatchery-related risks.
- Salmon harvest management: Total fishery exploitation rates have decreased substantially since the late 1990s when compared to years prior to listing (average reduction = -33%, range = -67 to +30%), (New FRAM base period validation results, August 2017), but weak natural-origin Chinook salmon populations in Puget Sound still require enhanced protective measures to reduce the risk of overharvest. The risk to the species' persistence because of harvest remains the same since the last status review for all three species. Increased harvest from the Canadian WCVI fisheries has impacted most Puget Sound populations. Further, there is greater uncertainty associated with this threat due to shorter term harvest plans and exceedance of management objectives for some Chinook salmon populations essential to recovery.
- Concerns regarding existing regulatory mechanisms: Existing regulatory mechanisms regarding water and land-use raise some concerns, 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, and certain Federal, state, and local land and water use decisions that 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.

The severity and relative contribution of these factors varies by natural population. In addition, cycles or variability in environmental conditions affecting plant and animal communities, for example increased predator abundances and decreased food resources in ocean rearing areas, likely have contributed to declines in fish populations in Puget Sound. For a comprehensive treatment of all limiting factors, please see Section 2.3, Environmental Baseline.

Whidbey Basin Biogeographical Region (BGR): The Whidbey Basin BGR contains 10 of the 22 Puget Sound ESU Chinook salmon populations, including the two Stillaguamish populations (Table 7). The Suiattle and at least one other population within the Whidbey Basin (one each of the early, moderately early and late spawn-timing) would need to be viable for recovery of the ESU. Evidence suggests that the Puget Sound Chinook Salmon ESU has lost 15 spawning aggregations that were either demographically independent historical populations or major components of the life history diversity of the remaining 22 extant independent historical populations identified (Ruckelshaus et al. 2006). Nine of the 15 putatively extinct spawning aggregations were thought to be early type Chinook salmon. The majority of extant populations with early run-timing are in this BGR, which also currently accounts for about 47 percent, and just under 70 percent, of the all-natural spawners and natural-origin Chinook salmon escapement in the ESU, respectively (Table 56 *in* NWFSC 2015).

Considering abundance in a number of different ways—for example, short-term geometric means versus long-term population growth rates—the data do not support any particular conclusion across the BGR. Abundance varies greatly among the populations (Table 8) with the Skagit populations comprising the majority (76%) of Chinook salmon in the BGR (NWFSC 2015). Based on estimates of the most recent 5-year geometric mean abundances, two populations in the BGR are above their rebuilding thresholds (representing early and moderately early life histories) and the South Fork fall-run Stillaguamish is in critical status (WDFW Score Database; NWFSC 2015). As described above, populations that showed an increase in abundance in the 5-year geometric mean natural-origin abundance since the 2015 status review are within the Whidbey Basin BGR. Long-term (1990-2017) escapement trends are increasing or stable for all but the South Fork fall-run Stillaguamish population (Table 9). Growth rates for escapement are stable or increasing for all populations within the BGR except for the Lower Sauk, South Fork Stillaguamish and Snoqualmie populations. In summary, the Whidbey Basin BGR is a stronghold of the ESU in terms of life history diversity, spatial structure, and abundance.

Stillaguamish River Basin Chinook: In Ruckelshaus et al. (2006), the NMFS Technical Recovery Team (TRT) originally described two demographically independent populations (DIPs) in the Stillaguamish basin. These two populations were described as spatially separated into a North Fork Stillaguamish population and a South Fork Stillaguamish population. Genetic sampling of the populations annually present in these two demographic areas since 2010 suggest the two populations overlap in distribution in both forks, with some temporal overlap. The co-managers on-going annual genetic sampling data suggest these two populations of Chinook in the Stillaguamish River are distinguished by differences in migration, spawn timing, and genetic characteristics, and would be more accurately described as a Stillaguamish summer run and a Stillaguamish fall run (Small et al. 2016), irrespective of river fork. Initial genetic analysis in 2006 did show that the Stillaguamish summer run is most closely associated by Bayesian lineage clustering of microsatellite DNA genotypes with spring and summer running populations from the Skagit and Skykomish Rivers. It also showed the Stillaguamish fall run associated more closely with native North/Central Puget Sound fall populations (Skagit and Snoqualmie) than to the cluster of fall populations associated with South Puget Sound hatchery releases that had also been released in the Stillaguamish in the past (Ruckelshaus et al. 2006), indicating that this run is not just a feral fall-run population resulting from past hatchery releases in the basin.

Returning summer run adults are observed in the North Fork as early as late May, with numbers increasing through July and August. Spawning activity begins in late August, peaking around mid-September and continues through late-October. Spawning takes place in the North Fork (NF), South Fork (SF), and the larger tributaries. The majority of summer run spawning takes place in the NF between river mile (RM) 14.3 and 30.0; locations known as Deer Creek and Swede Heaven Bridge. Boulder River and Squire Creek are the two most important spawning tributaries, although summer Chinook adults are also found in French, Deer, and Grant creeks, particularly when flows are high (Stillaguamish Tribe of Indians 2017a; Stillaguamish Tribe of Indians 2017b). The fall run population also spawns throughout the watershed, with genetic analysis indicating a substantial presence of fall run in the NF, and comprising a higher percentage of the limited spawner abundance in the SF and tributaries (Small et al. 2017a; Small et al. 2016). High flows typically start in the fall, thus limiting the direct observation and enumeration of fall run Stillaguamish Chinook (Stillaguamish Tribe of Indians 2017a; Stillaguamish Tribe of Indians 2017b). Genetic sampling results of carcasses from return years 2010 – 2017 indicate that summer run Chinook comprise approximately 85 percent of spawners in the North Fork, and 50 percent of spawners in the South Fork (Small et al. 2017a; Small et al. 2016).

Returning fall run Chinook salmon adults are observed in the mainstem Stillaguamish River, North and South Fork, and major tributaries thereof. The river entry timing is presumed to be later than that of the summers. As mentioned, since higher flows typically start in the fall direct observation and enumeration of fall run Stillaguamish adult Chinook is limited. Spawning typically takes place from mid-September through early November with peak activity in early to mid-October (Stillaguamish Tribe of Indians 2017a; Stillaguamish Tribe of Indians 2017b). Genetic sampling results of carcasses from return years 2010 – 2017 indicate that fall run Chinook comprise approximately 15 percent of spawners in the North Fork, and 50 percent of spawners in the South Fork (Small et al. 2017a; Small et al. 2016).

Stillaguamish Chinook populations, like most Puget Sound stocks, are classified as having an ocean-type life history. An estimated 98-99% of Stillaguamish Chinook smolts migrate to the estuary as fry/fingerlings within one to five months of emergence (Griffith and Arman 2010; Griffith et al. 2009; Griffith and Scofield 2012; Scofield and Griffith 2012; Scofield and Griffith 2013; Scofield and Griffith 2014). The out migration begins in January and continues through spring, with a few continuing their out migration through August. The remaining 1-2% are yearlings (90mm >) who begin their seaward journey in the late winter or early spring.

Analysis of scales collected from Stillaguamish Chinook between 2002-2013 revealed the following age structure: 2 yr. olds - 7.1%, 3 yr. olds - 33.1%, 4 yr. olds - 53.5%, 5 yr. olds - 6.1%, and 6 yr. olds 0.2%. This analysis also indicated that 98.6% of the Chinook adult returns during this period were sub-yearling juvenile out-migrants (Griffith and Arman 2010; Griffith et al. 2009; Griffith and Scofield 2012; Scofield and Griffith 2012; Scofield and Griffith 2013; Scofield and Griffith 2014; Scofield and Griffith 2015; Scofield and Griffith 2016). Spawning ground data from 2002-2013 shows the sex ratio of carcasses was nearly 1:1 (48.7% female /51.2% male). Carcasses recovered on the spawning grounds ranged from 33cm to 119cm (fork length) during this period. These data indicate that the natural Chinook populations in the

Stillaguamish River watershed display the necessary diversity expressed by viable populations, per the VSP criteria.

Abundance estimates, as historically derived, of the Stillaguamish Chinook salmon populations were based on geography by fork (Table 10). As mentioned above, recent genetic information indicates that these summer and fall Chinook salmon stocks overlap substantially in time and space in both forks. The co-managers continue to collect tissue samples for genetic analysis, and are developing methods to estimate escapement by population run type. Since these recent efforts by the co-managers to develop discrete escapement estimates for the fall and summer Chinook populations are in progress, the Chinook escapement/productivity estimates provided by the co-managers (Table 10) is a basin-wide population estimate that also estimates spawners by origin (PSIT and WDFW 2017).

Table 10. Stillaguamish basin total adult Chinook escapement, broodstock collected and estimated natural-origin / hatchery-origin spawning ground proportions for 1988 – 2015. EE = Estimated Escapement, SGS = Spawning Ground Survey, EST = Estimated, NOR = Natural Origin, HOR = Hatchery Origin.

YEAR	TOTAL EE	SGS EE	BROOD STOCK	TOTAL EST NOR	TOTAL EST HOR
1988	883	867	16	865	18
1989	983	956	27	934	49
1990	1098	1032	66	1021	77
1991	2044	1948	96	1880	163
1992	917	764	153	798	119
1993	1039	870	169	675	364
1994	1122	941	181	763	359
1995	1033	944	89	744	289
1996	1708	1563	145	1178	529
1997	1604	1447	157	1058	545
1998	2103	1959	144	1009	1094
1999	1501	1370	131	601	901
2000	2215	2092	123	1661	554
2001	1829	1702	127	1313	516
2002	2156	2017	139	1375	781
2003	1346	1224	122	801	545
2004	2045	1908	137	1292	754
2005	1427	1287	140	668	759
2006	1709	1576	133	768	941
2007	887	721	166	323	565
2008	1840	1711	129	831	1009
2009	1388	1239	149	486	902
2010	977	837	140	384	593
2011	1810	1637	173	576	1234
2012	1966	1787	179	1087	879
2013	1129	997	132	682	447
2014	563	419	144	211	352
2015	838	709	129	460	378

Smolt monitoring activity occurs in this system. Most downstream Chinook salmon migrants caught are sub-yearlings, although some yearlings are caught each year. Between 2005 and 2016 freshwater production of natural-origin Chinook has averaged of 170,386 migrants per year (Table 11).

Table 11: Stillaguamish River smolt trap Chinook and steelhead catches and total Chinook salmon out-migrant estimates.

Trapping Year	Natural Chinook[a]	Hatchery Chinook[a]	Wild Steelhead[b]	Hatchery Steelhead[b]
2005	2,504 (335,429)	602 (75,980)	NA[c]	NA[c]
2006	*3,500 (202,338)*	*3,180 (150,140)*	*378*	*370*
2007	1,194 (319,692)	713 (122,755)	247	30
2008	643 (186,115)	926 (277,019)	248	268
2009	1,524 (92,871)	2,027 (108,645)	436	836
2010	2,498 (305,784)	2,500 (233,258)	395	321
2011	617 (27,013)	2,696 (113,496)	416	427
2012	3,098 (185,471)	460 (201,585)	354	141
2013	3,260 (153,839)	2,641 (141,109)	315	111
2014	4,070 (177,749)	3,701 (121,905)	725	205
2015	200 (42,644)	906 (167,270)	317	8
2016	99 (47,639)	203 (181,480)	52	7
Avg.	**170,386**	**158,591**	**353**	**248**

Source: (Griffith and Arman 2010; Griffith et al. 2009; Griffith and Scofield 2012; Scofield and Griffith 2012; Scofield and Griffith 2013; Scofield and Griffith 2014; Scofield and Griffith 2015; Scofield and Griffith 2016)Stillaguamish Tribe 2006-2016 smolt trap reports.

[a] The number caught in the trap plus the estimated total number of migrants to pass the trap location. Includes both summer and fall populations.

[b] Steelhead numbers are total season catches on the Stillaguamish Tribe's Smolt Trap. No production estimate for Steelhead was made, nor can it be assumed that efficiencies for hatchery and wild smolts are the same.

[c] Prior to 2006, Trapping operations did not separate wild and hatchery steelhead.

Data for 2006 were excluded from the averages, per operator (Stillaguamish Tribe of Indians 2017a; Stillaguamish Tribe of Indians 2017b).

2.2.3. Status of Critical Habitat for Puget Sound Chinook Salmon

Designated critical habitat for the Puget Sound Chinook Salmon ESU includes estuarine areas and specific river reaches associated with the following sub basins: 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, September 2, 2005). The designation also includes some nearshore areas, adjacent to watersheds, occupied by the 22 populations and extending from extreme high water out to a depth of 30 meters, because of their importance to rearing and migrating juvenile Chinook salmon and their prey, but does not otherwise include offshore marine areas. There are 61 watersheds within the range of this ESU. Twelve watersheds received a low rating, nine received a medium rating, and 40 received a high rating of conservation value to the ESU (NMFS 2005a). Nineteen nearshore marine areas also received a rating of high conservation value. Of the 4,597 miles of stream and nearshore habitat eligible for designation, 3,852 miles are designated critical habitat (NMFS 2005b).

NMFS determines the range-wide status of critical habitat by examining the condition of its physical and biological features that were identified when the critical habitat was designated. 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). PBFs for Puget Sound Chinook salmon (70 FR 52731, September 2, 2005, using the term PCE), including the Stillaguamish salmon populations, include:

(1) Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation and larval development.
(2) 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 habitat that supports 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.
(3) 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.
(4) 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.
(5) 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.

(6) Offshore marine areas with water-quality conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation.

Critical habitat is designated for Puget Sound Chinook salmon within the Stillaguamish River watershed action area. Critical habitat includes the estuarine areas and the stream channels within the proposed stream reaches of the Stillaguamish sub-basin, and includes a lateral extent as defined by the ordinary high-water line (NMFS 2005a; NMFS 2005b). In the 2016 State of our Watersheds report, the Stillaguamish Tribe identified the current habitat status as low (NWIFC 2016). The Puget Sound Critical Habitat Analytical Review Team identified management activities that may affect the PBFs in the basin, including agriculture, grazing, channel modifications/diking, dams, forestry, urbanization, sand/gravel mining and road building/maintenance. Of these activities, forestry, road building, and maintenance were identified as the main activities affecting Chinook salmon PBFs in the Stillaguamish River watershed (NMFS 2005a).

The current productivity of Chinook salmon in the Stillaguamish River system remains limited by additional on-going effects of past activities, and the continuing degradation of water quantity and quality, reduction of floodplain and riparian processes, as well as reduced marine shoreline and functional habitat conditions (NWIFC 2016). From 2005 to 2013, permit exempt wells increased by 24 percent (from 666 to 827), riparian forest remains unchanged at 23 percent coverage, which is less than a third of that expected for primary functioning condition in the Puget Sound Salmon Recovery Plan, while net addition of bank armoring resulted in 0.22 miles (0.21 miles removed and 0.43 miles added). These habitat-limiting factors affect Stillaguamish Chinook salmon abundance and productivity. Lower water flows during the late summer due to drier summers, and exacerbated by exempt wells, subsequently reduce available rearing habitat, and thus juvenile survival. Peak winter flows caused by long-term increases in rainfall (but proportionally less snowfall) scour redds, and bed material needed during future spawning events, leading to losses during the incubation period, and loss of available spawning habitat (PSIT and WDFW 2017). As the Stillaguamish River watershed habitat deteriorates in diversity and complexity, it is limited in the quantity and quality of PBF's required to support Chinook salmon in all life stages.

2.2.4. Puget Sound Steelhead DPS

2.2.5. Life History and Status

Oncorhynchus mykiss has an anadromous form, commonly referred to as steelhead, which is the predominant form of the Puget Sound Steelhead DPS. Steelhead 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. They depend on freshwater areas for spawning and rearing and marine environments for growth and maturation.

Steelhead differ from other Pacific salmon in that they are iteroparous (capable of spawning more than once before death). Adult steelhead that have spawned and returned to the sea are often referred to as kelts. Averaging across all West Coast steelhead populations, eight percent of spawning adults have spawned previously, with coastal populations containing a higher incidence of repeat spawning compared to inland populations (Busby et al. 1996). Steelhead express two major life history types.

Summer steelhead enter freshwater at an early stage of maturation beginning in the late spring, migrate to headwater areas and hold until spawning in the winter and following spring. Winter steelhead typically enter freshwater at an advanced stage of maturation later in the year and spawn in the winter and spring (Busby et al. 1996; Hard et al. 2007).

Puget Sound steelhead are dominated by the winter life history type and typically migrate as smolts to sea at age two, with smaller numbers of fish emigrating to the ocean at one to three years of age. Seaward emigration commonly occurs from April to mid-May, with fish typically spending one to three years in the ocean before returning to freshwater. They migrate directly offshore during their first summer rather than migrating nearer to the coast as do salmon. During fall and winter, juveniles move southward and eastward (Hartt and Dell 1986). Adults from extant populations of winter steelhead return from December to May, and peak spawning occurs in March through May. Summer steelhead adults return from May through October and peak spawning occurs the following January to May (Hard et al. 2007). Temporal overlap exists in spawn timing between the two life history types, particularly in northern Puget Sound where both summer and winter steelhead are present, although summer run steelhead typically spawn farther upstream above obstacles that are largely impassable to winter steelhead (Behnke and American Fisheries Society 1992; Busby et al. 1996). The Proposed Action evaluates programs that could affect both summer-and winter-run populations in the Stillaguamish Basin.

The Puget Sound Steelhead DPS was listed as threatened in May of 2007 (72 FR 26722). Recovery planning for Puget Sound steelhead has produced a great deal of information. As part of the recovery planning process, NMFS convened the Puget Sound Steelhead Technical Recovery Team (PSSTRT) to identify historical populations and develop viability criteria for the recovery plan. The final technical team report describing historical population structure was released in March 2015 (Myers et al. 2015). NMFS also released the final PSSTRT report describing viability criteria for Puget Sound steelhead in May 2015 (Hard et al. 2015).
No new estimates of productivity, spatial structure, and diversity of Puget Sound steelhead have been made available since the 2007 review, when the Biological Review Team (BRT) concluded that low and declining abundance and low and declining productivity were substantial risk factors for the DPS/species (Hard et al. 2007). Loss of diversity and spatial structure were judged to be "moderate" risk factors due to reduced complexity and diminishing connectivity among populations, influences of non-native hatchery programs and the low numbers of summer steelhead populations in the Puget Sound DPS (Hard et al. 2007). The 2011 status review (Ford et al. 2011) determined that the DPS should remain in threatened status. The PSSTRT recently concluded that the DPS was at very low viability, as were all three of its MPGs, and many of the "Demographically Independent Populations" (DIPs) (Hard et al. 2015; Table 12).

The PSSTRT has completed a set of population viability analyses (PVAs) for these draft populations and major population groups (MPGs) within the DPS (Figure 6). The roles of individual populations in recovery of the Puget Sound steelhead DPS have not yet been defined, in contrast to the approach applied to delineate populations within the Puget Sound Chinook Salmon ESU using the PRA (NMFS 2010). However, the PSSTRT developed interim abundance-based guidelines for various potential recovery scenarios stating that, in order for the DPS to achieve full recovery, steelhead populations in the DPS need to be robust enough to withstand natural environmental variation and even some catastrophic events, and should be resilient enough to support harvest and habitat loss due to human population growth (Hard et al. 2015). In winter 2015, the Northwest Fishery Science Center completed an updated five-year review of the status of the DPS. This status review update concludes that biological risks faced by the DPS have not substantively changed since listing in 2007, and the viability status of the DPS and component MPGs continued to be very poor (NWFSC 2015).

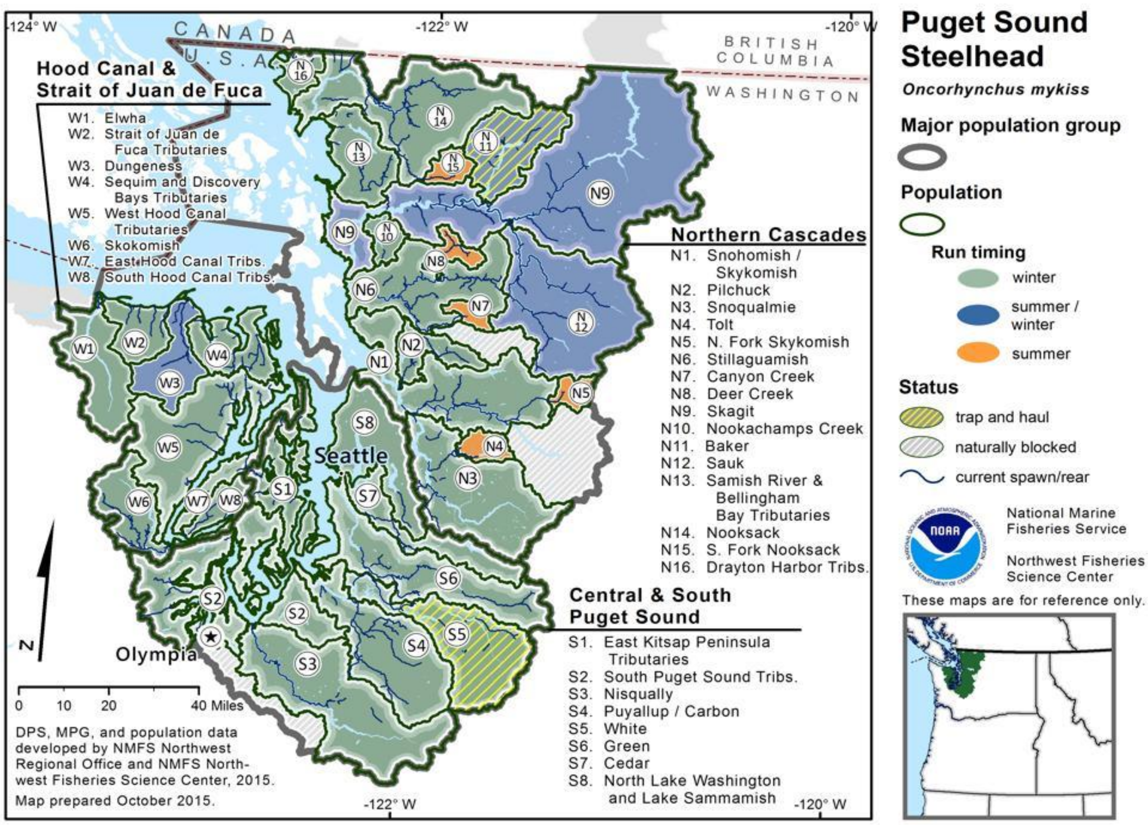

Figure 5. Map of the Puget Sound Steelhead DPS's spawning and rearing areas, identifying 32 demographically independent populations (DIPs) within 3 major population groups (MPGs). The 3 steelhead MPGs are Northern Cascades, Central & South Puget Sound, and Hood Canal & Strait of Juan de Fuca. Source: (NWFSC 2015).

Table 12. Puget Sound steelhead populations and risk of extinction (Hard et al. 2015).

Major Population Groups (MPGs)	Population (Run Time)	Extinction Risk (probability of decline to an established quasi-extinction threshold (QET) for each population)	Quasi-extinction threshold
Northern Cascades	Drayton Harbor Tributaries (winter)	Unable to calculate	
	SF Nooksack River (summer)	Unable to calculate	
	Nooksack River (winter)	Unable to calculate	
	Samish River/Bellingham Bay (winter)	Low—about 30% within 100 years	31
	Skagit River (summer/winter)	Low—about 10% within 100 years.	157
	Baker River (summer/winter)	Unable to calculate	
	Sauk River (summer/winter)	Unable to calculate	
	Snohomish/Skykomish River (winter)	Low—about 40% within 100 years	73
	Stillaguamish River (winter)	High—about 90% within 25 years	67
	Deer Creek (summer)	Unable to calculate	
	Canyon Creek (summer)	Unable to calculate	
	Tolt River (summer)	High—about 80% within 100 years	25
	NF Skykomish River	Unable to calculate	
	Snoqualmie (winter)	High---about 70% within 100 years	58
	Nookachamps (winter)	Unable to calculate	--
	Pilchuck (winter)	Low---about 40% within 100 years	34
Central and Southern Cascades	North L. Washington/L. Sammamish (winter)	Unable to calculate	
	Cedar River (summer/winter)	High---about 90% within the next few years	36
	Green River (winter)	Moderately High—about 50% within 100 years	69
	Nisqually River (winter)	High—about 90% within 25 years	55
	Puyallup/Carbon River (winter)	High—about 90% within 25-30 years	
	White River (winter)	Low—about 40% within 100 years	64
	South Sound Tributaries (winter)	Unable to calculate percentage	--
	East Kitsap (winter)	Unable to calculate	
Hood Canal and Strait of Juan de Fuca	Elwha River (summer[5]/winter)	High— about 90% currently	41
	Dungeness River (summer/winter)	High—about 90% within 20 years	30
	South Hood Canal (winter)	High---about 90% within 20 years	30
	West Hood Canal (winter)	Low—about 20% within 100 years	32
	East Hood Canal (winter)	Low—about 40% within 100 years	27
	Skokomish River (winter)	High—about 70% within 100 years	50
	Sequim/Discovery Bay Independent Tributaries (winter)	High—about 90% within 100 years (Snow Creek)	25 (Snow Creek)
	Strait of Juan de Fuca Independent Tributaries (winter)	High—about 90% within 60 years (Morse & McDonald creeks)	26 (Morse & McDonald Ck)

[5] Native summer-run in the Elwha River basin may no longer be present. Further work is needed to distinguish whether existing feral summer-run steelhead are derived from introduced Skamania Hatchery (Columbia River) summer run.

Abundance and Productivity. The 2007 BRT considered the major risk factors facing Puget Sound steelhead to be: widespread declines in abundance and productivity for most natural steelhead populations in the DPS (referred to, at that time, as an ESU), including those in Skagit and Snohomish rivers (previously considered to be strongholds); the low abundance of several summer-run populations; and the sharply diminishing abundance of some steelhead populations, especially in south Puget Sound, Hood Canal, and the Strait of Juan de Fuca (Hard et al. 2007).

The 2015 NMFS Puget Sound steelhead status review (NWFSC 2015) concluded that the most recent data available indicate some minor increases in spawner abundance and/or improving productivity over the last two to three years for Puget Sound steelhead; however, most of these improvements are viewed as small and abundance and productivity throughout the DPS remain at levels of concern. The recent increases in abundance observed in a few populations are encouraging; however, they are generally within the range of variability observed in the past several years and overall trends in abundance of natural-origin spawners remain predominantly negative (NWFSC 2015). Changes in hatchery production for both summer-run and winter-run hatchery steelhead, in particular reductions in the number of early-winter and Skamania summer hatchery fish released, as well as reduced harvest, have reduced adverse effects on natural populations in recent years. In general, the biological status of the Puget Sound Steelhead DPS has not substantively changed since the listing in 2007 (NWFSC 2015).

Spatial Structure and Diversity. The Puget Sound Steelhead DPS includes all naturally spawned anadromous winter-run and summer-run steelhead populations within streams in the river basins of the Strait of Juan de Fuca, Puget Sound, and Hood Canal, Washington, bounded to the west by the Elwha River (inclusive) and to the north by the Nooksack River and Dakota Creek (inclusive) (Figure 6). Also included as part of the ESA-listed DPS are six hatchery-origin stocks that are derived from and integrated with local natural steelhead populations (FR 79 20802, April 14, 2014). 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). Puget Sound steelhead populations are aggregated into three extant MPGs containing a total of 32 DIPs based on genetic, environmental, and life history characteristics (PSSTRT 2013) (Table 12). DIPs can include summer steelhead only, winter steelhead only, or a combination of summer and winter run timing (i.e., summer/winter).

Limiting factors. In its status review and listing documents for the Puget Sound Steelhead DPS (e.g.Ford et al. 2011; 76 FR 1392; 71 FR 15666), NMFS noted that the factors for decline for the DPS also persist as limiting factors:

- In addition to being a factor that contributed to the present decline of Puget Sound steelhead populations, the principal factor limiting the viability of the Puget Sound Steelhead DPS is the continued destruction and modification of steelhead habitat.
- Widespread declines in adult abundance (total run size), despite substantial reductions in harvest in recent years.
- Threats to diversity from non-local hatchery steelhead stocks (EWS and ESS).
- Declining diversity in the DPS, including the uncertain but weak status of summer-run steelhead in the DPS.
- A reduction in spatial structure for steelhead in the DPS. Large numbers of barriers, such as impassable culverts, together with declines in natural abundance, greatly reduce

opportunities for adfluvial movement and migration between steelhead groups within watersheds.

- Reduced habitat quality through changes in river hydrology, temperature profile, downstream gravel recruitment, and reduced movement of large woody debris.
- Increased flood frequency and peak flows during storms, and reduced groundwater-driven summer flows in the lower reaches of many rivers and their tributaries in Puget Sound where urban development has occurred, have 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.

In addition to being a factor that contributed to the present decline of Puget Sound steelhead natural 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 (NMFS 2013).

Northern Cascades MPG: The Northern Cascades MPG has 16 DIPs, including eight summer or summer/winter, and eight winter DIPs (Figure 6; Table 13). Differences in bedrock erodibility throughout the Northern Cascades MPG create cascades and falls that may serve as isolating mechanisms for summer-and winter-run natural populations. This geology is likely responsible for the relatively large number of summer-run populations (Myers et al. 2015) since returning summer steelhead tend to migrate to headwater areas in the spring and early-summer when flows are higher leading to better passage conditions.

Table 13. Naturally spawning steelhead abundance and trends for DIPs within the North Cascades MPG for which information is available. Populations within the action area are bolded. Note WR=winter-run, SUR=summer run, and SWR=summer/winter run population.

Population (Run Timing)	2005-2009 Geometric Mean Escapement (Spawners)[1]	2010-2014 Geometric Mean Escapement (Spawners)[1]	Percent Change[1]
Nooksack R WR	**NA**	**1,834**	**NA**
Pilchuck R WR	597	614	3%
Samish R WR	534	846	58%
Skagit R SWR[2]	4,767	5,123	7%
Snohomish/Skykomish WR	3,084[3]	930	-70%
Snoqualmie R. WR	1,249	680	-46%
Stillaguamish R. WR[4]	327	392	20%
Tolt River SUR	73	105	44%

[1] Source: (NWFSC 2015).
[2] Skagit data includes four DIPs: Skagit, Nookachamps, Baker, and Sauk.

3 Does not include return years 2007-2009, which were among the lowest abundance for Snohomish Basin populations.
4 Only includes the estimated number of naturally spawning steelhead in the North Fork Stillaguamish River index segments.

Eight of the 10 DIPs in the DPS with extant summer run-timing or summer components are in this MPG. This MPG accounts for 75 percent of the steelhead abundance in the DPS considering all DIPs for which data are available (NWFSC 2015). Although information on the DIPs within the Northern Cascades MPG is extremely limited, abundance appears to be highly variable among the natural populations (Table 12), with the Skagit and Snohomish populations comprising the majority of steelhead in the MPG. Through the most recent five year species status review, abundance trends from 1999 through 2014 for three DIPs within the MPG were evaluated (NWFSC 2015). Two of the DIPs had negative long-term trends and one had a positive long-term trend (Samish). Between the two most recent five-year periods (2004-2009 and 2010-2014), the geometric mean of estimated abundance for eight DIPs evaluated increased by an average of 3% in the North Cascades MPG (NWFSC 2015). Risk assessment by the PSSTRT indicated three populations are at high risk of extinction and four are at low risk (Table 12) with the Snohomish populations equally divided. However, more populations are at lower risk in this MPG than the other MPGs in the DPS. The criteria for DPS viability developed by NMFS (Hard et al. 2015), require at least 40 percent of the steelhead populations within each MPG to achieve viability (restored to a low extinction risk). At least 40 percent of each major life history type (e.g., summer-run and winter-run) historically present within each MPG must also be restored to a low extinction risk for the DPS to be considered viable. When compared to the other Puget Sound MPGs, the North Cascades MPG appears to be providing a stabilizing effect on the DPS due to both increasing escapements and a higher proportion of populations within the MPG at a low risk of extinction. In summary, the North Cascades MPG is a stronghold of the Puget Sound steelhead DPS in terms of life history diversity and abundance, viability, and has a relatively lower extinction risk overall than the other two Puget Sound MPGs.

Stillaguamish River Steelhead Populations: The Stillaguamish watershed includes three steelhead DIPs: Stillaguamish River winter-run; Deer Creek summer-run; and Canyon Creek summer-run (Myers et al. 2015). A non-native summer-run population (Skamania hatchery-origin [ESS]) spawns above Granite Falls and is not part of the DPS.

Winter-run steelhead in the Stillaguamish River watershed enter freshwater as adults between November and April (Washington State Conservation Commission (WSCC) 1999). Spawning occurs from mid-March through mid-June, with peak spawning in May (Myers et al. 2015). Winter-run steelhead spawn throughout the mainstem, South Fork, and North Fork, as well as in the larger tributaries (e.g., French, Squire, Pilchuck, Jim, and Canyon Creeks).

Summer-run steelhead in the Stillaguamish River basin enter freshwater as adults between May and October (WSCC 1999). Spawning occurs from mid-January through mid-May (WDFW and WWTIT 1994; WSCC 1999). The Deer Creek summer-run population has a July through mid-October run-timing, with spawning from early to mid-April through May (WDFW and WWTIT 1994). Most spawning takes place in the upper portion of the sub basin (Myers et al. 2015). Steep canyons and cascades from RM 1.5 to 5.1 may present a temporal barrier to winter-run steelhead (Myers et al. 2015). Ninety-five percent of the adult steelhead return as age-3 fish spending two years in freshwater and one in saltwater, and the remainder are four years old (having spent three years in freshwater and one in saltwater), or repeat spawners (WDFW and WWTIT 1994). The Canyon Creek summer-run population has a June through October run-timing; spawn timing remains unknown but is assumed to take place from February through April (WDFW and WWTIT 1994). A series of cascades and falls at RM 1.2 is thought to be a partial barrier to most adult salmon (Williams et al. 1975). This series of cascades may act as barrier to separate winter- and summer-run steelhead (Myers et al. 2015).

Abundance estimates for the species are lacking for the pre-developmental period, but steelhead harvest levels during the late 1800s and early 1900s indicate that steelhead abundance was moderately high. For the 1895 fishery (Wilcox 1898 in Myers et al. 2015), 182,000 pounds of steelhead were caught in the lower Stillaguamish. If the average steelhead was 10 pounds in individual size, this catch estimate equates to a harvest of 18,200 steelhead. Escapement surveys by the Washington Department of Fish and Game in 1929 found large aggregations of steelhead in the North Fork and South Fork Stillaguamish Rivers, and in Deer and Canyon Creeks (Myers et al. 2015, citing WDFG 1932). Intrinsic production potential estimates based on basin geological, hydrologic, and ecological characteristics indicate the Stillaguamish River basin, not including the Deer and Canyon Creek DIPs, could support a total winter-run steelhead abundance of approximately 19,118 to 38,236 adults; or over 191,180 smolts (Myers et al. 2015). There are no estimates of annual steelhead smolt production for the basin. There are no basin-wide estimates of spawning escapement; currently, escapement estimates only cover index areas (Figure 7). However, applying the estimated expansion factor of 4.06 to index area abundance for 2010 through 2015 yields a basin wide winter-run steelhead average escapement of 1,700, which is 8.9 and 4.4 percent of the low and high intrinsic potential[7] (IP) capacity for the basin.

Very little data is available on the status of summer-run steelhead in Deer and Canyon Creeks. Based on low juvenile densities, the Deer Creek population was considered to be depressed in 2002, while the status of the Canyon Creek population is currently unknown (WDFW SCoRE 2018).

Escapement data is also not available for the Deer or Canyon Creek summer steelhead populations. Estimates of intrinsic potential production indicate the Deer Creek DIP could support a total summer-run steelhead abundance of approximately 1,572 to 3,144 adults, or over 15,720 smolts (Myers et al. 2015). The last census of the Deer Creek population was conducted in October 1994, and yielded an estimate of 460 adult steelhead (Krawmer 1994 in Myers et al. 2015). Estimates of intrinsic potential production indicate the Canyon Creek DIP could support a total summer-run steelhead abundance of approximately 121 to 243 adults, or over 1,210 smolts (Myers et al. 2015).

[7] How landscape characteristics affect a particular fish species may vary with the underlying capacity of a stream to provide high-quality habitat for that species, or in other words, the 'intrinsic potential' of a stream. Intrinsic potential is derived from reach-scale stream attributes (gradient, stream size, and valley constraint) that influence availability of the fine-scale habitat features (e.g., pools, spawning gravel, and large wood) preferred by salmonids and steelhead.

The average number of natural-origin Stillaguamish River winter steelhead spawners estimated in the index areas from 2009 - 2016 was 433 (Table 14; Figure 6). Data are estimates of spawner escapement to an index area. This is because there are large reaches where survey visibility precludes marked redd census throughout the spawn timing, including reaches of the Mainstem, the Mainstem South Fork, and the Mainstem North Fork. For this reason, the index of escapement estimate is based on the consistently surveyable reaches of the NF Stillaguamish, including the Mainstem of the North Fork above Deer Creek, and index tributaries of the North Fork. The biological reference (escapement goal) for the whole Stillaguamish winter stock is 3,059 fish and for just the surveyable area, 754 fish. Cumulative redd counts in the North Fork and tributaries upstream of Deer Creek (index of escapement) are multiplied by 0.81 (females) and the result is doubled (males and females) to estimate spawner escapement (WDFW 2018a).

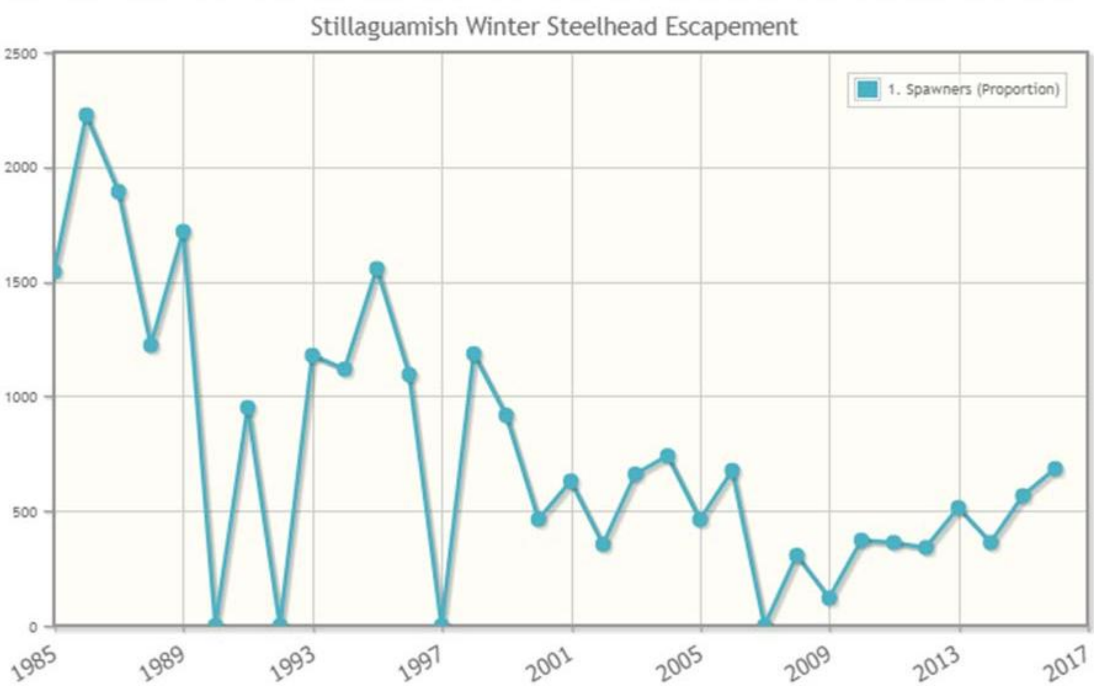

Figure 6. Stillaguamish winter steelhead index escapement 1985 – 2016. Source: (WDFW 2018a).

Ford et al. (2011) used spawner data collected through 2008 and concluded the following: "Steelhead counts in the Stillaguamish River have declined steadily since the 1980s. The estimated probability that this steelhead population would decline to 10% of its current estimated abundance (i.e., to 37 fish) is high— about 90% within 60 years. With an estimated mean population growth rate of −0.071 ($\lambda = 0.931$) and process variance of 0.016, NOAA was highly confident ($P < 0.05$) that a 90% decline in this population will not occur within the next 15 years, and that a 99% decline will not occur within the next 30 years. However, a 50% decline is highly likely within 100 years. Beyond the next 30−40 years, NOAA was highly uncertain about

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the precise level of risk." Based on a preliminary intrinsic potential estimate by the PSSTRT (2013), the capacity for winter steelhead in this system ranged from 1,912 to 38,236 adults.

Table 14. Stillaguamish River wild winter steelhead index escapement estimates 2005-2016.

Year	Index Escapement
2005	462
2006	676
2007	N/A
2008	306
2009	120
2010	372
2011	362
2012	340
2013	514
2014	362
2015	566
2016	684
Average	**433**

Source: (WDFW 2018a).

Current smolt trap monitoring for Chinook, coho, or chum salmon productivity incidentally captures wild steelhead smolts, but due to the evasive ability of steelhead smolts in large systems, no methodology has been developed to estimate total productivity. Productivity for Deer Creek summer run stock has been estimated from juvenile estimates per 100 sq. meters from six index areas in Deer Creek. From 1981 – 2001, these estimates ranged from 4 – 20 juvenile fish per m^2 (SaSI, WDFW 2002). Productivity estimates from Ford et al. (2011) for the Stillaguamish River winter-run steelhead population have ranged between 0.910 (1985-2009) and 0.879 (1995-2009).

Data are not available to evaluate changes in the diversity of steelhead in the Stillaguamish River basin. However, it is likely that the degradation and loss of habitat in the watershed, and past harvest practices that disproportionately affected earliest returning fish, have reduced the diversity of the species relative to historical levels. Similarly, releases of EWS from basin hatcheries 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. The introduction of ESS into the South Fork Stillaguamish has created a non-native, self-sustaining population (Myers et al. 2015). In an analysis of genetic samples collected from hatchery and natural-origin steelhead juveniles in the Stillaguamish River watershed, Warheit (2014a) found that the Whitehorse Ponds EWS and ESS hatchery programs affected the genetic structure of natural-origin steelhead populations in the basin to varying degrees. Warheit (2014a) reported no Whitehorse Ponds EWS hatchery influence (measured as "Proportion Effective Hatchery Contribution" or "PEHC") among aggregate samples of juvenile winter and summer-run fish, but a large hatchery-origin summer-run influence in a collection of steelhead smolts analyzed.

2.2.6. Status of Critical Habitat for Puget Sound Steelhead

Critical habitat for the Puget Sound Steelhead DPS was proposed for designation on January 14, 2013 (78 FR 2726). On February 12, 2016, NMFS announced the final critical habitat designation for Puget Sound steelhead along with the critical habitat designation for Lower Columbia River coho salmon (81 FR 9252, February 24, 2016). The specific areas designated for Puget Sound steelhead include approximately 2,031 miles of freshwater and estuarine habitat in Puget Sound, Washington. NMFS excluded areas where the conservation benefit to the species was relatively low compared to the economic impacts of inclusion. Approximately 138 stream miles were excluded from the designation based on this criterion. Approximately 1,361 stream miles covered by four habitat conservation plans and approximately 70 stream miles on tribal lands were also excluded because the benefits of exclusion outweighed the benefits of designation.

There are 72 HUC5 watersheds occupied by Puget Sound steelhead within the range of this DPS. NMFS also designated approximately 90 stream miles of critical habitat on the Kitsap Peninsula that were originally proposed for exclusion, but, after considering public comments, determined 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. Puget Sound steelhead also occupy marine waters in Puget Sound and vast areas of the Pacific Ocean where they forage during their juvenile and sub adult life phases before returning to spawn in their natal streams (NMFS 2012b). The NMFS (NMFS 2012a) could not identify "specific areas" within the marine and ocean range that meet the definition of critical habitat. Instead, NMFS considered the adjacent marine areas in Puget Sound when designating steelhead freshwater and estuarine critical habitat.

Physical or biological factors for Puget Sound steelhead 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.

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. 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 2006a), and consultations on Washington State Water Quality Standards (NMFS 2008c), the National Flood Plain Insurance Program (NMFS 2008d), the Washington State Department of Transportation Preservation, Improvement and Maintenance Activities (NMFS 2013), and the Elwha River Fish Restoration Plan (Ward et al. 2008). In 2012, the Puget Sound Action Plan was also developed and can be found online at: http://www.westcoast.fisheries.noaa.gov/habitat/conservation/puget_sound_action_plan.html. Several federal agencies (e.g., EPA, NOAA Fisheries, the Corps of Engineers, NRCS, USGS, FEMA, and USFWS) are collaborating on an enhanced approach to implement the Puget Sound Action Plan. These documents provide a more detailed overview of the status of critical habitat in Puget Sound and are incorporated by reference here. Effects of these activities on habitat, including primarily critical habitat, are also addressed in Section 2.4.2.7.

2.3. Environmental Baseline

Under the Environmental Baseline, NMFS describes activities that have occurred or are occurring in the action area prior to any effects resulting from the Proposed Action, and their impacts on listed species and designated critical habitat. The “Environmental Baseline” includes “the past and present impacts of all Federal, state, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of state or private actions that are contemporaneous with the consultation in process” (50 CFR 402.02).

In order to understand what is affecting a species, it is first necessary to understand the biological requirements of the species. Each stage in a species’ life history has its own biological requirements (Groot and Margolis 1991; NRC 1996; Spence et al. 1996). Generally, during spawning migrations, adult salmon require clean water with cool temperatures and access to thermal refugia, dissolved oxygen near 100 percent saturation, low turbidity, adequate flows and depths to allow passage over barriers to reach spawning sites, and sufficient holding and resting sites. Anadromous fish select spawning areas based on species-specific requirements of flow, water quality, substrate size, and groundwater upwelling. Embryo survival and fry emergence depend on substrate conditions (e.g., gravel size, porosity, permeability, and oxygen concentrations), substrate stability during high flows, and, for most species, water temperatures of 13ºC or less. Habitat requirements for juvenile rearing include seasonally suitable microhabitats for holding, feeding, and resting. Migration of juveniles to rearing areas, whether the ocean, lakes, or other stream reaches, requires free access to these habitats.

2.3.1. Habitat Geography and Land Use

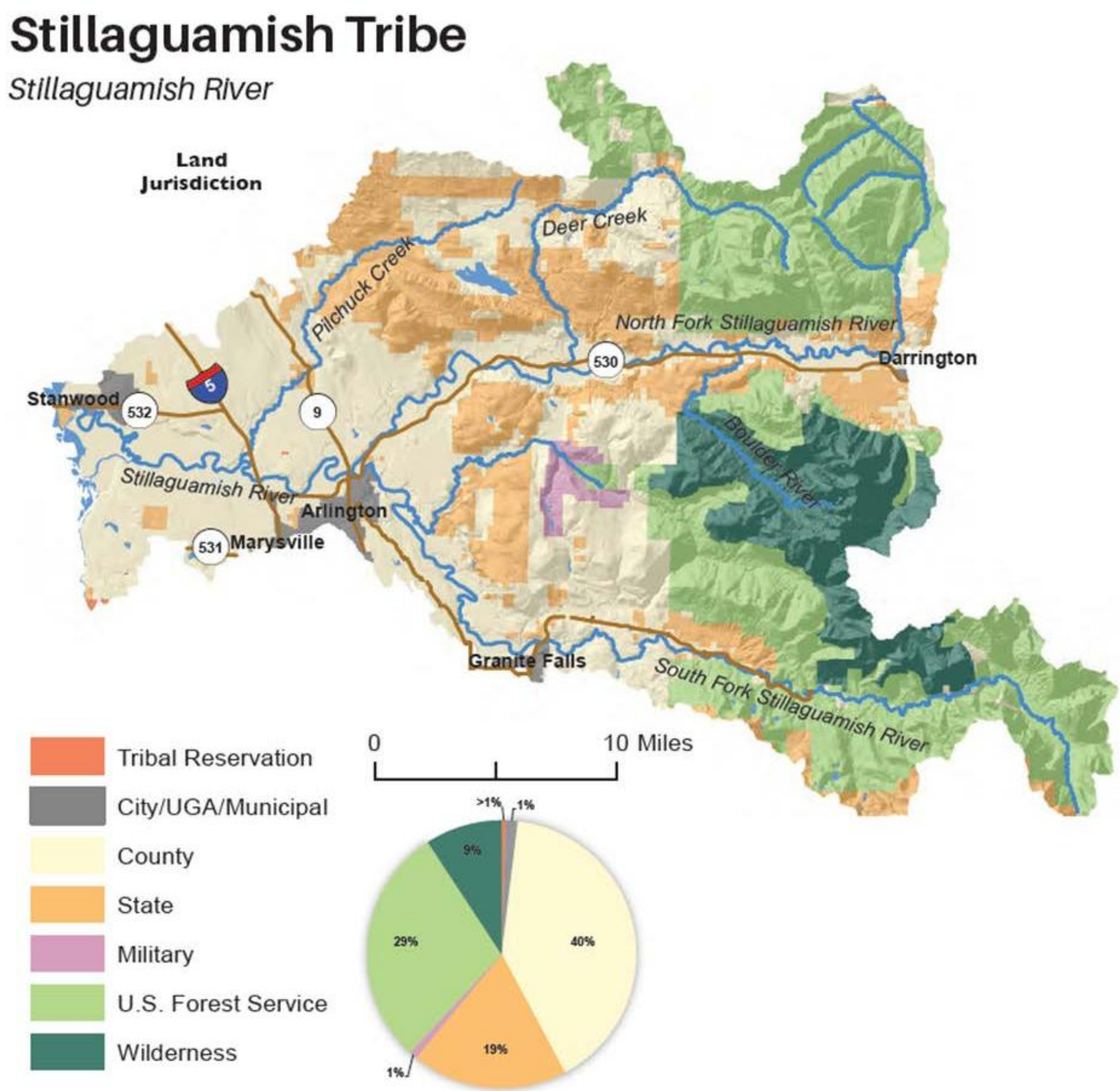
The Stillaguamish is the fifth-largest river basin draining into Puget Sound (SIRC 2005). It drains the west slope of the Cascade Mountains and foothills and has a watershed area of approximately 684 sq. miles (1,772 km^2) (Beechie et al. 2001; Williams et al. 1975). The Stillaguamish River enters Puget Sound near Stanwood, through a complex delta system. The primary delta channel (Hat Slough) enters Port Susan, but the Old Stillaguamish River (distributary at RM 3.0) flows to the north and splits into two primary channels: South Pass (which enters Port Susan) and West Pass (which enters Skagit Bay). The watershed can be divided into three primary sub-basins: lower mainstem Stillaguamish, South Fork Stillaguamish, and North Fork Stillaguamish (SIRC 2005; WSCC 1999). The mainstem is formed by the confluence of the North and South Forks at RM 17.8, in the city of Arlington. The North and South Fork sub-basins drain 284 and 254 square miles of the Stillaguamish River watershed, respectively (SIRC 2005).

The North Fork Stillaguamish emerges from a shallow canyon about 2 miles northwest of the city of Darrington and then turns west and flows 35 miles over a low-gradient valley to its confluence with the South Fork (Williams et al. 1975). The South Fork Stillaguamish originates in the vicinity of Lewis Peak and flows north for approximately 8 miles until its confluence with Coal Creek, where the river turns west and flows approximately 45 miles to its confluence with the North Fork. Elevations within the watershed range from sea level to 6,854 feet at Three Fingers Mountain (SIRC 2005). The three largest tributaries to the watershed include: Pilchuck Creek (76.2 sq. mi.; 11% by area), tributary to the mainstem; Deer Creek (66 sq. mi.; 9.6% by area), tributary to the North Fork; and Canyon Creek (63 sq. mi.; 9.2% by area), tributary to the South Fork (Myers et al. 2015; SIRC 2005; Williams et al. 1975). The Stillaguamish basin includes more than 3,112 miles of river, stream, and marine shore habitat (SIRC 2005); including more than 890 miles of anadromous stream habitat (WSCC 1999 citing Pess et al., in press).

The Stillaguamish watershed is within the boundaries of Snohomish (73% of the watershed) and Skagit (27%) Counties, as well as the cities of Arlington, Stanwood, and Granite Falls (WSCC 1999). Land use within the watershed is 76 percent forestry (includes federal, state, and private lands), 17 percent rural, 5 percent agriculture, and 2 percent urban (SIRC 2005). The Stillaguamish River watershed has extensive consumptive surface and ground water withdrawals, which include the permitted consumptive use of 81.3 and 56.4 cubic feet per second of surface water and groundwater, respectively (Pelletier and Bilhimer 2004). Irrigation withdrawals represent the majority of consumptive surface water use within the basin (Pelletier and Bilhimer 2004). The human population within the Stillaguamish River watershed in 2005 was estimated to be 58,441, and population growth in Snohomish County is growing at an annual rate of 2.7 percent (SIRC 2005). Continued population growth will place increasing pressure on water use within the basin. In 2005, Washington State established the Stillaguamish Basin Water Management Rule (WAC 173-505), which established minimum instream flows for 32 stream and river segments throughout the basin.

As described above, 76 percent of the watershed area land use is classified as forestry with 28, 21, and 51 percent under private, state, and federal ownerships, respectively (SIRC 2005; Figure

8). Less than 7 percent of Mt. Baker-Snoqualmie National Forest lands are designated for timber production (i.e., matrix land) (SIRC 2005). Extensive landslides and increased frequency and magnitude of high stream flows have been attributed to past forest practices within the basin (WSCC 1999). Forestry-related impacts on salmonid habitat have contributed, along with other land use impacts, to the decline of the historical salmonid habitat quality and productivity within the basin, thus effecting the existing populations of salmonids (SIRC 2005, and following). Many important river and stream habitats within the basin are on or near agricultural lands. Floodplain wetlands and riparian areas along the mainstem, North and South Forks, and larger tributaries have been converted to agricultural lands and are actively farmed. Large portions of floodplain habitats throughout the basin have been cleared of native forests, diked, and drained for agricultural use. The conversion of existing forest and agricultural lands to rural residential and urban uses contributes to habitat degradation. Continued population growth and subsequent conversion of lands to more intensive uses will place increasing pressure on hydrologic and floodplain function, water quality, and habitat quality. Salmon and steelhead populations are facing increasing loss of functional habitat from land-use development. The areas along mainstem rivers and along some lowland tributaries are most likely to be affected by growth and development pressures. When riverine lands are converted to residential and urban areas, forest cover and ecosystem processes are altered or lost, which can reduce the amount of spawning and rearing habitat available, worsen condition of that habitat and its utility, or even restrict access to that habitat.



Land Jurisdiction of the Stillaguamish Watershed. Map Source (NWIFC 2016).

Historically, a mixed forest consisting of deciduous and coniferous trees dominated the lower Stillaguamish River; however, between 1870 and 1910, most large conifers were cut down along the mainstem and lower South and North Forks (SIRC 2005). By the 1940s, most of the riparian areas within the basin had been logged. Factors for the decline of riparian function can be attributed to: forest removal, road and railroad construction, land use conversion, dike and revetment construction, grazing, and invasive plants (SIRC 2005). Historically, the Stillaguamish estuary consisted of a well-developed network of blind tidal channels that drained large areas of salt marsh wetland (SNRD 2005 citing Collins 1997, and following). The lower mainstem contained numerous, large, channel-spanning logjams and log rafts that maintained adjacent subsidiary sloughs. By the 1870s, most of the forest along the lower river had been cleared and this reduced the input of large woody debris and associated fish habitats. These lower river areas were largely converted to agricultural use and many of the salt marsh and blind tidal areas and most of the large logjams were eliminated. These lower river areas, and salt marshes or estuaries, are critically important to salmon and steelhead, particularly as juvenile fish make the transition from fresh to saltwater. Prior to Euro-American settlement there were approximately 4,448 acres of salt marsh connected to the basin, by 1886, only one-third of the salt marsh remained. By 1968, only 15 percent of the original salt marsh remained with a similar loss of blind tidal channels. From 1968 to the 1990s, approximately 863 acres of newly accreted salt marsh were formed; however, this new habitat lacks a well-developed channel network, and is not of the same quality as the historical salt marsh that was destroyed. As a result, the available rearing habitat in the basin for juvenile salmonids is less than 90 percent of these historical levels.

Numerous limiting factors may have caused the decline in salmon in this area, including factors that are currently limiting the productivity of salmonids within the basin. Currently, known or hypothesized limiting factors include: barriers to fish passage (e.g., culverts and tide gates), floodplain connectivity, riparian conditions, channel conditions, water quality, hydrology, and nearshore and estuarine habitat conditions (WSCC 1999). Access to spawning and rearing habitat within the basin is affected by culverts, tide gates, the Cook Slough Weir, and the Granite Falls Fishway (WSCC 1999). Three types of barriers exist throughout the basin - culverts, tide gates, and the Cook Slough Weir. All of these features can reduce, delay, or eliminate altogether access to rearing and spawning habitats. The Granite Falls Fishway vertical baffled fish ladder, measuring 580 feet, constructed by the Washington Department of Fisheries in 1954, provides access upstream of a natural barrier thereby providing access to anadromous fish, which otherwise could not occupy habitats upstream of the falls. The final inventory and assessment of fish barriers in the Stillaguamish River basin was scheduled to be completed by late 2015. A 2018 query into the WDFW Fish Passage website https://geodataservices.wdfw.wa.gov/hp/fishpassage/index.html displays 1,389 barriers in the Water Resource Inventory Area 5 – Stillaguamish Basin. Since approximately 2006, there have been 25 constructed fish passage projects in the Stillaguamish River watershed (personal communication, David Price, Habitat Biologist, OWCO-NMFS, 2018).

Floodplain function has been altered throughout much of the basin; this is mainly attributable to the floodplain being disconnected from the river due to levees, dikes, and other flood control structures and bank modifications. Floodplain areas are important for salmon and steelhead survival, particularly when fish require shelter and refuge during higher flow periods, so alteration of the floodplain can have detrimental effects. Other factors affecting floodplain function include: channelization and/or straightening, removal of snags, large wood debris (LWD), and gravel, constriction and simplification of stream and river channels from railroad and road construction (SIRC 2005). As described above riparian function has been affected by past land use throughout the basin. As of 1999, only 11 percent of riparian forests within the basin were "intact" and fully functional (WSCC 1999).

Channel conditions have been affected by changes in location and abundance of LWD, pool habitat, sediment supply, channel morphology, and gravel mining (WSCC 1999). The quantity and characteristics of in-channel LWD have been altered due to large-scale wood removal projects, the condition of riparian areas, and altered channel processes that affect wood recruitment. Loss of in-channel pool habitat is associated with the removal and reduction of LWD, increases in sediment supply, and increased peak flows (WSCC 1999). Landslides associated with human land uses are the primary source of sediment in the watershed; 75 percent of the landslides are associated with logging roads and clearcuts and 98 percent of the sediment volume is associated with clearcuts and logging roads (WSCC 1999).

Within the Stillaguamish River watershed, the primary water quality problems for salmonids include: high stream temperatures, high levels of fine sediment in spawning gravels, low dissolved oxygen levels, and high total suspended sediments (WSCC 1999). Nonpoint source pollution from agricultural practices, onsite sewage disposal, development and urban runoff, and forest practices are the leading causes affecting degraded water quality conditions (WSCC 1999).

While harmful land-use practices continue in some areas, many land management activities, including forestry practices, now have fewer impacts on salmonid habitat due to raised awareness and less invasive techniques. For example, timber harvest on public land has declined drastically since the 1980s and current harvest techniques (e.g., the use of mechanical harvesters and forwarders) and silvicultural prescriptions (i.e., thinning and cleaning) require little, if any, road construction and produce much less sediment. In addition, the Federal Conservation Reserve and Enhancement Program (CREP) began in the 1990's. Under the CREP, highly erodible and other environmentally sensitive lands that have produced crops are converted to a long-term resource-conserving vegetative cover. Participants in the CREP are required to seed native or introduced perennial grasses or a combination of shrubs and trees with native forbs and grasses.

Although habitat restoration is proceeding, key habitat protection components of the Puget Sound Chinook Recovery Plan are not being implemented and consequently habitat function is still declining in Puget Sound (Judge 2011; NWIFC 2016).

2.3.2. Habitat Restoration and Recovery Activities in the Action Area

The Pacific Coastal Salmon Recovery Fund (PCSRF) was established by Congress to help protect and recover salmon and steelhead populations and their habitats (NMFS 2007). The states of Washington, Oregon, California, Idaho, and Alaska, and the Puget Sound, Pacific Coastal, and Columbia River Basin tribes, receive PCSRF appropriations from NMFS each year. The fund supplements existing state, tribal, and local programs to foster development of Federal-state-tribal-local partnerships in salmon and steelhead recovery. The PCSRF has made substantial progress in achieving program goals, as indicated in annual Reports to Congress, workshops, and independent reviews. In addition, other federal, state, tribal, local, and private funding sources support recovery planning and on-the-ground restoration activities throughout the regions.

Over the last several years, 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 2006a), and consultations on Washington

State Water Quality Standards (NMFS 2008c) and the National Flood Plain Insurance Program (NMFS 2008d). These documents encompassed the effects of the proposed habitat effect actions that would occur up to the next 50 years on the ESA listed salmon and steelhead species in the Puget Sound basin. 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 biological opinions and HCPs, in addition to the watershed specific information in the Puget Sound Salmon Recovery Plan mentioned above, provide a current and comprehensive overview of baseline habitat conditions in Puget Sound. The portions of those documents that deal with effects in the action area (described in Section 2.4) are hereby incorporated by reference.

The federally approved Shared Strategy for Puget Sound Recovery Plan for Puget Sound Chinook Salmon, Volume II of the plan (SSPS 2007), and the Stillaguamish Salmon Recovery 3 Year Work Plans (i.e. PSP 2013) describe, in detail, on-going and proposed state, tribal, and local government restoration and recovery activities for listed Chinook salmon in the Stillaguamish River watershed.

Specific actions to recover listed salmon and steelhead have included: implementation of land use regulations to protect existing habitat and habitat-forming processes through updating and adopting Federal, state, and local land use protection programs, as well as more effectively combining regulatory, voluntary, and incentive-based protection programs; implementation of nearshore and shoreline habitat protection measures such as purchase and protection of estuary areas important for salmon productivity; protection and restoration of habitat functions in lower river areas, including deltas, side-channels, and floodplains important as rearing and migratory habitat; implementation of protective instream flow programs to reserve sufficient water for salmon production; and implementation of protective actions on agricultural lands.

Recent examples of habitat restoration and salmon recovery projects funded through the PCSRF in the action area are:

- Installation of up to 6 engineered log jam structures in the North Fork Stillaguamish River in reaches identified as of high value for ESA-listed Chinook salmon productivity
- Installation of five additional log jams in the North Fork Stillaguamish near the town of Hazel, Washington.
- Acquisition and restoration of 14 acres of high value riparian habitat on the Stillaguamish River.

These projects are all expected to have positive effects on salmon and steelhead habitat. The zis a ba tidal estuary restoration project re-established tidal influence to 88 acres funded by a National Coastal Wetlands Conservation Grant and the Washington Salmon Recovery Fund Board. Monitoring activities revealed juvenile Chinook salmon along with other salmonids had begun to utilize the newly created habitat.

2.3.3. Climate Change

Climate change has negative implications for designated critical habitats in the Pacific Northwest (Climate Impacts Group 2004; ISAB 2007; Scheuerell and Williams 2005; Zabel et al. 2006). The distribution and productivity of salmonid populations in the region are likely to be affected by climate change (Beechie et al. 2006). Average annual Northwest air temperatures have increased by approximately 1ºC since 1900, or about 50 percent 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 generally, across the greater landscape, over the next 40 years:

- Warmer air temperatures will result in diminished snow packs 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, watersheds will see their runoff diminished earlier in the season, resulting in lower streamflows in the June through September period.
- 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 streamflows 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 (Crozier et al. 2008a; Martins et al. 2012; Mote et al. 2003; 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. Figure 9 shows egg-to migrant survival decreasing linearly as daily peak freshwater flows increase during the incubation period, noticeably when flows exceed 18,000 cubic feet per second (cfs). Naturally spawning Stillaguamish Chinook salmon have also faced higher frequency of peak flows in recent years (50% probability compared to the historical 10%) (STI MUP - PSIT and WDFW 2017, Figure 9; USGS 2018, Figure 10).

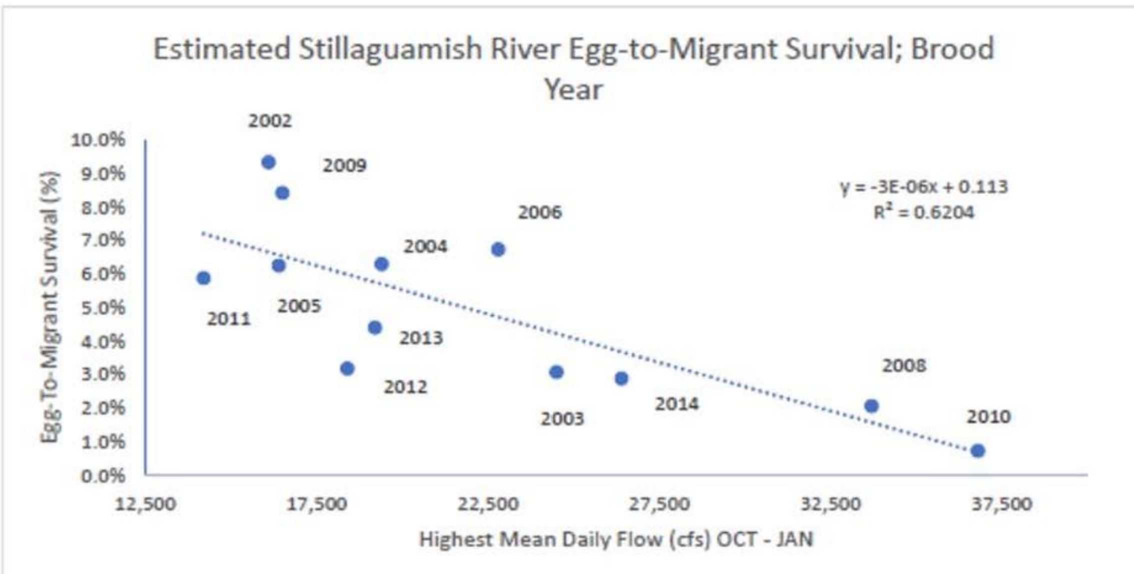


Figure 7. Stillaguamish Natural Origin (NOR) Egg-to-Migrant Survival and Stillaguamish River Peak Flows 2002-2014. Egg-to-Migrant survival was calculated by dividing estimated Chinook smolt outmigration by number of females that spawned naturally in the given brood year and their associated fecundity (PSIT and WDFW 2017).

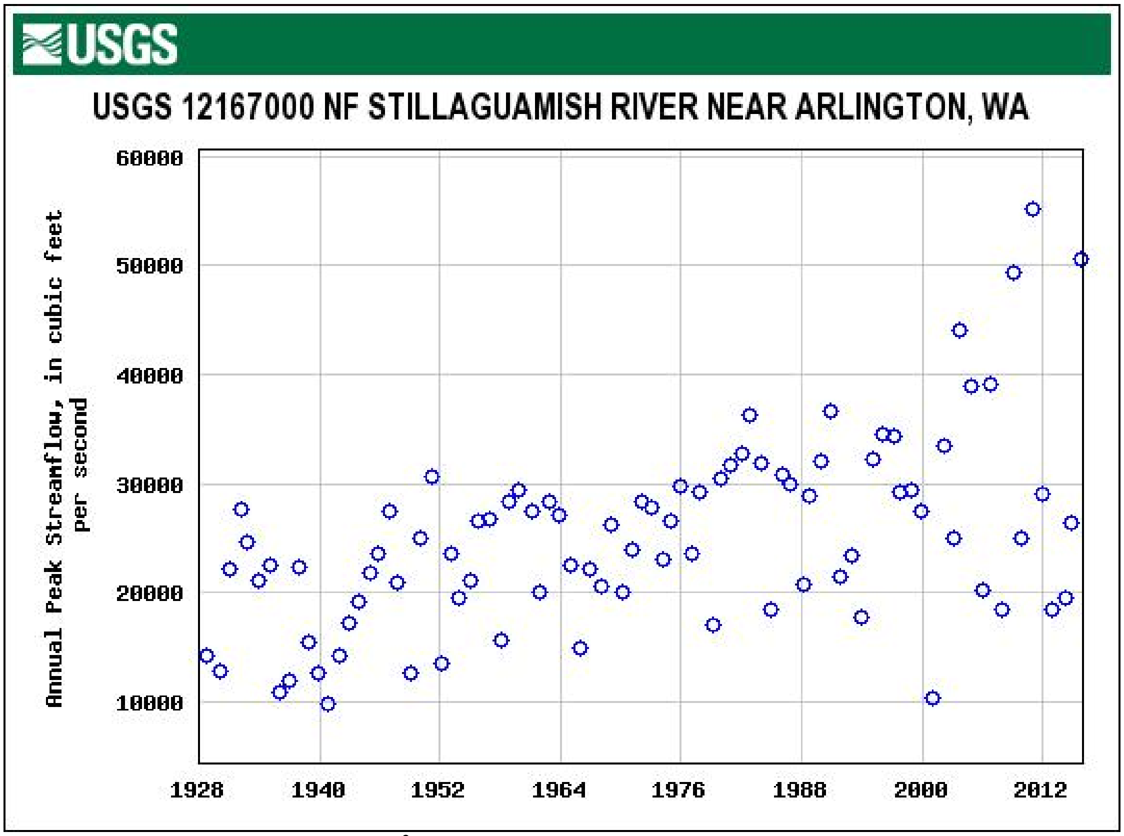


Figure 8. Annual peak flow in ft^3/second measured on the North Fork Stillaguamish River 1928 – 2017. Data Source: USGS website 2018.

The USGS North Fork gauging records from 1928 to present show a consistent increase in the highest measured flows annually (Figure 10). Additionally, flow levels that were measured at the historically as a twenty year flood event, are now measured approximately every two years (Griffith unpublished data, 2016).

Climate change may also have long-term effects that include accelerated embryo development, premature emergence of fry, and increased competition among species (ISAB 2007). The uncertainty associated with these potential outcomes of climate change do provide some justification for hatchery programs as reservoirs for some salmon stocks.

2.3.4. Hatcheries

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.

However, the long-term benefits and risks of hatchery supplementation remain untested (Christie et al. 2014). Therefore, fixing the factors limiting viability is essential for long-term viability.

Stillaguamish River Hatchery Steelhead Programs

Steelhead hatchery programs in Puget Sound were initiated beginning in the early 1900s. In 1935, steelhead returning to Chambers Creek were used to establish a hatchery stock that was subsequently released throughout much of Puget Sound (Crawford 1979), including in the Stillaguamish River watershed (WDFW 2014). During the 1960s, advances in hatchery cultural techniques led to further development of the Chambers Creek (aka "Early Winter") hatchery-origin stock through broodstock selection and accelerated rearing practices (Crawford 1979). Early summer steelhead (ESS) returns in Puget Sound, derived approximately 40 years ago from transplanted Columbia River basin Washougal and Klickitat stock, were similarly developed through hatchery release programs in the Snohomish and Green River watersheds. Self-sustaining broodstock returns have been maintained in Stillaguamish River watershed hatcheries for about 30 years (WDFW 2005). Hatchery smolts from these cultured stocks, released at a size of 5 to 6 fish per pound (198 – 210 mm fl), have been shown to emigrate quickly seaward after release, and survive well to adult return. Both EWS and ESS are thought to spawn somewhat earlier than natural steelhead populations in Puget Sound (Myers et al. 2015), with spawn timing analyses suggesting peak spawning activity for both EWS and ESS in February, and peak spawning for steelhead from natural-origin populations in mid-April.

A recent analysis of genetic samples collected from hatchery and natural-origin steelhead adults and juveniles in Puget Sound region watersheds (including programs in the Stillaguamish and Nooksack River basins), Warheit (2014b) found that isolated winter- run (EWS) and summer-run steelhead (ESS) hatchery programs have affected the genetic structure of associated natural-origin steelhead populations to varying degrees. A higher level of gene flow (measured as "Proportion Effective Hatchery Contribution" or "PEHC") from hatchery-origin steelhead was found in the Stillaguamish River compared to the Nooksack River. No samples collected from summer-run steelhead under propagation at Whitehorse Ponds were included in the analysis. In the Stillaguamish watershed, Warheit (2014b) reported small to no hatchery influence (again, measured as PEHC) among aggregate samples of juvenile summer-run fish, but a large hatchery-origin summer-run influence in a collection of steelhead smolts analyzed. Analysis of the Stillaguamish River smolt sample indicated an average hatchery-origin summer-run steelhead PEHC of 18%, with a ninety percent confidence interval of 13% to 25% (Warheit 2014b, Table 8). Of concern in the Stillaguamish River watershed is that more detailed gene flow analysis, including analysis of samples from summer-run steelhead under propagation at Whitehorse Ponds, would indicate similar PEHC effects on extant, native summer-run steelhead populations.

On April 15, 2016, NMFS announced the release of a Final Environmental Impact Statement (FEIS) (NMFS 2016c) and signed a Record of Decision (ROD). The FEIS and 4(d) assessment reviewed five HGMPs for early winter steelhead (EWS) hatchery programs submitted by the co-managers for review and approval under section 4(d) of the ESA. The HGMPs describe three EWS hatchery programs operating in the Dungeness, Nooksack, and Stillaguamish basins.

NMFS subsequently approved the programs as consistent with ESA requirements (NMFS 2016a).

2.3.5. Fisheries

Stillaguamish Summer and Fall Chinook Salmon
In the Stillaguamish River watershed portion of the action area, ceremonial, and subsistence fisheries by the Stillaguamish Tribe and Tulalip Tribes are conducted each year in the river (Stillaguamish Tribe) and adjacent marine areas (Tulalip). Fisheries in these areas harvest Chinook, coho, and chum salmon, and in odd-numbered years, pink salmon. There are no WDFW-managed non-Treaty commercial fisheries in the river or in the adjacent nearshore marine area, but surplus Chinook, coho, chum, and pink salmon may be harvested by the non-Treaty fleet in more seaward marine areas. Recreational fisheries for salmon and unlisted steelhead managed by WDFW may occur in the Stillaguamish River and adjacent marine areas.

Historically, the management guidelines for Stillaguamish Chinook included an exploitation rate (ER) ceiling (25% FRAM estimated) and low abundance escapement thresholds (LAT- 500 for NF NORs, 200 for SF NORs). When forecasts of abundance indicate that spawning escapement will be at or less than the LAT for either stock, the co-managers will constrain southern U.S. (SUS) fisheries to ensure that total SUS ER on the Stillaguamish management unit does not exceed 15% (PSIT and WDFW 2010).

On average since 1999, 7% of the fishery-related mortality of Stillaguamish summer Chinook salmon occurred in Alaska (CTC 2017). Chinook salmon catch in the Northern B.C. and WCVI troll fisheries increased dramatically in 2002. Stillaguamish summer and fall Chinook salmon stocks were among those most impacted by increasing British Columbia fisheries, as can be seen in CWT distribution data presented in the management unit (MU) profiles in the 2017 Puget Sound Chinook Harvest Management Plan.

A substantial proportion of the fishing mortality on many Puget Sound Chinook salmon stocks occurs outside the jurisdiction of the Puget Sound Chinook Harvest Management Plan, in Canadian and/or Southeast Alaskan fisheries, based on recoveries of coded-wire tags from indicator stocks (PSIT and WDFW 2017). Of the Puget Sound indicator stocks, more than half of total mortality of Stillaguamish summer/fall Chinook salmon occurs in Alaska and Canada (PSIT and WDFW 2017).

In recent years, the impact of some fisheries in British Columbia (notably those on the west coast of Vancouver Island) on some populations of Puget Sound and Columbia River Chinook increased substantially (PSC 2006a). The 2008 PST Chinook Agreement was intended to address conservation of ESA listed populations, but reductions in northern fisheries stipulated in the Agreement were only expected to reduce exploitation rates (ER) on Puget Sound MUs by about 2 – 3%, and did not offset the increase in mortality on some Puget Sound stocks that occurred in 2003 – 2005 (PSC 2006b). Fishery performance under the 2008 Agreement through 2015, however, resulted in an increase in the average ER for Puget Sound Chinook salmon stocks (PSC 2006b). The 2018 PST Chinook Agreement is anticipated to restructure the coast wide fishery to reverse this trend and increase escapement for these Puget Sound stocks over the duration of the agreement (PSIT and WDFW 2017).

Critical or near-critical status is expected to persist for the Stillaguamish summer and fall Chinook salmon populations, requiring constraint of Southern United States (SUS) fisheries consistent with the 2018 Puget Sound Chinook Harvest Management Plan, as well as hatchery recovery programs to ensure their persistence. Chinook-directed fisheries in the terminal areas have been closed, except for tribal ceremonial & subsistence (C&S) harvest in the Stillaguamish River. Pre-terminal SUS fishery impacts from 2010 to 2014 have been held to 5 – 12% for the Stillaguamish MUs based on a New Base (BY 2005 -2008) period post-season runs. Recent declines in escapement for these populations is most likely due to factors other than mortality in SUS fisheries. As analyzed in NMFS (2018), if SUS fisheries were not to occur in 2018, NFMS estimated that an additional seven natural-origin spawners would return to the South Fork Stillaguamish River, which would not provide sufficient additional spawners to substantially change the status or trends of the populations from what would occur without the fisheries. Growth rates for natural-origin escapement are consistently higher than growth rates for natural-origin recruitment for most populations within the Region, including the South Fork fall-run Stillaguamish population (Table 9). This indicates that sufficient fish are escaping the fisheries to maintain or increase the number of spawners from the parent generation, providing some stabilizing influence for abundance and reducing demographic risks.

Stillaguamish Steelhead

Between 2000/2001 and 2012/2013, the total annual tribal and non-Indian fishery harvests of EWS in the Stillaguamish River portion of the analysis area averaged 12 and 572 fish, respectively (WDFW 2018b; WDFW 2019). Management measures, including time and area closures, are applied in all fisheries to minimize incidental harvest impacts on natural-origin steelhead, and to ensure that encounters with late winter-returning natural-origin steelhead remain low. There are no tribal steelhead-directed commercial fisheries in the Stillaguamish River, and tribal EWS harvests are restricted to marine areas (WDFW 2018b; WDFW 2019). The generic steelhead season is open from June 1, to January 31 or February 15, with two marked hatchery-origin steelhead over 20 inches allowed. All tribal harvest of summer steelhead occurs incidental to fisheries directed at Chinook, coho, and pink salmon. The tribes have chosen to take their allocation of summer steelhead in the EWS fishery, pursuant to court orders. Tribal commercial and C&S net fisheries targeting EWS are normally open from early December through mid-January. The recreational fishery for EWS in the mainstem Stillaguamish River and its two forks are normally open from the first Saturday in June through January of each year, and through February 15 in the North Fork Stillaguamish River near the Whitehorse Ponds hatchery facility. The EWS sport fishery is open within selected stream reaches with a bag limit of two hatchery-origin steelhead over 14 inches.

2.4. Effects of the Action

This section describes the effects of the Proposed Action, independent of the Environmental Baseline and Cumulative Effects. The methodology and best scientific information NMFS follows for analyzing hatchery effects is in Section 2.4.1 and application of the methodology and analysis of the Proposed Action is in Section 2.4.2.

Under the ESA, "effects of the action" means "the direct and indirect effects of the action on the species and on designated critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline" (50 CFR 402.02). Indirect effects are those that are caused by the Proposed Action and are later in time, but still are reasonably certain to occur. Effects of the Proposed Action that are expected to occur later in time (i.e., after the 10-year timeframe of the Proposed Action) are included in the analysis in this opinion to the extent they can be meaningfully evaluated. The Proposed Action, the status of ESA-protected species and designated critical habitat, the Environmental Baseline, and the Cumulative Effects are considered together to determine whether the Proposed Action is likely to appreciably reduce the likelihood of survival and recovery of ESA protected species or result in the destruction or adverse modification of their designated critical habitat.

Hard et al. (1992) discuss a need for considering balance of benefits and risks in the use of artificial propagation: "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". 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 a salmon 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 (Hard et al. 1992).

NMFS' analysis of the Proposed Action considers whether the actions would be expected to have effects 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 2.4.2). Once determined, these effects are combined with other baseline and cumulative effects on the species to determine the likelihood of posing jeopardy to the species as a whole (Section 2.7).

As described in Section 2.1, NMFS's analyses of the Proposed Action effects on ESA-listed Chinook salmon in the Stillaguamish River basin applies the PRA (NMFS 2010), with other factors, to derive conclusions regarding Stillaguamish River basin salmon hatchery-related effects on the ESA-listed Puget Sound Chinook salmon ESU. The assigned standing of both Chinook salmon populations as Tier 2 populations (secondary role in recovery of the ESU) is a factor in considering the magnitude of effects that would result from implementation of the Proposed Action at the population and ESU levels.

2.4.1. 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; Jones 2006; McElhany et al. 2000; NMFS 2004; NMFS 2005c; NMFS 2008a; NMFS 2011b). 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—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.

This section describes the methodology NMFS follows to analyze hatchery effects. The methodology is based on the best available scientific information. Analysis of the Proposed Action itself is described in Section 2.4.2 of the opinion.

The effects, positive and negative, for two categories of hatchery programs on listed salmon and steelhead in the action area are summarized in Table 15. Generally, effects range from beneficial to negative for programs that use local fish[8] for hatchery broodstock and from negligible to negative when a program does not use local fish for broodstock[9]. Only propagation programs that use fish that are integrated with the local natural population can benefit population viability. Integrated hatchery programs use local fish for broodstock (natural-origin and hatchery-origin fish included in an ESU or DPS), follow "best management practices" and are designed around natural evolutionary processes that promote population viability (NMFS 2004). When hatchery programs produce fish that are not intended to spawn naturally, such as those that use fish originating from a different population, MPG, or from a different ESU or DPS, NMFS is particularly interested in how effective the program will be at isolating hatchery fish and avoiding co-occurrence and effects that potentially disadvantage fish from natural populations. The range in effects are refined and narrowed after available scientific information and the circumstances and conditions that are unique to individual hatchery programs are accounted for.

[8] The term "local fish" is defined to mean fish that are no more than moderately divergent from the associated local natural population. See 70 FR 37204, June 28, 2005.

[9] Exceptions include restoring extirpated populations and gene banks.

Table 15. Range in effects on natural population viability parameters from two categories of hatchery programs. The range in effects are refined and narrowed after the circumstances and conditions that are unique to individual hatchery programs are accounted for.

Natural population viability parameter	Hatchery broodstock originate from the local population and are included in the ESU or DPS	Hatchery broodstock originate from a non-local population or from fish that are not included in the same ESU or DPS
Productivity	**Positive to negative effect.** Hatcheries are unlikely to benefit productivity except in cases where the natural population's small size is, in itself, a predominant factor limiting population growth (i.e., productivity).	**Negligible to negative effect.** Effects dependent on differences between hatchery fish and the local natural population (i.e., the more distant the origin of the hatchery fish the greater the threat), the duration and strength of selection in the hatchery, and the level of isolation achieved by the hatchery program (i.e., the greater the isolation the closer to a negligible effect).
Diversity	**Positive to negative effect.** Hatcheries can temporarily support natural populations that might otherwise be extirpated or suffer severe bottlenecks and they also have the potential to increase the effective size of small natural populations. Broodstock collection that homogenizes population structure is a threat to population diversity.	**Negligible to negative effect.** Effects dependent on the differences between hatchery fish and the local natural population (i.e., the more distant the origin of the hatchery fish the greater the threat) and the level of isolation achieved by the hatchery program (i.e., the greater the isolation the closer to a negligible effect).
Abundance	**Positive to negative effect.** Hatcheries can increase genetic resources to support recovery of an ESU or DPS in the wild. Using natural fish for broodstock can reduce abundance.	**Negligible to negative effect.** Effects dependent on the level of isolation achieved by the hatchery program (i.e., the greater the isolation the closer to a negligible effect), and specific handling, RM&E, and facility operation, maintenance and construction actions.
Spatial Structure	**Positive to negative effect.** Hatcheries can accelerate re-colonization and increase population spatial structure, but only in conjunction with remediation of the factor(s) that limited spatial structure in the first place.	**Negligible to negative effect.** Effects dependent on facility operation, maintenance, and construction actions and the level of isolation achieved by the hatchery program (i.e., the greater the isolation the closer to a negligible effect).

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.

NMFS analyzes six factors for their effects on ESA-listed species. The six factors are:

(1) broodstock collection,
(2) hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds,
(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),
(5) the operation, maintenance, and construction of hatchery facilities, and
(6) fisheries that exist because of the hatchery program.

The analysis assigns an effect for each factor from the following categories. The categories are:

(1) positive or beneficial effect on population viability,
(2) negligible effect, positive or negative, on population viability, and
(3) negative effect on population viability.

The category of effect assigned is based on an analysis of each factor weighed against:

- the affected population(s) current risk level for abundance, productivity, spatial structure, and diversity (low, moderate, high, or very high);
- the role or importance of the affected natural population(s) in ESU or steelhead DPS recovery;
- the target viability status (highly viable, viable, or maintained) for the affected natural population(s); and,
- the factors limiting population viability.

2.4.2. Factor 1: Broodstock collection

Broodstock collection is arguably the single most important aspect of a hatchery program and it is a particularly important factor in the effects analysis. The first consideration in analyzing and assigning effects for broodstock collection is the origin and number of fish collected. The analysis considers whether broodstock are of local origin and the consequences of using ESA-listed fish (natural or hatchery-origin). It considers the maximum number of fish proposed for collection, the proportion of the donor population tapped for broodstock, and whether the program "backfills" with fish from outside the local or immediate area. "Mining" a natural population to supply hatchery broodstock can reduce population abundance and spatial structure.

The analysis also considers the effects from encounters with ESA-listed fish that are incidental to the conduct of broodstock collection. Here, NMFS analyzes the effects on ESA-listed fish when they encounter weirs, volunteer into fish ladders, or are subject to sorting and handling in the course of broodstock collection. Some programs collect their broodstock from fish volunteering into the hatchery itself, typically into a ladder and holding pond, while others sort through the run at large, usually at a weir, ladder, or sampling facility. Generally, 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 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 considers the physical process of collecting hatchery broodstock, and the effect of the process on ESA-listed species, under Factor 2.

2.4.3. Factor 2: Hatchery fish and the progeny of naturally spawning hatchery fish on the spawning grounds

NMFS also analyzes the effects of hatchery returns and the progeny of naturally spawning hatchery fish on the spawning grounds. There are two aspects to this part of the analysis: genetic effects and ecological effects. NMFS generally views genetic effects as detrimental because at this time, based on the weight of available scientific information, NMFS believes that artificial breeding and rearing is likely to result in some degree of genetic change and fitness reduction in hatchery fish and in the progeny of naturally spawning hatchery fish relative to desired levels of diversity and productivity for natural populations. Hatchery fish thus pose a threat to natural population rebuilding and recovery when they interbreed with fish from natural populations. However, NMFS recognizes that there are benefits as well, and that the risks just mentioned may be outweighed under circumstances where demographic or short-term extinction risk to the population is greater than risks to population diversity and productivity. Conservation hatchery programs may 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).

Furthermore, NMFS also recognizes there is considerable uncertainty regarding genetic risk. The extent and duration of genetic change and fitness loss and the short and long-term implications and consequences for different species, for species with multiple life-history types, and for species subjected to different hatchery practices and protocols, remains unclear and should be the subject of further scientific investigation. As a result, NMFS believes that hatchery intervention is a legitimate and useful tool to alleviate short-term extinction risk, but otherwise managers should seek to limit interactions between hatchery and natural-origin fish and implement hatchery practices that harmonize conservation with the implementation of treaty Indian fishing rights and other applicable laws and policies (NMFS 2011b).

Hatchery fish can have a variety of genetic effects on natural population productivity and diversity when they interbreed with natural-origin fish. Although there is biological interdependence between them, NMFS considers three major areas of genetic effects of hatchery programs: within-population diversity, outbreeding effects, and hatchery-influenced selection. As stated above, in most cases, the effects are viewed as risks, but in small populations, these effects can sometimes be beneficial, reducing extinction risk.

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, a random loss of diversity due to population size. The rate of loss is determined by the population's effective population size (N_e). Effective population size, census size adjusted for variation in sex ratio, and reproductive success, determine the level of genetic diversity that can be maintained by a population, and the rate at which diversity is lost. Effective size can be considerably smaller than its census size. For a population to maintain genetic diversity reasonably well, the effective size should be in the hundreds (e.g., Lande and Barrowclough 1987), and diversity loss can be severe if N_e drops to a few dozen. Effective size is typically a per-generation measure. Diversity issues in anadromous salmonids are usually discussed in terms of the single-year version of N_e, the effective number of breeders (N_b).

Hatchery programs, simply by virtue of creating more fish, can increase N_e. In very small populations this 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, such as the programs preserving and restoring Snake River sockeye salmon, South Fork Nooksack Chinook salmon, and Elwha River Chinook salmon, are important genetic reserves. However, hatchery programs can also directly depress N_e through two principal methods. One is by the simple removal of fish from the population so that they can be used in the hatchery. 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). N_e can also be 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 semen is especially problematic because when semen 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). Factorial mating schemes, in which fish are systematically mated multiple times, can be used to increase N_e (Busack and Knudsen 2007; Fiumera et al. 2004). An extreme form of N_e reduction is the Ryman-Laikre effect (Ryman et al. 1995; Ryman and Laikre 1991), which N_e is reduced through the return to the spawning grounds of large numbers of hatchery fish from very few parents.

Inbreeding depression, another N_e-related phenomenon, is caused by the mating of closely related individuals (e.g., siblings, half-siblings, or cousins). The smaller the population, the more likely spawners will be related. Related individuals are likely to contain similar genetic material, and the resulting offspring may then have reduced survival because they are less variable genetically or have double doses of deleterious mutations. The lowered fitness of fish due to inbreeding depression accentuates the genetic risk problem, helping to push a small population toward extinction.

Outbreeding effects are caused by gene flow from other populations. Gene flow occurs naturally among salmon and steelhead populations, a process referred to as straying (Quinn 1993; Quinn 1997). 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 programs can result in straying outside natural patterns for two reasons. First, hatchery fish may exhibit reduced homing fidelity relative to natural- origin fish (Goodman 2005; Grant 1997; Jonsson et al. 2003; Quinn 1997), resulting in unnatural levels of gene flow into recipient populations, either in terms of sources or rates. Second, even if hatchery fish home at the same level of fidelity as natural-origin fish, their higher abundance can cause unnatural straying levels into recipient populations. One goal for hatchery programs should be to ensure that hatchery practices do not lead to higher rates of genetic exchange with fish from natural populations than would occur naturally (Ryman 1991). Rearing and release practices and ancestral origin of the hatchery fish can all play a role in straying (Quinn 1997).

Gene flow from other populations can have two effects. It 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 (ICTRT 2007), and the greater potential for outbreeding depression (Figure 11). For this reason, NMFS advises hatchery action agencies to develop locally derived hatchery broodstocks. Additionally, unusual rates of straying into other populations within or beyond the population's MPG or ESU or a steelhead DPS can have an 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. Reduction of within-population and among-population diversity can reduce adaptive potential.

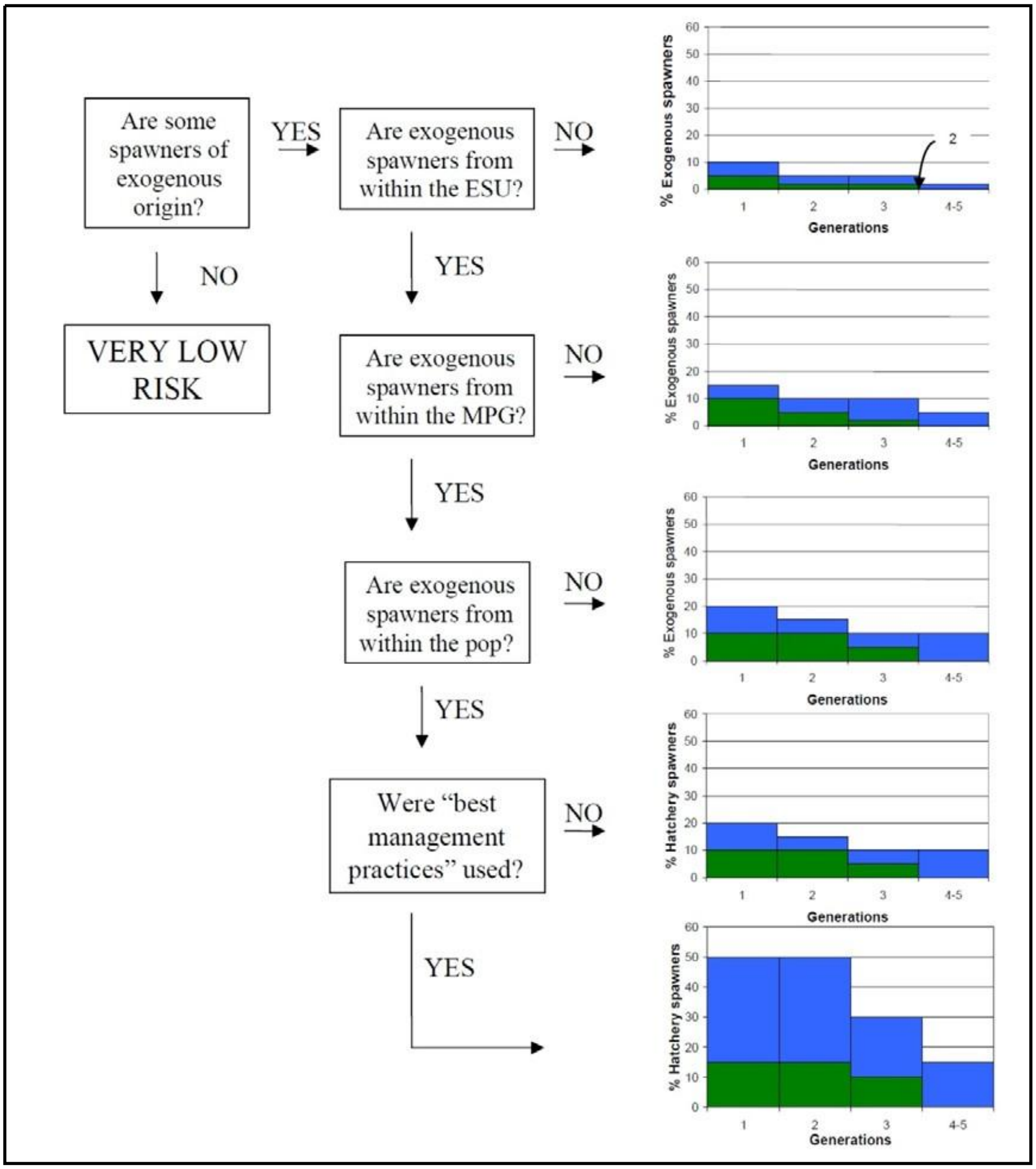


Figure 9. ICTRT (2007) risk criteria associated with spawner composition for viability assessment of exogenous spawners on maintaining natural patterns of gene flow. Green (darkest) areas indicate low risk combinations of duration and proportion of spawners, blue (intermediate areas indicate moderate risk areas and white areas and areas outside the graphed range indicate high risk. Exogenous fish are considered to be all fish hatchery origin, and non-normative strays of natural origin.

The proportion of hatchery fish among natural spawners, or "pHOS", is often used as a surrogate measure of gene flow. Appropriate cautions and qualifications should be considered when using this proportion to analyze hatchery effects. Adult salmon may wander on their return migration, entering and then leaving tributary streams before finally spawning. 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). Caution must also be applied in assuming that strays contribute genetically in proportion to their abundance. Several studies demonstrate little genetic impact from straying despite a considerable presence of strays in the spawning population (Blankenship et al. 2007; Saisa et al. 2003). The causative factors for poorer breeding success of strays are likely similar to those identified as responsible for reduced productivity of hatchery-origin fish in general; for example, differences in run and spawn timing, spawning in less productive habitats, and reduced survival of their progeny (Leider et al. 1990; McLean et al. 2004; Reisenbichler and McIntyre 1977; Williamson et al. 2010).

Hatchery-influenced selection (often called domestication) occurs when selection pressures imposed by 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 hatchery-origin 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 1991).

Genetic change and fitness reduction resulting from hatchery-influenced selection depends on: (1) the difference in selection pressures; (2) the exposure or amount of time the fish spends in the hatchery environment; and, (3) the duration of hatchery program operation (i.e., the number of generations that fish are propagated by the program). On an individual level, exposure time in large part equates to fish culture, both the environment experienced by the fish in the hatchery and natural selection pressures, independent of the hatchery environment. On a population basis, exposure is determined by the proportion of natural-origin fish in the hatchery broodstock and the proportion of natural spawners consisting of hatchery-origin fish (Ford 2002; Lynch and O'Hely 2001), and then by the number of years the exposure takes place. In assessing risk or determining impact, all three levels must be considered. Theoretically, strong selective fish culture with low hatchery-wild interbreeding can pose less risk than relatively weaker selective fish culture with high levels of interbreeding.

Most of the empirical evidence of fitness depression due to hatchery-influenced selection comes from studies of species that are reared in the hatchery environment for an extended period – one to two years – prior to release (Berejikian and Ford 2004). Exposure time, in the hatchery, for fall and summer Chinook salmon and for Chum salmon is much shorter, just a few months. One especially well- publicized steelhead study (Araki et al. 2007; Araki et al. 2008) showed dramatic fitness declines in the progeny of naturally spawning Hood River hatchery steelhead. Researchers and managers alike have wondered if these results could be considered a potential outcome applicable to all salmonid species, life-history types, and hatchery rearing strategies.

Besides the Hood River steelhead work, a number of studies are available on the relative reproductive success (RRS) of hatchery-origin and natural-origin fish (e.g., Berntson et al. 2011; Ford et al. 2012; Hess et al. 2012; Theriault et al. 2011). All have shown that generally hatchery-origin fish have lower reproductive success, though the differences have not always been statistically significant, and, in some years, and in some studies (e.g., Anderson et al. 2012), the opposite is true. Lowered reproductive success of hatchery-origin fish in these studies is typically considered evidence of hatchery-influenced selection. Although RRS may be a result of hatchery-influenced selection, studies must be carried out for multiple generations to unambiguously detect a genetic effect. To date, only the Hood River steelhead (Araki et al. 2007; Christie et al. 2011) and Wenatchee spring Chinook salmon (Ford et al. 2012) RRS studies have reported multiple-generation effects.

Critical information for analysis of hatchery-influenced selection includes the number, location and timing of naturally spawning hatchery fish, the estimated level of gene flow between hatchery-origin and natural-origin fish, the origin of the hatchery stock (the more distant the origin, compared to the affected natural population, the greater the threat), the level and intensity of hatchery selection, and the number of years the operation has been run in this way. Efforts to control and evaluate the risk of hatchery-influenced selection are currently largely focused on gene flow between natural-origin and hatchery-origin fish[10]. The Interior Columbia Technical Recovery Team (ICTRT) developed guidelines based on the proportion of spawners in the wild consisting of hatchery-origin fish (pHOS: Figure 12).

More recently, the Hatchery Scientific Review Group (HSRG) developed gene flow criteria/guidelines based on mathematical models developed by Ford (2002) and by Lynch and O'Hely (2001), and divided hatchery programs into two categories called integrated and segregated (isolated). Functionally the distinction is based on linking the broodstock to the natural population: integrated programs use some level of natural-origin fish as broodstock and segregated do not. Guidelines for isolated programs as recommended by the HSRG are based on pHOS, but recommended HSRG guidelines for integrated programs are also based on a metric called proportionate natural influence (PNI), which is a function of pHOS and the proportion of natural-origin fish in the broodstock (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. The HSRG guidelines vary according to type of program and conservation importance of the population. For a population of high conservation importance, their guidelines are a pHOS of no greater than 5% for segregated programs or a pHOS no greater than 30% and PNI of at least 67% for integrated programs (HSRG 2009c). Higher levels of hatchery influence are acceptable, however, when a population is at high risk or very high risk of extinction due to low abundance and the hatchery program is being used to conserve the population and reduce extinction risk, in the short-term. HSRG et al. (2004) offered additional guidance regarding segregated programs, stating that risk increases dramatically as the level of divergence increases, especially if the hatchery stock has been selected directly or

[10] Gene flow between natural-origin and hatchery-origin fish is often, and quite reasonably, interpreted as meaning actual matings between natural-origin and hatchery-origin 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, hatchery-origin spawners in the wild will either spawn with other hatchery-origin fish or with natural-origin fish. Natural-origin spawners in the wild will either spawn with other natural-origin fish or with hatchery-origin fish. But all these matings, to the extent they are successful, will generate the next generation of natural-origin fish. In other words, all will contribute to the natural-origin gene pool.

indirectly for characteristics that differ from the natural population. The HSRG recently produced an update report (HSRG 2014) in which they stated that the guidelines for isolated programs may not provide as much protection from fitness loss as the corresponding guidelines for integrated programs.

Another HSRG team recently reviewed California hatchery programs and developed guidelines that differed considerably from those developed by the earlier group (California HSRG 2012). The California HSRG felt that truly segregated programs in which no hatchery-origin returnees interact genetically with natural populations were impossible in California, and was "generally unsupportive" of the concept. However, if programs were to be managed as segregated, they recommend a pHOS of less than 5%. They 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 natural-origin 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 hatchery- and natural-origin fish, and societal values, such as angling opportunity" (California HSRG 2012). They 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% in most cases, although in supplementation or reintroduction programs the acceptable pHOS could be much higher than 5%, even approaching 100% at times. They also recommended for conservation programs that pNOB approach 100%, but pNOB levels should not be so high they pose demographic risk to the natural population.

Discussions involving pHOS can be problematic due to variation in its definition. Most commonly the term pHOS refers to the proportion of the total natural spawning population consisting of hatchery fish, and the term has been used in this way in all NMFS documents. However, the HSRG has defined pHOS inconsistently in its Columbia Basin system report, equating it with "the proportion of the natural spawning population that is made up of hatchery fish" in the Conclusion, Principles and Recommendations section (HSRG 2009c), but with "the proportion of *effective* hatchery origin spawners" in their gene flow criteria. In addition, in their Analytical Methods and Information Sources section (HSRG 2009b) they introduce a new term, *effective pHOS*. Despite these inconsistencies, their overall usage of pHOS indicates an intent to use pHOS as a surrogate measure of gene flow potential. This is demonstrated very well in the fitness effects appendix (HSRG 2009c), in which pHOS is substituted for a gene flow variable in the equations used to develop the criteria. This was clarified in the 2014 update document (HSRG 2014), which stated that the metric of interest is effective pHOS.

In the 2014 report, the HSRG explicitly addressed the differences between *census* pHOS and *effective* pHOS (HSRG 2014). In the document, the HSRG defined PNI as

$$\text{PNI} = \frac{\text{pNOB}}{(\text{pNOB} + \text{pHOS}_{\text{eff}})}$$

where $pHOS_{eff}$ is the effective proportion of hatchery fish in the naturally spawning population (HSRG 2014). The HSRG recognized that hatchery fish spawning naturally may on average produce fewer adult progeny than natural-origin spawners, as described above. To account for this difference, the HSRG defined *effective* pHOS as

$$pHOS_{eff} = RRS * pHOS_{census}$$

where $pHOS_{census}$ is the proportion of the naturally spawning population that is composed of hatchery-origin adults (HSRG 2014) [11].

Adjusting census pHOS by RRS should be done very cautiously as the (Ford 2002) model, 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 effects in the hatchery that are assumed to be genetically heritable and detrimental. A component of reduced RRS of hatchery fish is therefore already incorporated in the model and by extension the calculation of PNI and 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, where there is strong evidence of a non-genetic component to RRS, adjusting pHOS downward may be appropriate. An example of a case in which an adjustment by RRS might be justified is that of Wenatchee spring Chinook salmon (Williamson et al. 2010), where the spatial distribution of natural-origin and hatchery-origin spawners differs and the hatchery-origin fish tend to spawn in poorer habitat. However, 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. One example would be if hatchery juveniles produced from natural-origin 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, causing the "effective" pNOB to be much lower than the census pNOB.

PNI is an approximation of relative trait value, based on a simplistic model that may fail to capture important biological information, so including this information in the underlying models may be more accurate than making ad hoc adjustments to a statistic intended to be rough

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[11] Due to a typo, the published equation was erroneous; the correct equation is: $pHOS_{eff} = RRS*pHOS/(RRS*pHOS+(1-pHOS))$. See NMFS. 2017b. Endangered Species Act 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 Six Hatchery and Genetic Management Plans for Snohomish River basin Salmon under Limit 6 of the Endangered Species Act Section 4(d) Rule. September 27, 2017. NMFS Consultation No.: NWR-2013-9699. 189p..

guideline for managers. We look forward to research clarifying this issue in the near future. In the meantime, except for cases in which gene flow data reflecting natural spawning effects of hatchery-origin fish are available, or an adjustment for RRS has strong justification, NMFS feels that census pHOS is the appropriate metric to use for genetic risk evaluation.

Additional perspective on pHOS that is independent of HSRG modelling is provided by a simple analysis of the expected proportions of mating types. Figure 12 shows the expected proportion of mating types in a mixed population of natural-origin (N) and hatchery-origin (H) fish as a function of the census pHOS, assuming that N and H adults mate randomly. For example, the vertical line on the diagram marks the situation at a census pHOS level of 10%. At this level, expectations are that 81% of the matings will be NxN, 18% will be NxH, and 1% will be HxH. This diagram can also be interpreted as displaying the probability of parentage of naturally produced progeny, assuming random mating and equal reproductive success of all mating types. Under this interpretation, progeny produced by a parental group with a pHOS level of 10% will have an 81% chance of having two natural-origin parents, etc.

Random mating assumes that the natural-origin and hatchery-origin spawners overlap completely spatially and temporally. As overlap decreases, the proportion of NxH matings decreases and with no overlap the proportion of NxN matings is (1-pHOS) and the proportion of HxH matings is pHOS. RRS does not affect the mating type proportions directly, but changes their effective proportions. Overlap and RRS can be related.

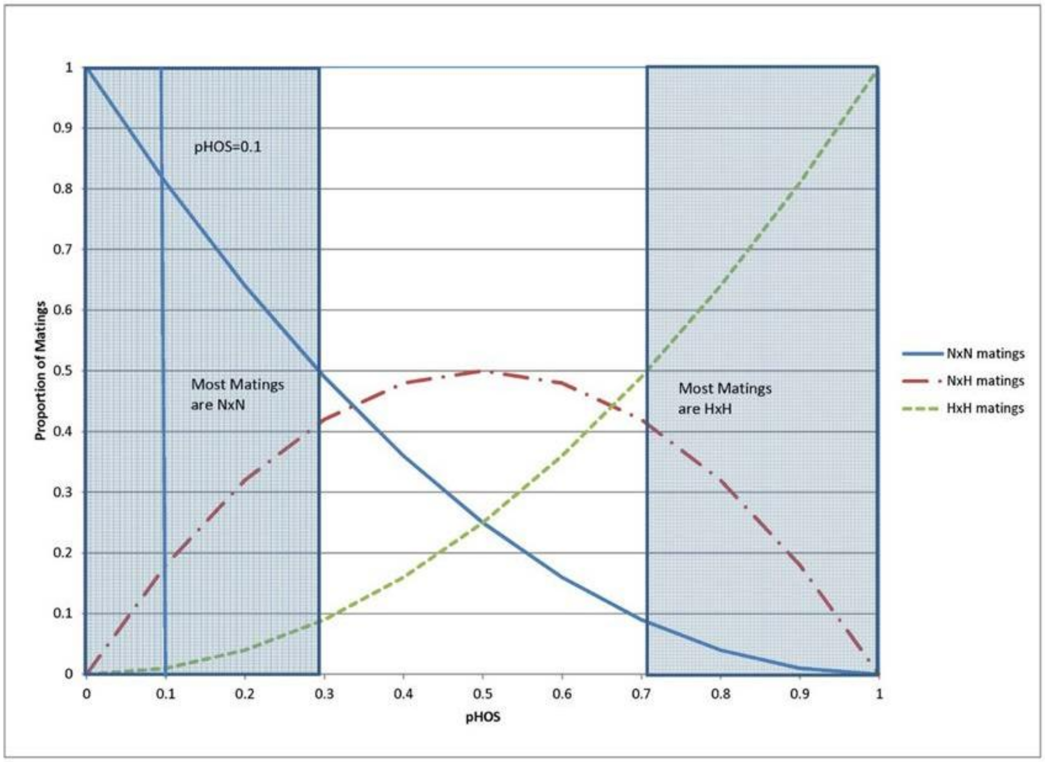

Figure 10. Relative proportions of types of matings as a function of proportion of hatchery-origin fish on the spawning grounds (pHOS) (NxN – natural-origin x natural-origin; NxH – natural-origin x hatchery; HxH – hatchery x hatchery).

Ecological effects included under this factor (i.e., "[h]atchery 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 of hatchery fish on the spawning grounds may be positive or negative. In hatcheries that 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 (Bell 2001; Bradford et al. 2000; Brakensiek 2002; Gresh et al. 2000; Kline et al. 1990; Larkin and Slaney 1996; Murota 2003; Piorkowski 1995; Quamme and Slaney 2003; Quinn and Peterson 1996; Wipfli et al. 1998). As a result, the growth and survival of juvenile salmonids may increase (Bilton et al. 1982; Hager and Noble 1976; Hartman and Scrivener 1990; Holtby 1988; Johnston et al. 1990; Ward and Slaney 1988).

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. This is an example of a negative ecological effect of hatchery fish.

Further, the added spawner density resulting from hatchery-origin fish spawning in the wild can have negative consequences if there is spatial overlap between hatchery and natural spawners, the potential exists for hatchery-derived fish to superimpose or destroy the eggs and embryos of listed species. Redd superimposition has been shown to be a cause of egg loss in pink salmon and other species (Fukushima et al. 1998, and references therein).

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

NMFS also analyzes the potential for competition, predation, and premature emigration when the progeny of naturally spawning hatchery fish and hatchery releases share juvenile rearing areas. Generally, competition and a corresponding reduction in productivity and survival may result from direct interactions when hatchery-origin fish interfere with the accessibility to limited resources by natural-origin fish or through indirect means, when the utilization of a limited resource by hatchery fish reduces the amount available for fish from the natural population (Rensel et al. 1984). Naturally produced fish may be competitively displaced by hatchery fish early in life, especially when hatchery fish are more numerous, are of equal or greater size, when hatchery fish take up residency before naturally produced fry emerge from redds, and if hatchery fish residualize. Hatchery fish might alter naturally produced salmon behavioral patterns and habitat use, making them more susceptible to predators (Hillman and Mullan 1989; Steward and Bjornn 1990). Hatchery-origin fish may also alter naturally produced salmonid migratory responses or movement patterns, leading to a decrease in foraging success (Hillman and Mullan 1989; Steward and Bjornn 1990). Actual impacts on naturally produced fish would 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).

Competition may result from direct interactions, or through indirect means, as when utilization of a limited resource by hatchery fish reduces the amount available for naturally produced fish (Rensel et al. 1984). Specific hazards associated with competitive impacts of hatchery salmonids on listed naturally produced salmonids may include competition for food and rearing sites (NMFS 2012a). In an assessment of the potential ecological impacts of hatchery fish production on naturally produced salmonids, the Species Interaction Work Group (Rensel et al. 1984) concluded that naturally produced coho and Chinook salmon and steelhead are all potentially at "high risk" due to competition (both interspecific and intraspecific) from hatchery fish of any of these three species. In contrast, the risk to naturally produced pink, chum, and sockeye salmon due to competition from hatchery salmon and steelhead was judged to be low.

Several factors influence the risk of competition posed by hatchery releases: whether competition is intra- 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. Although newly released hatchery smolts are commonly larger than natural-origin fish, and larger fish usually are superior competitors, natural-origin fish have the competitive advantage of prior residence when defending territories and resources in shared natural freshwater habitat. Tatara and Berejikian (2012) further reported that hatchery- influenced developmental differences from co-occurring natural-origin fish life stages 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 naturally produced juvenile salmonids from occupied stream areas, leading to abandonment of advantageous feeding stations, or premature out-migration (Pearsons et al. 1994). 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 naturally produced 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. They also may prey on younger, smaller-sized juvenile salmonids. 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 from residual Chinook and coho hatchery salmon on naturally produced salmonids are a possibility given that the number of smolts per release is generally higher and that the issue of residualism for these species that have not been as widely investigated compared to steelhead. Therefore, for all species, the monitoring of natural stream areas downstream of hatchery release points is necessary to determine magnitude of hatchery smolt residualism on the natural-origin juvenile salmonids.

The risk of adverse competitive interactions between hatchery-origin 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 naturally produced fish in freshwater (California HSRG 2012; Steward and Bjornn 1990).
- Releasing all hatchery fish at times when natural-origin fish vulnerable to resource competition are not present in downstream areas in substantial numbers.
- Releasing all hatchery fish after the majority of sympatric natural-origin juveniles have emigrated seaward to reduce the risk of competition for food and space.
- Operating hatcheries such that hatchery fish are reared to sufficient size and uniform individual size such that smoltification occurs in nearly the entire population (Bugert et al. 1992).

- Releasing hatchery smolts in lower river areas, below areas used for stream-rearing naturally produced juveniles.
- Monitoring the incidence of non-migratory smolts (residuals) after release and adjusting hatchery rearing strategies, fish release location, and release timing if substantial competition with naturally rearing juveniles is documented.

Critical to analyzing competition risk is information on the quality and quantity of spawning and rearing habitat in the action area, 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-origin 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, distribution, and timing for juvenile hatchery fish in the action area; and the size of hatchery fish relative to co-occurring natural-origin fish.

Another important possible ecological effect of hatchery releases is predation. Salmon and steelhead are piscivorous and can prey on other salmon and steelhead. Predation, either direct (direct consumption) 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 and by the progeny of naturally spawning hatchery fish (direct predation effects), and predation by avian and other predators attracted to the area by an abundance of hatchery fish (indirect effects). 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 as smolts that emigrate quickly to the ocean can prey on fry and fingerlings that are encountered during the downstream migration. As mentioned above, some of these hatchery fish do not emigrate and instead take up residence in the stream (residuals) where they can prey on stream-rearing juveniles over a more prolonged period. 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 and 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. More studies are now available, but they are still too sparse to allow many generalizations to be made about risk. Newly released hatchery-origin yearling salmon and steelhead may prey on juvenile fall Chinook and steelhead, and other juvenile salmon in the freshwater and marine environments (Hargreaves and LeBrasseur 1985; Hawkins and Tipping 1999; Pearsons and Fritts 1999). Low predation rates have been reported for released steelhead juveniles (Hawkins and Tipping 1999; Naman and Sharpe 2012).

Hatchery steelhead timing and release protocols used widely in the Pacific Northwest were shown to be associated with negligible predation by migrating hatchery steelhead on fall Chinook 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, predominantly) 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 (HSRG 2004b; Pearsons and Fritts 1999), but other studies have concluded that salmonid predators prey on fish 1/3 or less their length (Beauchamp 1990; Cannamela 1992; CBFWA 1996; Hillman and Mullan 1989; Horner 1978). Hatchery fish may also be less efficient predators as compared to their natural-origin conspecifics, reducing the potential for predation impacts (Bachman 1984; Olla et al. 1998; Sosiak et al. 1979).

Large concentrations of migrating hatchery fish may attract predators (birds, fish, and seals) and consequently contribute indirectly to predation of emigrating wild fish (Steward and Bjornn 1990). The presence of large numbers of hatchery fish may also alter natural-origin salmonid behavioral patterns, potentially influencing their vulnerability and susceptibility to predation (Hillman and Mullan 1989; Kostow 2009; USFWS 1994). Hatchery fish released into natural-origin fish production areas, or into migration areas during natural-origin fish emigration periods, may therefore pose an elevated, indirect predation risk to commingled listed fish. Alternatively, a mass of hatchery fish migrating through an area may overwhelm established predator populations, providing a beneficial, protective effect on co- occurring natural-origin fish. Newly released hatchery-origin smolts generally exhibit reduced predator avoidance behavior relative to co-occurring natural-origin fish (Flagg et al. 2000; Olla and Davis 1989). In addition, newly released smolts have been found to survive at a reduced rate during downstream migration relative to their natural-origin counterparts (Flagg et al. 2000; Melnychuk et al. 2014). These studies suggest that predator selection for hatchery-origin and natural-origin fish in commingled aggregations is not equal. Rather, the relatively naïve hatchery-origin fish may be preferentially selected in any mixed schools of migrating fish until they acclimate to the natural environment, and hatchery fish may in fact sate (and swamp) potential predators of natural-origin fish, shielding them from avian, mammal, and fish predation.

There are several management actions that hatchery programs can implement to reduce or avoid the threat of predation:

- Releasing all hatchery fish as 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.
- Releasing all hatchery fish at times when natural-origin fish of individual sizes

vulnerable to direct predation are not present in downstream areas in substantial numbers.
- Releasing all hatchery fish after the majority of sympatric natural-origin juveniles have emigrated seaward to reduce the risk that avian, mammal, and fish predators may be attracted to commingled abundances of hatchery and natural-origin salmon or steelhead.
- 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.

The release of hatchery fish and hatchery effluent into juvenile rearing areas can lead to transmission of pathogens, contact with chemicals or altering of environmental parameters (e.g., dissolved oxygen) that can result in disease outbreaks. Fish diseases can be subdivided into two main categories: infectious and non-infectious. Infectious diseases are those caused by pathogens such as viruses, bacteria, and parasites. Non-infectious diseases are those that cannot be transmitted between fish and are typically caused by genetic or environmental factors (e.g., low dissolved oxygen). Pathogens can also be categorized as exotic or endemic. Exotic pathogens are those that have no history of occurrence within state boundaries. For example, *Oncorhynchus masou virus* (OMV) would be considered an exotic pathogen if identified anywhere in Washington state because its natural geographic range has so far been limited to Japan and Eastern Asia (USFWS 2004). 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. 2008), including:

- Introduction of exotic pathogens
- Introduction of endemic pathogens to a new watershed
- Release of infected fish or fish carcasses
- Continual pathogen reservoir
- Pathogen amplification

The transmission of pathogens 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 (Naish et al. 2008; Steward and Bjornn 1990).

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).

Adherence to a number of state, federal, and tribal fish health policies limits the disease risks associated with hatchery programs (IHOT 1995; NWIFC and WDFW 2006; ODFW 2003; USFWS 2004). Specifically, the policies govern the transfer of fish, eggs, carcasses, and water to prevent the spread of exotic and endemic reportable pathogens. 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 facility through the treatment of incoming water (e.g., by using ozone) or by leaving the hatchery through hatchery effluent (Naish et al. 2008). Although preventing the exposure of fish to any pathogens prior to 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. 2008). Treating the hatchery effluent would also minimize amplification, but would not reduce disease outbreaks within the hatchery itself 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.

Non-infectious diseases are those that cannot be transmitted between fish and are typically caused by genetic or 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 NPDES permit administered by the U.S. Environmental Protection Agency (EPA). Other chemicals are discharged in accordance with manufacturer instructions. The NPDES permit also requires monitoring of settleable and unsettleable solids, temperature, and dissolved oxygen in the hatchery effluent on a regular basis 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 period of time. Based on the vast literature available on successful rearing of salmon and trout in aquaculture, one group of non-infectious diseases that are rarely expected to occur in current hatchery operations includes those caused by nutritional deficiencies.

Juvenile hatchery-origin salmon that would be released to emigrate into estuarine and marine waters within and adjacent to the action area each year have the potential to adversely affect natural populations of Chinook salmon and steelhead through competition and predation. As juvenile salmon released from the proposed programs arrive in the estuary, they may compete with other Chinook salmon and steelhead in areas where they co-occur, if shared resources are limiting. The hatchery-origin salmon may also prey on natural fish of sizes vulnerable to consumption. Effects may be more pronounced in 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 the main body of the Puget Sound and into the Pacific Ocean.

Regarding competition effects in estuarine and marine waters, the main limiting resource for Chinook 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 (Duffy 2003; Pearcy and McKinnell 2007; Rensel et al. 1984). 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 (Brodeur 1991; Holt et al. 2008; Rensel et al. 1984). Researchers have looked for evidence that marine area carrying capacity can limit salmonid survival (Beamish et al. 1997; HSRG 2004a). Some evidence suggests density-dependence in the abundance of returning adult salmonids (Bradford 1995; Emlen et al. 1990; Lichatowich et al. 1993), associated with cyclic ocean productivity (Beamish and Bouillon 1993; Beamish et al. 1997; Nickelson et al. 1986). 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 (Beamish and Bouillon 1993; Beamish et al. 1997; Mahnken et al. 1998; Nickelson et al. 1986).

Complicating any assessment of the marine area predation and competition effects of hatchery-origin Chinook salmon production is that the temporal distribution, trophic interactions, and marine area limiting factors for Puget Sound Chinook salmon populations in marine waters are poorly understood (Duffy 2003). Assessment of the effects of hatchery Chinook salmon on natural populations of Chinook salmon in Puget Sound is problematic because there is a lack of basic information about what shoreline habitats are used by Chinook salmon and to what extent this nearshore life stage contributes to growth and survival through subsequent life stages (Fresh

2006). There is also an absence of information regarding the carrying capacity of Puget Sound for juvenile Chinook salmon on which to base analyses of food resource competition risks. Naish et al. (2008) could find no systematic, controlled study of the effects of density on wild salmon, or of interactions between wild and hatchery salmon, nor on the duration of estuarine residence and survival of salmon. Further complicating any assessment of ecological effects are observed natural cycles and fluctuations in the carrying capacity of marine environments. The Puget Sound marine ecosystem was until recently believed to be stable, internally regulated and largely deterministic. The current view is that Puget Sound is dynamic with much environmental stochasticity and ecological uncertainty (Francis 2002; Mahnken et al. 1998).

For these reasons, it is difficult to make judgments regarding the carrying capacity of Puget Sound and the Pacific Ocean, and whether there are any ecological effects associated with hatchery-origin salmon production that are adversely affecting salmon and steelhead productivity and survival, particularly when natural populations are contributing few fish toward any carrying capacity level. The limited information available is insufficient to identify the source of any ecological interactions and limiting factors, for example which species might be responsible for density dependent interactions let alone which hatchery or hatcheries, and consequently what remedies are likely to be effective. Assigning marine area ecological and demographic effects specifically for hatchery-origin salmon production from any individual Puget Sound region (e.g., the Stillaguamish River watershed) would be speculative, since hatchery-origin fish intermingle at the point of ocean entry with natural populations and other hatchery fish from many other Pacific Northwest regions. At best, it can be said that, during years of limited food supply, juvenile fish survival and size may be reduced, and this is true with or without hatchery-origin fish. Hatchery enhancement of salmon populations could exacerbate density-dependent effects during years of low ocean productivity. However, there are no studies that demonstrate or suggest, the magnitude of hatchery salmon smolt release numbers in Puget Sound that might be associated with adverse changes in natural population Chinook salmon survival rates in the estuary, the Puget Sound, or in the Pacific Ocean.

Available knowledge and research abilities are insufficient, at the present time, to discern the role and contribution of hatchery fish in any density-dependent interactions affecting salmon and steelhead growth and survival in Puget Sound and in the Pacific Ocean. From the scientific literature, the conclusion seems to be that the influence of density-dependent interactions on growth and survival is likely small compared with the effects of large scale and regional environmental conditions. While there is evidence that hatchery production on a scale many times larger than the production considered in this biological opinion can impact salmon survival, the degree of impact or level of influence is not yet understood or predictable. NMFS will monitor emerging science and information and will reinitiate section 7 consultation in the event that new information reveals effects of the action that may affect listed species or critical habitat in a manner, or to an extent, not considered in this consultation.

2.4.5. Factor 4. Research, monitoring, and evaluation (RM&E)

NMFS also analyzes proposed RM&E actions for effects on listed species and on designated critical habitat. Generally, negative effects on the fish from RM&E are weighed against the value or benefit of new information, particularly information that tests key assumptions and that reduces critical uncertainties. RM&E actions including, but not limited to, collection and handling (purposeful or inadvertent), holding the fish in captivity, sampling (e.g., the removal of scales and tissues), tagging and fin-clipping, and observation (in-water or from the bank) can cause harmful changes in behavior and reduced survival. Similar effects include handling during broodstock collection—those effects are analyzed in Section 2.4.2.2.3 below.

In addition, NMFS also considers the overall effectiveness of the RM&E program. There are five factors that NMFS takes into account when it assesses the beneficial and negative effects of hatchery RM&E: (1) the status of the affected species and effects of the proposed RM&E on the species and on designated critical habitat, (2) critical uncertainties over effects of the Proposed Action on the species, (3) performance monitoring and determining the effectiveness of the hatchery program at achieving its goals and objectives, (4) identifying and quantifying collateral effects, and (5) tracking compliance of the hatchery program with the terms and conditions for implementing the program. After assessing the proposed hatchery RM&E, and before making any recommendations to the action agencies, 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.

Hatchery actions also must be assessed for masking effects. For these purposes, masking is when hatchery fish included in the Proposed Action mix with and are not identifiable from other fish. The effect of masking is that it 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. 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.

2.4.6. Factor 5. The operation, maintenance, and construction of hatchery facilities

Operation, maintenance, and construction activities can alter fish behavior and can injure or kill eggs, juveniles, and adults. They can also degrade habitat function. Here, NMFS analyzes a hatchery program for effects on listed species from encounters with hatchery structures and for effects on habitat conditions that support and promote viable salmonid populations. For example, NMFS wants to know if the survival or spatial structure of ESA-listed fish (adults and juveniles) is affected when they encounter weirs and other hatchery structures, or by changes in the quantity or quality of streamflow caused by hatchery facility-related diversions. NMFS analyzes changes to riparian habitat, channel morphology and habitat complexity, and in-stream substrates attributable to operation, maintenance, and construction activities and confirms whether water diversions and fish passage facilities are constructed and operated consistent with NMFS criteria. The level of effect for this factor can range from negligible, when in-water structures are absent or few, to negative, when screening or intakes do not meet NMFS 2011 guidelines.

2.4.7. Factor 6. Fisheries that Exist Because of the Hatchery Program

There are two aspects of fisheries that NMFS considers here. One is when listed species are inadvertently and incidentally taken in fisheries targeting hatchery fish. The other is when fisheries are used as a tool to prevent hatchery fish, including hatchery fish included in an ESA listed ESU or DPS that are surplus to recovery needs, from spawning naturally. In each case, the fishery must be strictly regulated based on take levels, including catch and release effects, of natural-origin ESA-listed species. The effects of these fisheries can range from positive (productivity and diversity VSP parameters) to negative (abundance VSP parameter).

2.4.8. Analysis of the Effects of the Proposed Action

Analysis of the proposed action identified one risk factors, and the associated take pathways, that may potentially have negative effects on ESA protected Puget Sound Chinook salmon and/or Puget Sound steelhead and on designated critical habitat, and two factors that are likely to be beneficial to listed Puget Sound Chinook salmon. The Proposed Action would have a negligible effect on two other hatchery-related risk factor, and one factor is not applicable. A summarized analysis of all applicable (i.e., negative, beneficial, or negligible) hatchery effect factors is presented below. The framework NMFS followed for analyzing effects of the proposed hatchery programs is described in Section 2.4.1 of this opinion.

2.4.9. Factor 1. Broodstock Collection

All four of the proposed salmon hatchery programs remove fish from the local natural population for broodstock which is typically viewed as a negative effect for salmon because removing mature natural-origin adults from the spawning grounds can reduce the effective genetic size and N_e of the population, through a reduction in the number of available natural spawners. However, the removal of adult Stillaguamish summer and fall Chinook salmon for broodstock is limited to a set number of 65 pairs for the summer program, and 15 pairs for the fall program, which represents 11% of the total escapement for the combined Stillaguamish Chinook salmon populations. Additionally, in-river egg-to-migrant survival is estimated within the range of 1.5 - 12.5% (Figure 9), in recent years, which may contribute to the variables that effect the recruits per spawner productivity estimate of less than replacement (Table 8). The hatchery program reduces in river mortality experienced by juveniles the programs rear and release as smolts. The result is a higher survival to the smolt stage for the overall populations, than would have otherwise been measured through natural spawning alone. Thus, the effects of this factor are considered beneficial.

Due to the overlap on the North Fork Stillaguamish River spawning grounds, both summer and fall adult Chinook salmon are handled in order to collect adult summer broodstock. In recent years with data available, approximately 7-17 Chinook salmon genetically assigned as fall were captured (pers. comm., Kate Konoski and Charlotte Scofield, STI, May 15, 2018). These fall assigned Chinook salmon were subsequently volunteered for use in the fall captive brood program (Stillaguamish Tribe of Indians 2017a). Stress associated with handling during the summer and early fall may be increased due to temperatures above 59°F (15°C) (Bjornn and Reiser 1991). This increased stress response, as well as the higher fecundity recorded during spawning from these anadromous returns in relation to their captive reared counterparts (unpublished intake data, STI 2018) facilitates the need to retain these fish for program use. The operators have set a goal of 30 adult fall identified Chinook salmon to be retained through this collection method annually (Table 2). The fall assigned fish are included in the 11% estimated above for the total summer and fall Chinook populations combined.

The number of smolts retained annually for captive broodstock for the fall Chinook salmon program is limited to 450 smolts. Smolts are retained based on the genetic assignment likelihood of greater than 90% (Small et al. 2017a) to the fall population. The number of smolts retained for the program annually has been lower than the program goals as shown in Table 17 below.

When the maximum target of 900 smolt captures in order to obtain the program goal of 450 fall smolts for retention as captive brood occurs, the estimated total proportion of the juvenile Stillaguamish Chinook populations subjected to handling, transport and subsequent release during broodstocking activities in the South Fork River would be 0.52 percent. Comparing data provided on the number of smolts captured annually via seine in the South Fork for retention as captive brood (Table 16) with the average wild smolt out-migrants reported over the 2005-2016 trapping seasons (170,386), the number of smolts retained for the captive brood programs represents approximately 0.07 percent of the total out-migrating wild Stillaguamish Chinook salmon population. This represents a very small proportion of the total natural smolt population, and is likely a negligible effect. Additionally, the egg to smolt survival in the Stillaguamish River has been chronically low (Figure 9), with an average of 8.5%, with a range of 1.5 – 12.5%, for the 2005 -2016 timeframe (Griffith and Arman 2010; Griffith et al. 2009; Griffith and Scofield 2012; Scofield and Griffith 2012; Scofield and Griffith 2013; Scofield and Griffith 2014; Scofield and Griffith 2015; Scofield and Griffith 2016). Survivals of juveniles retained for the captive brood program to spawn are reported in the 64-80% range. Thus, the overall effect should be considered beneficial due to the increased survival benefit the captive brood program is providing to the overall abundance of the Stillaguamish fall Chinook population.

Physical handling effects on target and non-target species are discussed further below in Section 2.4.2.2.3. Broodstock Collection.

2.4.10. 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 hatchery programs can pose both genetic and ecological risks, there are benefits to the species from these integrated programs designed to supplement the natural populations, providing an overall beneficial effect to within population diversity and to viability. The overall net effect on Chinook salmon is negligible, as discussed below.

Only ecological and physical broodstock collection effects are relevant for Puget Sound steelhead because these proposed programs do not propagate steelhead. The overall ecological effect is negligible, and the broodstock collection effect is low, as discussed below.

2.4.10.1.1. Genetic effects

Evaluation of Proposed Adult Management

For the two listed Stillaguamish Chinook salmon programs, NMFS considers three major areas of genetic effects: within-population diversity, outbreeding effects, and hatchery-influenced selection. For both Chinook salmon programs, all three areas of genetic effects could occur. Rarely is it possible to measure the three types of effects separately, however. Until more direct genetic tools are available, our metrics for inferring the magnitude of these effects are pHOS, pNOB, and in the case of integrated programs, PNI.

NMFS has not adopted HSRG gene flow (i.e., pHOS, pNOB, PNI) standards. However, at present, these gene flow standards and the 5% stray standard (Grant 1997) are the only widely acknowledged quantitative standards available, so NMFS considers them a useful screening tool[12]. Programs must be evaluated individually. For a particular program NMFS may consider a pHOS or PNI level to be a lower risk than the HSRG would, but generally, if a program meets HSRG standards, NMFS will consider the risk it poses to be acceptable.

Integrated programs

To perform the analysis, NMFS uses models that consider the best available information for the target populations to determine the likely PNI of the population based on the applicants proposed proportion of natural-origin broodstock (pNOB) and the pHOS in the target populations' natural spawning areas. Recall from Section 2.4.1.2 that PNI is computed as pNOB/ (pNOB + pHOS). A PNI of > 0.50 indicates that natural selection outweighs hatchery-influenced selection and is the target for 'contributing' populations according to the HSRG (e.g., HSRG 2009a); per the PRA (NMFS 2010) a 'contributing' population is analogous to a Tier 2 population. The timeline associated with achieving a PNI > 0.50 is unique to each program.

Hatchery Influenced Selection - Stillaguamish Summer Chinook

The analysis for the summer Chinook salmon program demonstrates that, under the current management regime as described over the past ten years of operations, obtaining a PNI of > 0.50 on an annual basis is likely to occur fifty percent of the time. To make this determination, NMFS used data from 2006 to 2015 provided by the co-managers in Table 10 (Harbeck and Hurst 2017). NMFS believes that data from 2006 to 2015 are a good basis for estimating future program genetic effects, and are within the range of natural- and hatchery-origin returns to the Stillaguamish basin, observed over the last ten years of program operations. The modeling results indicated that the current program PNI is often above a PNI of 0.50, with a ten year average of 0.44 (range is 31-62%), consistent with a PRA Tier 2 population. This PNI level would indicate that hatchery influenced selection is negligible for the composite population (HSRG 2009a), since the average estimated PNI value is estimated near 50%. This estimated PNI value indicates that the natural-origin spawners represent an equal, if not higher proportion, of the spawning population as measured annually during the past ten years of typical operations. Thus, broodstock collection practices for the program appear to be mitigating for any possible domestication effects on the composite population, which may be introduced through hatchery-influenced selection processes (HSRG 2004b; HSRG 2009a), and are ensuring the composite population is maintaining genetic diversity.

A final consideration in the analysis is that in some years, pHOS estimates for the Stillaguamish aggregate can exceed the HSRG recommended value of 0.30 for an integrated program operating on a contributing population. The estimated pHOS range between return years 2006 – 2015 was 38- 69%. However, these standards are not required when a natural population is in the first two

[12] In addition, HSRG standards have been used multiple recent court cases regarding hatchery practices, and have been incorporated into policy by Washington's Fish and Wildlife Commission Washington Fish and Wildlife Commission. 2009. Policy POL-C3619: Hatchery reform. Olympia, Washington.

stages of recovery, preservation and/or recolonization (HSRG 2014). As designed, by providing a demographic boost to the natural population through an increased abundance of spawners this hatchery program may also provide additional beneficial effects, such as increased diversity and spatial structure to this depressed natural population. Thus, based on the estimated PNI values for the program, the effect of hatchery influenced selection on the natural population is considered negligible.

Within Population Diversity - Stillaguamish Summer Chinook
Chinook salmon collected as adults for broodstock are randomly collected in the North Fork across the extent of the August through early-September return period. Broodstock collection leads to the removal of an average of 11% of the total adult Stillaguamish Chinook salmon escapement (summer and fall populations combined), as reported in Table 10. The program removes summer Chinook males, females, and jacks at proportions equivalent to total return proportions. Given the above, proposed broodstock collection practices minimize the risk of within population genetic diversity reduction effects on the population that spawns naturally. An estimated 50% of the adult Chinook salmon captured as broodstock are marked hatchery-origin fish. An evaluation of the genetic heterozygosity for both the natural and hatchery Stillaguamish Chinook was conducted over a period of four years. Results from this analysis concluded that the wild and captive stocks representing the Stillaguamish Summer Chinook salmon population are not genetically divergent from one another, and do not significantly differ in respect to genetic statistics such as allelic richness and heterozygosity (Eldridge and Killebrew 2008). Therefore, effects on within population diversity are expected to be negligible.

Mating designs (1x1 pairwise with back-up male use applied to 65 males and 65 females; incorporation of jacks at levels similar to their proportions in the naturally spawning population) and rearing protocols applied at the hatchery (e.g., acclimation of fish for release in natural fish production area) are designed to retain populations that are representative of the total returns, and that maintain high effective population sizes (> than 250 fish). The program produces sub-yearling fish, limiting the duration of time spent in the hatchery environment, and mimicking the natural emigration strategy for the natural Chinook salmon population. Protocols applied through the program appear adequate to minimize the risk of genetic change and loss of genetic diversity and fitness within the propagated population, and among regional Chinook salmon populations.

Adequate survival rates for hatchery program Chinook releases, and apparent low recruitment levels for naturally spawning fish have led to an increased annual proportion of F1 hatchery-origin Chinook of the total naturally spawning population: 7% in 1990, and 60% in 1999. The importance of maintaining appropriate, effective broodstock collection and mating protocols to maintain within-population diversity of the total population is highlighted by this circumstance (to the extent possible, minimize the risk of the Ryman-Laikre effect). Thus, as discussed, the effect of the proposed action on population diversity of the Stillaguamish summer Chinook salmon population is beneficial to the overall population viability by maintaining the existing genetic diversity despite the small number of effective spawners.

Hatchery Influenced Selection and Within Population Diversity (Combined) – Stillaguamish Fall Chinook

Our analysis of the Stillaguamish Fall Chinook salmon population PNI is complicated by the overlap in time and space with the Stillaguamish summer Chinook salmon, some of which are included in this proposed action. Thus, we examined the summer and fall populations combined, as examining the fall population is currently not possible due to the limited data thus far on the fall program returns.

Mating of mature captive brood is determined by the exclusion of full and half siblings using genetic screening at the time of maturity to ensure maximum effective breeders are used, and heterozygosity is maintained (Small et al. 2017a; Small et al. 2017b; Small et al. 2016). Due to this screening, the effects of both hatchery influenced selection and within population diversity should be negligible.

Implementing the long-term goal the co-managers provided is contingent on obtaining enough captive brood fall Chinook smolts and adults annually to bolster the captive brood component of the program to reach the 200,000 release goal. Operators anticipate a release of approximately 125,000 fall Chinook salmon smolts in 2018. Survival rates to maturity for the captive brood program have averaged 70% over 2014 -2016 (STI unpublished data, MS Excel file 5/2018). As the program continues to evolve and returns increase, it is expected that diversity should increase as the number of individuals available for broodstock increases.

Table 16. Smolts retained for the fall Chinook salmon captive brood program 2008-2016.

Brood Year	Total Sampled	Total Fall Retained
2008	35	19
2009	162	61
2010	200	96
2011	258	119
2012	286	145
2013	269	170
2014	127	67
2015	407	224
2016	525	241

Data Source: STI unpublished data, 5/2018.

Outbreeding Effects - Summer and Fall Chinook Salmon Programs (Combined)

Similar to segregated programs, we must also consider the effects of fish that stray from these programs into non-target ESA-listed populations, Outbreeding Effects (Table 16), as well as effects from fish, which stray into the Stillaguamish watershed.

There is no attempt to limit the proportions of hatchery and natural-origin adults collected. However, operators read coded wire tags removed from fish held as adult broodstock as well as conduct genetic analysis at the time of spawning and cull fish identified to originate from other watersheds. This practice should eliminate any risk of including non-target Stillaguamish stocks, thus outbreeding effects on Stillaguamish Chinook populations from outside populations are considered to be negligible.

2.4.10.1.2. Ecological Effects

Adult Nutrient Contribution

The return of hatchery fish likely contributes nutrients to the action area. Table 17 shows that if all estimated returning fish spawn naturally, they would contribute an estimated 66 kg of phosphorous to the action area annually. With known harvest rates outside of the United States (Section 2.3.4) and fish collected for broodstock, the true contribution is likely less than this value. Regardless, hatchery-origin salmon increase phosphorous concentrations, which likely compensates for some marine-derived nutrients lost from declining numbers of natural-origin fish. Thus, the potential effect of additional nutrients is beneficial, but negligible.

Table 17**.** Total phosphorous imported by adult returns from the proposed hatchery salmon programs based on the equation (Imports= hatchery adults*mass*phosphorous concentration) in Scheuerell et al. (2005).

Program	Release number	SAR[1]	Estimated number of hatchery-origin adults[2]	Adult mass (kg)	Phosphorous concentration (kg/adult)	Phosphorous imported (kg/year)
Summer Chinook	220,000	0.43	946	5.5	0.0038	20
Fall Chinook	200,000	0.43	860	5.5	0.0038	18
Coho	60,000	0.48	288	5.5	0.0038	6
Chum	250,000	0.35	875	5.5	0.0038	18

[1] Smolt-to-adult survival rate (SAR). Fall Chinook returns have been limited, thus the summer Chinook SAR was used as a surrogate.

[2] Calculated by multiplying the release number by the smolt to adult return (SAR) values.

Competition with Natural-origin Chinook for Spawning Sites

Competition and density-dependent effects of hatchery program-origin adult summer and fall Chinook on listed natural Chinook salmon populations (redd superimposition and competition for mates and spawning sites) are possible. These Chinook salmon programs have a restoration focus, and, as such, program fish are intended to spawn naturally. Based on the reported proportion of marked hatchery fish recovered on the spawning grounds from 2006-2015 (Table 10) the ratio of hatchery fish to naturally spawning fish is nearly equal with a ten-year average of 56%. The competition risks are limited by the small program size and, as a result, minimize any displacement of natural Chinook salmon. Benefits to population diversity and viability as described above regarding salmon recovery hatchery programs are balanced against this small, negative competition risk. Thus, effects on listed populations through this effect are negligible. Similarly, the small size of the coho and chum programs also limit the potential number of returning adults (Table 17) and thus any potential for spawning site competition with natural listed Chinook salmon populations. The majority of coho and chum salmon spawn later in the season, typically October through December, and in different river reaches (Table 2), so there is very little spatial or temporal overlap between naturally spawning Chinook salmon and naturally spawning coho and chum salmon. The effect from the coho and chum programs on listed Chinook populations for spawning site competition is negligible.

The difference in spawn timing and preferred locations in the Stillaguamish watershed for Chinook, coho, and fall chum salmon relative to listed steelhead makes adult fish interactions and substantial competitive or redd superimposition effects in listed steelhead spawning areas unlikely, and therefore negligible (Table 18, Table 22).

Competition with Listed Steelhead for Spawning Sites

Competition between adult hatchery-origin salmon and listed summer and winter steelhead is likely negligible due to differences in run timing, holding, and spawn timing (Table 18). Chinook, coho and chum salmon complete spawning earlier than steelhead (by December) and prefer different spawning locations in the watershed, such as the lower mainstem (chum and Chinook) and tributaries (coho) (Table 2; Stillaguamish Tribe of Indians 2015; Stillaguamish Tribe of Indians 2016).

Table 18. Run timing, holding, and spawn timing of listed Stillaguamish summer and fall Chinook salmon and summer and winter steelhead.

Species	River Entry Timing	Spawning	Locations
Summer Chinook Salmon	Late May - August	Late August-mid October	NF and SF, large tributaries
Fall Chinook Salmon	August - September	Mid-September – Mid-November	NF and SF, mainstem and large tributaries
Summer Steelhead	May – October	Jan - May	Deer Creek upstream of RM 5.1 and Canyon Creek upstream of RM 2.1
Winter Steelhead	November - April	March - June	Mainstem, NF and SF, tributaries

2.4.10.1.3. Broodstock Collection

Broodstock Collection of Juveniles for Captive Brood

The operators collect smolts for broodstock in the South Fork Stillaguamish River using small mesh gill or seine nets beginning in early March and extending through July. Seining occurs in eddies from South Fork Stillaguamish River confluence of the mainstem (RM 17.8) to the anadromous barrier of Granite Falls (RM 34.5). Past operations consisted of seining two days a week. In order to capture and retain the goal of 450 fall Chinook smolts, seining may occur up to five days a week (pers. comm., Kate Konoski, May 15, 2018).

When the maximum target of 900 smolt captures in order to obtain the program goal of 450 fall smolts for retention as captive brood occurs, the estimated total proportion of the juvenile Stillaguamish Chinook populations subjected to handling, transport and subsequent release during broodstocking activities in the South Fork River would be 0.52 percent. Comparing data provided on the number of smolts captured annually via seine in the South Fork for retention as captive brood (Table 16) with the average wild smolt out-migrants reported over the 2005-2016 trapping seasons (170,386), the number of smolts retained for the captive brood programs represents approximately 0.07 percent of the total out-migrating wild Stillaguamish Chinook salmon population. This represents a very small proportion of the total natural smolt population, and is likely a negligible effect. Additionally, the egg to smolt survival in the Stillaguamish River has been chronically low (Figure 9), with an average of 8.5%, with a range of 1.5 – 12.5%, for the 2005 -2016 timeframe (Griffith and Arman 2010; Griffith et al. 2009; Griffith and Scofield 2012; Scofield and Griffith 2012; Scofield and Griffith 2013; Scofield and Griffith 2014; Scofield and Griffith 2015; Scofield and Griffith 2016). Survivals of juveniles retained for the captive brood program to spawn are reported in the 64-80% range. Thus, the overall effect should be considered beneficial due to the increased survival benefit the captive brood program is providing to the overall viability of the Stillaguamish fall Chinook population.

The effects of seining for juveniles on listed juvenile steelhead populations has been minimal at the past level of seining two days a week (done to obtain 200 fall smolts). The operators report past operations resulted in the direct mortality of less than 1% of the smolts seined (Stillaguamish Tribe of Indians 2017a). This mortality estimate is likely conservative because it includes estimated effects on both listed anadromous steelhead parr and trout captured and released. Based on the direct observation of juveniles handled during seining operations (Stillaguamish Tribe of Indians 2017a), 30-160 juvenile steelhead have been collected annually. It is uncertain if these are all anadromous juveniles. If this collection effort was expanded to the full 20 weeks, increased to five times a week, using the estimate of up to 26 smolts a day being captured, per the past effort, this could equate to 2,600 juvenile steelhead handled. NMFS performed a conservative estimate, assuming these juveniles were all anadromous, and using the average SAR value reported for steelhead released at Whitehorse Ponds Hatchery of 0.61% (WDFW 2014). Assuming all of these juveniles were anadromous, and all handling resulted in mortality, multiplying the survival by the total encounters indicates that an adult equivalent equal to 16 natural-origin steelhead would die. If assigned to a single steelhead population in the basin (e.g., see table 14), this would result in a 3.2% reduction of the spawning population. However, based on the data provided by the operators, the observed direct handling mortality is <1%, therefore the likely mortality is only 26 juveniles. Using this estimate and multiplying the survival by this total encounter number does not equal one adult equivalent natural-origin steelhead. It is unlikely that all the juvenile mortalities would be from one population, so the likely result would be much less than one adult equivalent. This is therefore a low negative effect.

Adult Chinook Broodstock Collection

Small mesh seine nets actively fished by STI staff are used to collect adult broodstock from the river. The small mesh design leads to entanglement of the Chinook rather than gilling. This method has been effective in obtaining a sufficient number of broodstock required for the summer Chinook salmon program, when the total return to the river, and arriving male to female ratios are amenable. Broodstock collection occurs in Chinook salmon holding areas (RM 15 to RM 30), within the geographic area of fish spawning (bulk of natural spawning occurs between RM 14.3 and RM 30.0) but prior to the time when fish move onto the reaches to spawn (estimated to be ~August 25 through ~mid-October). Because the collection process occurs in holding pools and not in spawning reaches, the likelihood for disruption of redds and injury to incubating eggs is low. The average percent of the total Chinook escapement to the Stillaguamish removed through broodstocking for the program was 11% over the most recent ten years reported (2005-2015). As previously discussed, up to 20 adults, which equates to 10% of the total adults captured via this method may be genetically identified as fall Chinook salmon, and retained for broodstock for the fall Chinook salmon program. The overall effect on the spawning grounds of seining adults out of the river for broodstock collection is a low negative effect.

Annual in-river snorkel assessments occur in the days prior to broodstocking activities to ensure fish are holding in the area targeted, and numbers are sufficient to begin adult broodstock collection. Obtaining estimates of adult escapement, sex ratios, habitat conditions, and location utilization that occur prior to broodstock activities result in stress to adult Chinook holding in pools when snorkelers disturb them out of their holding positions (Stillaguamish Tribe of Indians 2017a). The effects of these in-river activities associated with adult broodstock collection are negative, but likely very low in magnitude and transitory, resulting in probably very little difference from normal avoidance responses.

Although the proportion of the total adult Chinook salmon which return to the river and are taken through the program is quite low (11%), the operators expressed a concern regarding repeated exposure of Chinook salmon in holding pools that are not taken as broodstock to multiple broodstock collection events. This repeated exposure occurs because fish may be encountered multiple times during the four plus weeks operators are in the river seining pools to collect adult fish that are holding in pools before moving upstream to the spawning grounds. An additional concern is that the seine net method of capture may be leading to an enhanced level of handling, stress, injury, and mortality to Chinook taken and held as broodstock, relative to other collection methods (e.g., V-weir or fish wheel traps, drag seines). Stressful ambient water temperatures—that is, those in excess of 59 degrees Fahrenheit—in the river that are periodically encountered during the broodstock collection add to this concern. Elevated mortality rates for adult fish taken at higher temperatures and held for 2-4 weeks until spawning are a concern (the operators indicated a past pre-spawning mortality of 3 to 13% of the broodstock collected over the past 20 years), as are effects on the viability of gametes collected from adult fish that are adversely affected (via the gill net method, and/or as amplified by stressful ambient water conditions under which collection took place). These potential negative effects, however, must be balanced with the low proportion of the total escapement affected (11%), and the likely benefit of the program to the preservation and recovery of the listed stock. From a review of estimated natural recruit per spawner and Stillaguamish hatchery Chinook salmon contribution (Table 8, Table 9), it is likely that the program is helping to sustain the listed population in the midst of severe freshwater habitat degradation resulting from surrounding land use practices. This degradation is expected to continue based on projections in the 2017 climate report, continued low snowpack and increased rainfall, peak flows and extreme flood events (Stillaguamish Tribe of Indians 2017c). Therefore, the net effect is beneficial.

Operators apply mitigation measures to reduce the risk of harm to broodstock procured using seine nets by collecting Chinook salmon in early morning hours, when water temperatures do not typically exceed 59°F (15°C). The operators also curtail collection when an increased stress response is observed during handling. The application of these measures help to minimize the negative effects from broodstocking on Stillaguamish Chinook salmon.

Handling of adult natural-origin steelhead during in-river Chinook salmon broodstock collecting has been reported through observation by the operators at less than two annually (Stillaguamish Tribe of Indians 2017b). Over these same years of operation, mortalities are reported through observation of no more than one during years of encounter. While operators try to ensure handling results in minimal mortalities, effects on listed steelhead are negative due to these reported handlings and mortalities.

Effects on listed Chinook salmon and steelhead during broodstock collection activities for the coho and chum salmon programs are negligible due to the minimal overlap in return timing and non-presence in collection locations (Table 18; Table 2).

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

The action area for this action includes the freshwater of the Stillaguamish, and adjacent Skagit and Snohomish River watersheds. Based on the science available to detect the effects of salmon hatchery releases in the ocean, and the small number of releases from these four programs relative to the total number of juvenile salmonids detected in the freshwater, estuary, and ocean, NMFS believes it is not possible to detect a measureable effect specific to this proposed action once these releases reach the ocean. Thus, this analysis will only consider effects of juvenile hatchery fish in juvenile freshwater rearing areas. The effects of this factor on all listed species considered in this opinion is negative, as discussed below.

2.4.11.1.1. Hatchery release competition and predation effects

The PCD Risk Model quantifies the potential number of natural-origin salmon and steelhead juveniles lost to competition and predation from the release of hatchery-origin juveniles (Pearsons and Busack 2012). The parameters and their values considered in the model are shown in Tables 19-21.

It is important to emphasize that the PCD Risk model is not a total simulation of ecological interactions between hatchery and wild fish. Competition is modeled as a direct interaction between hatchery-origin and natural-origin fish; the model does not include the effects of density dependence on food availability, for example. The model also does not include predation or competition from other fish species, such as bass, or non-fish species, such as piscivorous birds. It also does not account for the possible beneficial effects of juvenile hatchery-origin fish releases, mainly in the form of prey for natural-origin salmon and steelhead. Another limitation is that neither species grows during the simulation; in reality fish growth could greatly change competition dynamics and susceptibility to predation. Finally, and perhaps most relevant, PCD Risk runs are limited to evaluating interactions between one hatchery-origin species and one natural-origin species under specified conditions in a limited area over a limited time.

Simulated predation and competition interactions in PCD Risk must be interpreted differently. Within the parameter values chosen and the mechanisms for interactions coded into the model, a predation event is an actual loss of a fish: the fish is removed from the simulated population. Competition events in the PCD model have quite different consequences than predation events. Whereas a predation event denotes a mortality, a competition event means that a fish does not eat for a day, and suffers some weight loss as a result. The same fish could suffer another competition event the next day, and possibly one each day of the interaction period. Thus at the end of the interaction period (set as the residence time parameter), a particular natural-origin fish could have sustained competitive interactions that will have resulted in weight loss. Ten interactions are expected to result in a weight loss of approximately 10- 15%. In reality, a weight loss of this magnitude is unlikely to directly result in death, but could result in increased susceptibility to disease (Pearsons and Busack 2012), or perhaps to further interactions, neither of which mechanism is included in the model. The model reports instead, "competition equivalent" deaths, which are computed as how many fish would die if the cumulative weight loss of all the natural-origin fish due to competitive interactions were concentrated into individual fish to reach lethal levels (typically programmed at 50% weight loss). In other words, if an individual fish suffering 20 competitive interactions dies from weight loss, and if 5,000 total competitive interactions occurred in a run of the model, this would result in 250 competition equivalent deaths, even if no fish in the simulation truly suffered 20 interactions. Detailed analysis of model runs done for this consultation have revealed that, even with substantial time periods over which for interactions to occur, a substantial proportion of fish may not suffer any competitive "hits," and maximally affected fish suffer only a few. However, because we believe that the model underestimates the effects of competition, we aggregated the competitive interactions so that they all happened on the same natural-origin fish until that fish died (i.e., competition equivalent deaths). Although this is not a realistic scenario in the natural environment, it allowed us to put an upper bounds on potential mortalities. We also acknowledge that a 100% population overlap in microhabitats likely overestimates effects.

For our model runs, we assumed a 50-percent population overlap between hatchery salmon and all natural-origin species present. Hatchery salmon are released from April to June, and may overlap with natural-origin Chinook, coho, and chum salmon. However, our analysis is limited to assessing effects on listed species. Because the population overlap parameter represents microhabitat overlap, not basin wide-scale overlap, a 100-percent population overlap in microhabitats would likely be an overestimation.

In addition, our model does not consider ecological effects on age-0 steelhead because steelhead spawn from March to June with a peak from April to May in the action area (Busby et al. 1996). Thus, it is unlikely that any age-0 steelhead would have emerged in time to interact with the hatchery salmon smolts as they migrate downstream.

Table 19. Parameters in the PCDRisk model that are the same across all programs.

Parameter	Value
Habitat complexity	0.31
Population overlap	0.50
Habitat segregation	0.3 for steelhead, 0.6 for all other species
Dominance mode	3
Piscivory	0.0023
Maximum encounters per day	3
Predator:prey length ratio for predation	0.40
Average temperature across release sites	13°C[2]

[2](Griffith and Arman 2010; Griffith et al. 2009; Griffith and Scofield 2012; Scofield and Griffith 2012; Scofield and Griffith 2013).

Table 20. Hatchery fish parameter values for the PCDRisk model.

Program	Proposed Release #	Size in mm (SD)	Survival to Estuary	Travel Rate (river miles/day)	Residence Time
Stillaguamish Chinook[1]	420,000	85 (11)	0.63	10	32
Stillaguamish Coho	60,000	133 (20)	0.63	5	46
Stillaguamish Chum	250,000	48 (10)	0.63	11	21

Sources: (Griffith and Arman 2010; Griffith et al. 2009; Griffith and Scofield 2012; NMFS 2014; Scofield and Griffith 2012; Scofield and Griffith 2013; Stillaguamish Tribe of Indians 2015; Stillaguamish Tribe of Indians 2016; Stillaguamish Tribe of Indians 2017a; Stillaguamish Tribe of Indians 2017b).

[1]The two summer and fall-run Chinook programs were combined due to the small number of fall releases to date.

Based on the data above, our model results show that hatchery coho program releases are likely to be the fish having the largest negative effect on natural-origin Chinook salmon in the Stillaguamish watershed. We assumed 182,000 juvenile natural-origin Chinook were present within our action area in our calculations, to obtain the maximum estimated numbers of fish lost shown in Table 21. This estimate based on modeling predation and competition using the

PCDRisk model indicates 2.15% of the juveniles present would be lost due to the hatchery programs considered here. This percentage of loss is likely to have only a slightly negative effect on the Stillaguamish Chinook salmon population.

Table 21**.** Maximum numbers and rate of natural-origin salmon lost to competition and predation with hatchery-origin salmon released from the Proposed Action.

Program of Release	**Chinook salmon**	
	Pred.	**Comp.**
Su/Fa Chinook[1]	8	447
Coho	3020	436
Chum[2]	0	0
Total Number	**3911**	
Rate[3]	**2.2**	

[1] The summer and fall programs were combined due to the small size of the fall program, and overlap in release dates.
[2] Chum are released as fry, and due to the timing of outmigration would not be of a size large enough to consume natural-origin Chinook or steelhead (Table 22).
[3] This represents the rate of mortality for predation and competition effects combined, per the output file of the PCDRisk Model.

Due to the limited information about the native summer and winter steelhead populations in the Stillaguamish system, the PCDRisk model could not be used to evaluate risks to these populations. Based on the emigration timing and target size at release for the four hatchery salmon programs (Table 22), predation and competition effects on listed steelhead populations in the Stillaguamish watershed are likely occurring at a small scale due to some overlap from the coho program releases with natural-origin steelhead fry and smolts, but overall are expected to be negligible due to the fully smolted condition of Coho salmon when released.

Table 22. Comparative individual sizes and freshwater occurrence timings for rearing and/or emigrating fish from natural Puget Sound populations, by species and life stage, and hatchery-origin salmon juveniles proposed for release from the Stillaguamish River watershed hatchery programs.

Species/Origin	***Life Stage***	***Individual Size – Avg. FL mm (and range)***	***Occurrence or Release Timing***
Chinook salmon (wild)	Fry	*55 (40-70)*	*February - April*
Chinook salmon (wild)	Parr/Sub-yearling	*64 (39-95)*	*May - June*
Chinook salmon (wild)	Yearling	*75 (70-105)*	*Mid-March - mid-May*
Chinook salmon (hatchery)	Sub-yearling	*88 (80-100)*	*April - June*
Steelhead (wild)	Fry	*60 (23-100)*	*June - Oct.*
Steelhead (wild)	Parr	*96 (65-131)*	*Oct.- mid May*
Steelhead (wild)	Smolt	*165 (109-215)*	*late April - June*
Coho (wild)	Fry	*30 (29-36)*	*February - March*
Coho (wild)	Parr	*56 (37-70)*	*April - April*
Coho (wild)	Yearling	*95 (70-150)*	*May - June*
Coho (hatchery)	Yearling	*133 (130-137)*	*May - June*
Chum (wild)	Fry	*38 (33-50)*	*March - May*
Chum (hatchery)	Fed Fry	*52 (48-65)*	*April - mid May*
Pink (wild)	Fry	*34 (32-43)*	*March - April*

Wild Chinook salmon data from Beamer et al. (2005) (yearling data), and Stillaguamish Tribe juvenile out-migrant trapping reports for the Stillaguamish River including average individual fish size, size range, and emigration timing (Griffith and Arman 2010; Griffith et al. 2009; Griffith and Scofield 2012; Scofield and Griffith 2012; Scofield and Griffith 2013; Scofield and Griffith 2014; Scofield and Griffith 2015; Scofield and Griffith 2016).
- Wild steelhead individual size data and occurrence estimates from Shapovalov and Taft (1954) and WDFW juvenile out-migrant trapping reports (Kinsel et al. 2008; Volkhardt et al. 2006a; Volkhardt et al. 2006b).
- Wild coho data for Skykomish River from Nelson and Kelder (2005) (smolts); Beacham and Murray (1990) and Sandercock (1991) (fry); parr size range extrapolated from smolt and fry data considering year-round residence.

- Wild chum data from Volkhardt et al. (2006b) (Green River fall-run), and Tynan (1997) (Hood Canal summer-run).
- Wild Dungeness River pink salmon data (Topping et al. 2008a; Topping et al. 2008b).
- Hatchery-origin fish release size and timing data are average individual fish size and standard release timing targets proposed in the Stillaguamish Hatchery salmon HGMPs, and average size and size range data for regional hatcheries (WDFW and PNPTT 2000). Estimated mm fish lengths converted from fish per pound data using conversion tables in Piper et al. (1986).

Density-Dependent Effects

The release of up to 420,000 total sub-yearling Chinook salmon at a size range of 80 to 100 fpp beginning in April may lead to competitive or density-dependent interactions with co-occurring listed natural juvenile Chinook fry and fingerlings in freshwater as the hatchery fish emigrate. The extent to which competition may occur was evaluated using the PCDRisk model, and was found to represent less than 0.3% of total encounters between hatchery and natural-origin Chinook salmon during outmigration (Table 21). Per the PDCRisk model, these encounters would also need to result in the loss of 50% body weight to cause a detectable negative effect on an individual. Despite this low risk, further risk minimization measures are applied by the operators to decrease the likelihood for negative competition and density-dependent effects. These measures include: releasing juvenile fish below the spawning grounds, which limits the spatial and temporal overlap with natural-origin Chinook salmon during outmigration; volitional release practices; and the release of the hatchery fish as migrating smolts, which limits the instantaneous concentration of hatchery fish to which natural fish are exposed and the duration of interaction with natural-origin fish.

Effects on listed Chinook salmon in nearshore estuarine and marine areas are unknown. The cumulative effects of Puget Sound hatchery Chinook programs on listed Chinook in the marine environment should be addressed through an ESU-wide scale research initiative collaboratively conducted by the Co-managers and NMFS in future years.

Residualism

The operators indicate that a small percentage of the natural-origin juvenile Chinook salmon population residualize post-release to migrate as yearling fish the subsequent spring. Smolt trapping data has indicated that on average less than 10 fish per year (Griffith and Arman 2010; Griffith et al. 2009; Griffith and Scofield 2012; Scofield and Griffith 2012; Scofield and Griffith 2013; Scofield and Griffith 2014; Scofield and Griffith 2015; Scofield and Griffith 2016) are caught emigrating from February through July. Sub-yearling hatchery fish released from Brenner Creek Hatchery and the Whitehorse Ponds acclimation site have the potential to adopt a yearling life history strategy to at least the same, low extent. The risk of predation to natural-origin Chinook salmon in the freshwater environment due to residual hatchery-origin released Chinook salmon based on these data is estimated to be no more than 0.002% of the natural-origin sub-yearling Chinook annually. Additionally, risks to listed sub-yearling Chinook salmon from residual hatchery-origin releases through competition is expected to be minimal due to the ocean-rearing life history strategy for the majority of the natural-origin Chinook salmon in the Stillaguamish River watershed (Griffith and Arman 2010; Griffith et al. 2009; Griffith and Scofield 2012; Scofield and Griffith 2012; Scofield and Griffith 2013; Scofield and Griffith 2014; Scofield and Griffith 2015; Scofield and Griffith 2016). Zero-age steelhead would not be present in the lower reached of the watershed where hatchery salmon releases occur due to the emergence timing and upriver location of spawning (Table 18; Table 22). Therefore, effects on all listed populations as a result of residualism are considered negligible.

2.4.11.1.2. Naturally-produced progeny competition

There is no data to indicate if the spawning grounds are fully seeded in the Stillaguamish watershed. However, recent productivity estimates affirm that the size of the current salmon programs is not creating a density-dependent affect that would decrease productivity in the watershed (Table 9). Increased abundance is actually a desired result of the integrated recovery programs. Risk associated with density-dependence is mitigated for by the small size of the hatchery programs, and the on-going associated RM&E to address changes to current capacity of the Stillaguamish watershed, as measured annually through freshwater production estimates such as egg-to-migrant survival (Figure 9). The expected effect on listed populations in the watershed as a result of naturally-produced competition is negligible.

2.4.11.1.3. Disease and In-Hatchery Loss

Fish health management protocols defined in the Co-manager's Fish Health Policy are designed so that compliance with these protocols minimizes the likelihood for fish disease amplification and loss within the listed, propagated population, or transmission to listed natural-origin Chinook salmon. This requires on-going monitoring prior to release, and treatment as prescribed to minimize disease outbreaks prior to release. Culling of diseased fish is also considered when necessary to protect listed populations within the release basin.

Broodstock originate from in-river collections, and importation of fish disease agents from outside the watershed is not a risk factor. The risk of disease amplification and/or transfer from broodstock brought on-station and spawned at Harvey Creek Hatchery is minimized through application of Co-manager Fish Health Policy disease certification, sanitation, and treatment protocols, including fish vaccination. The Harvey Creek/Whitehorse and Brenner Creek Hatchery programs have generally demonstrated acceptable green-egg-to-release survival rates for the listed fish under propagation (64-80%), and vaccines are used to suppress ubiquitous fish diseases. The operators report a rearing density goal of 1.2 lbs. fish / gpm inflow, which is well below any density that would potentially cause a fish health risk (Piper et al. 1986).

Over the last twenty years, salmon from the programs have been infected as described in Section 1.3.2 by periodic losses of eggs, swim up fry, and pre-release fry due primarily to *Saprolegnia* and coagulated yolk. Bacterial kidney disease (BKD), cold-water disease, and *Costia* (a parasite that can rapidly reproduce in warm water, and is typically experienced as a result of handling stress by adult salmonids) have periodically caused mortality during some years.

The programs are unlikely to adversely affect listed natural-origin Chinook salmon populations in the basin as a result of disease epizootics and transmission. However, in-hatchery loss effects to on the listed natural-origin Stillaguamish Chinook salmon populations are negative because there have been years in which reported in-hatchery losses resulted in a loss of between 20-36% of the captive brood fish held prior to maturity. Literature on acceptable captive brood losses prior to maturation is limited; however, based upon the records maintained to monitor captive brood losses in a similar program in the Nooksack basin, and the associated data collected over the duration of the captive brood life cycle at the Manchester Research Station, indications are that without a saltwater rearing phase expected losses for captive brood salmonids are near 40% prior to maturation (pers. comm., Kip Killebrew, June 28, 2018).

The risk of pathogen transmission to natural-origin salmon and steelhead is negligible for these salmon programs. This is because juvenile rearing for all four programs takes place at either Harvey Creek or Brenner Creek hatcheries, which rear fish only on spring water with minimal, if any, exposure to pathogens through non-fish bearing surface water sources. Therapeutics are used as needed so that the risk of releasing smolts that could transmit pathogens is negligible. Additionally, the outmigration timing of the hatchery released smolts and co-occurring listed natural steelhead parr would be minimal due to the known separation between natural spawning locations and hatchery release locations (Table 18, Table 22).

2.4.12. Factor 4. Research, monitoring, and evaluation that exists because of the hatchery program

The proposed hatchery program actions address the five factors that NMFS takes into account to analyze and weigh the beneficial and negative effects of hatchery effects-related research, monitoring, and evaluation (RM&E) (see Section 2.4.1.5). As expected, the programs include RM&E to monitor compliance with this opinion and to reduce risks to ESA-listed Stillaguamish River basin Chinook salmon and steelhead. The RM&E included in the HGMPs analyzed in this biological opinion are expected to lead to a better understanding of the status of ESA-listed species in the Stillaguamish River watershed, and what is affecting them. Data gathered through the RM&E activities will greatly supplement best available information regarding how to help recover ESA-listed Stillaguamish Chinook salmon and steelhead. While some lethal and sub-lethal effects on listed species are expected to occur as a result of implementing RM&E actions, the knowledge gained through these actions allow for better conservation and management of these stocks which has an overall benefit to the Stillaguamish Chinook salmon population.

General monitoring and evaluation measures are included in the HGMP (Stillaguamish Tribe of Indians 2017a; Stillaguamish Tribe of Indians 2017b). The intention to provide monitoring and evaluation measures specific to the Stillaguamish summer and fall Chinook salmon restoration programs are indicated.

All hatchery-origin Chinook salmon will receive a coded wire tag and an adipose clip prior to release. This marking will be done in order to assess the harvest impacts on these Chinook stocks in mixed stock fisheries in WVCI and BC, as well as Southeast Alaska. Discussions were had with the operators to forego the external mark in order to maximize escapement to the spawning grounds. The fact that there is no sampling of fish harvested without an adipose clip in these Northern fisheries, coupled with the need to collect survival and harvest data on these depleted stocks in fisheries north of the SUS, led the operators to elect to apply the adipose fin clip to the hatchery released fish. Additionally the operators would like to establish the fall stock as an indicator stock. The full value of this monitoring may not be realized for a few more years as the largest release of the fall Chinook program to date is anticipated to be approximately 125,000 in 2018. Estimated rates of mortality due to the application of marks and tags are considered negligible based on the vast literature collected annually through the PST- RMIS database.

Estimates of fishery mortality, total exploitation rate, and escapement for Stillaguamish Chinook by mark-status, either adipose fin clipped or adipose fin intact, were used to model the effects of fisheries on the combined summer and fall Stillaguamish Chinook salmon population due to the application of the external mark. For brood years contributing to the 2010 - 2014 return years, all hatchery production of Stillaguamish Chinook was mass-marked. Applying the unclipped exploitation rate to the total hatchery abundance from 2010 – 2014 resulted in an average increase of approximately 9% to hatchery escapement, or roughly 43 fish, assuming comparable marine survival levels and hatchery production similar to that of the brood years that contributed to the 2010 - 2014 return years. The model assumes vulnerability to fisheries of the fall Chinook is similar to that of the summer Chinook.

Sampling of juveniles occurs in the mainstem of the Stillaguamish River using a screw trap to assess juvenile outmigration, residualization, and abundance. This is approved through an existing permit (Table 4). Estimated effects of this sampling on juvenile ESA-listed Chinook and steelhead are negligible.

The four HGMPs include RM&E actions designed to identify the performance of the programs in meeting their conservation objectives and to minimize adverse effects on ESA-listed fish. Specific RM&E actions for the four HGMPs are described in section 1.10 and section 11.0 of each hatchery plan. Another important action is monitoring of the number and proportions of the total escapements of hatchery-origin adults escaping to the basin. This monitoring action includes collecting tissues from approximately 300 natural- and hatchery-origin spawners (carcasses) and all out-migrants collected at the smolt trap (up to approximately 4,000 Chinook and 1,000 steelhead annually to date) for DNA analysis to enumerate genetically the composition of the composite spawning populations in the basin. There are negligible effects anticipated through these activities.

The Stillaguamish Tribe and WDFW would continue their collaboration on monitoring and biological sampling of juvenile salmonids in the mainstem Stillaguamish River through juvenile out-migrant trapping in the watershed. This is approved through an existing tribal 4(d) research permit (Table 4). The co-managers are also collaborating in the proposed continuation of the Pacific Salmon Commission Sentinel Stock Committee funded Trans-Genetic Mark Recapture (tGMR) Project, which would benefit Chinook salmon escapement and productivity evaluations (PSC 2016). These monitoring programs would provide information for hatchery-origin fish and natural populations regarding temporal and spatial co-occurrence, juvenile outmigration timing, fish size, habitat utilization. These data may be used to assess the potential for any adverse ecological and genetic interactions between hatchery fish and natural populations of Stillaguamish Chinook salmon.

Specific actions described in the HGMPs would include monitoring of salmon escapement to the Stillaguamish River watershed natural spawning areas and hatcheries. All juvenile fish released through the programs would be marked, tagged, and/or fin clipped to allow for their differentiation from natural- origin salmon, after their release from the hatcheries, and when the fish return as adults to Stillaguamish River freshwater areas, and incidentally are harvested in mixed stock fisheries. Recoveries will provide indicator stock CWT data to assess harvest rates on the Stillaguamish Management unit. Recovery of the Stillaguamish Chinook populations depends upon harvest management decisions informed with Stillaguamish-specific data. Twenty-five years of CWT data from the Stillaguamish summer Chinook program has shown that Stillaguamish Chinook have a unique distribution in fisheries from Alaska to Washington (CTC 2017).

The ability to identify hatchery-origin fish would allow for appropriate monitoring of the performance and effects of the hatchery programs in meeting their conservation objectives, while minimizing risks to listed fish in the Stillaguamish basin. Recovery of marked or tagged hatchery-origin salmon would allow for estimation of the number of clipped and tagged fish escaping to basin streams each year. Foot and boat spawning ground surveys would count spawning fish and sample carcasses for scales, adipose-fin clips, CWT's, and tissues for DNA analysis. The same level and types of biological sampling would occur for fish collected as broodstock in the river.

Other effects of the proposed hatchery salmon programs on ESA-listed salmon and steelhead populations would also be monitored. In general, this would include monitoring of water withdrawal and effluent discharge to ensure compliance with permitted levels; monitoring of broodstock collection, egg take, fish survival rates, and smolt release levels for each program to determine compliance with program goals; and fish health monitoring and reporting in compliance with "The Salmonid Disease Control Policy of the Fisheries Co-managers of Washington State" (NWIFC and WDFW 2006).

As detailed in the status section, the information available on the two Stillaguamish Chinook salmon populations are limited. Information obtained via the proposed monitoring and evaluation of these listed Chinook populations would provide data on both occurrence, exploitation in all marine area fisheries, and be able to precisely estimate adult escapement in the Stillaguamish River watershed which is currently unknown. Therefore, overall effects of this action would be beneficial to the population.

Effects of RM&E on listed steelhead are negligible, as steelhead would not be affected during any activities in addition to those already permitted (Table 4), and those limited to in river broodstock collection which are low, as discussed in Section 2.4.2.2.3.

2.4.13. Factor 5. Construction, operation, and maintenance of facilities that exist because of the hatchery program

Proposed off-site construction and installation of a V trap for the collection of adult broodstock at Brenner Creek Hatchery is expected to commence in the fall of 2019. When construction and installation plans are available, the operators will provide a copy of these to NMFS.

Effects on ESA-listed Chinook salmon and steelhead from in-water structures and associated screening for the Whitehorse Ponds Hatchery are negligible. ESA-listed fish do not utilize Whitehorse Spring Creek, or habitat upstream of the water intake structure (WDFW 2014), so there would be no hatchery facility-related effects. The surface water supply at the hatchery is limited by seasonal flows and range from 0.2 cfs during the summer low flows to 6.2 cfs during high flows (spring). During low flow periods, well water can be used to supplement surface water for fish rearing at a flow rate of approximately 1.1 cfs. Neither the Harvey Creek nor Brenner Creek hatcheries pose facility operation risks due to the absence of ESA-listed fish in the area where these hatcheries operate.

Fish rearing at the Whitehorse Ponds facility is implemented consistent with NPDES permit number WAG 13-3008 issued by WDOE. Under its NPDES permit, Whitehorse Ponds Hatchery operates a water cleaning treatment system to remove pollutants before effluent is discharged back into natural waters (WDFW 2014).

Table 23. Program water source and use.

Facility	Program	Maximum Surface Water Use (cfs)[1]	Maximum Ground or Spring Water Use (cfs)[1]	Surface Water Source/ Discharge Location	Diversion Distance (km)[1]	Mean Monthly Surface Water Flow During Operation[2] (cfs)
Harvey Creek Hatchery	Summer Chinook	0.93	0.33 (well)	Harvey/Armstrong Creek	0.01	100
Brenner Creek Hatchery	Fall Chinook	N/A	0.67 (spring)	Brenner Creek	0	Not applicable
Whitehorse Ponds Hatchery	Summer Chinook	5.0	1.74 (well)	Whitehorse Springs Creek	0.2	500

[1] Data Source: STI 2018.
[2] (WDOE 1981). Surface flow determined by closest control station and Stream Management Unit. Value listed is the minimum flow established per WAC-173-505-010. At this value new surface water withdrawal is prohibited and a low flow closure is in effect.

Under the Proposed Action, because there is no change in water withdrawals from current operation, water withdrawals are expected to have similar effects into the future. For Harvey Creek and Whitehorse Ponds hatcheries, a minimal amount of surface water is used, and thus the facilities will not cause a change in habitat use or decrease availability (Table 23). However, dewatering of redds or prevention of natural-origin fish movement is not a concern because the creek surface water sources used by the facilities are non-fish bearing sources. Water diverted at all facilities is diverted over a relatively short distance, and is non-consumptive. As described Brenner Creek Hatchery uses spring water for all operations, which would not lead to any dewatering or prevention of fish movement.

Withdrawal of surface water at maximum permitted levels for fish rearing would reduce the quantity of water available for salmon and steelhead migration and rearing between the hatchery water intake and water discharge points. However, this situation, diverting the maximum permitted levels of flow and adverse effects is unlikely because water withdrawal amounts for hatchery fish rearing during the summertime low flow periods when any effects would be most pronounced will be much less than the permitted maximum (Table 23).

Hatchery maintenance activities may displace juvenile fish through noise and instream activity or expose them to brief pulses of sediment as activities occur instream. The Proposed Action includes best management practices that limit the type, timing, and magnitude of allowable instream activities. In general, the measures would limit effects to short-term sub-lethal effects that would not result in death or substantial reductions in fitness.

No major construction is included as part of the Proposed Action. There are little to no anticipated effects during trap install or use on listed steelhead, as current information suggests that Brenner Creek is not used by steelhead or trout (pers. comm., Kate Konoski –STI, May 23, 2018). If steelhead are intercepted, they will be removed immediately and placed upstream of the trap. Additionally, coho may be intercepted, with the same protocol used to remove them immediately and place them upstream of the trap.

Operation and maintenance of the facilities associated with the hatchery programs included in the Proposed Action would have a negligible effect on ESA-listed Chinook salmon and steelhead or their designated critical habitat.

2.4.14. Factor 6. Fisheries that exist because of the hatchery program

The objective of the Chinook salmon programs are the restoration of two "Category 1" (PSIT and WDFW 2017) and Tier 2 Chinook salmon stocks (NMFS 2010). The Chinook salmon under propagation have been designated as essential for the recovery of the listed Puget Sound Chinook ESU (PSTRT 2002). Intercepting fisheries are managed to limit harvests of the Stillaguamish summer and fall Chinook stocks, and no changes from this strategy are proposed in response to the continued operation of these restoration programs. There are no fisheries that exist as a direct result of the Proposed Action. The effects of fisheries that may impact fish produced by these programs are described in Section 2.3.3. Therefore, the effects are considered in the Environmental Baseline.

2.4.15. Effects of the Action on Critical Habitat

This consultation analyzed the Proposed Action for its effects on designated critical habitat. NMFS has determined that operation of the hatchery programs would have a negligible effect on designated critical habitat PBFs in the action area.

The 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. In addition, no new facilities are proposed. Hatchery maintenance activities are expected to retain existing conditions, and would have minimal adverse effects on designated critical habitat.

Most facilities that use surface water diversions return that water to a creek a short distance from the diversion point, and use only a small proportion of the total surface water volume (Table 23). Because the uses are non-consumptive, these withdrawals would not affect adult spawning and juvenile rearing critical habitat of ESA-listed Chinook or steelhead.

Another potential effect on critical habitat is the use of chemicals for cleaning or treating pathogens that are present in the hatchery effluent at Brenner Creek, Harvey Creek Hatcheries, and Whitehorse Ponds. At this time, no information exists to suggest the use of the chemicals and their subsequent dilution to manufacturer's instructions would cause adverse effects on ESA-listed fish. Furthermore, the use of abatement ponds at hatcheries to allow chemical degradation into less toxic components, and the mixing of effluent with the remaining water in the creek or river, is not likely to lead to a detectable change in water quality. Thus, negligible effects on water quality in spawning and rearing critical habitat are expected.

2.5. 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.

For the purpose of this analysis, the action area is that part of the Stillaguamish, River watershed described in Section 1.4. To the extent ongoing activities have occurred in the past and are currently occurring, their effects are included in the baseline (whether they are Federal, state, tribal or private). To the extent those same activities are reasonably certain to occur in the future (and are tribal, state or private), their future effects are included in the cumulative effects analysis.

State, tribal, and local governments have developed plans and initiatives to benefit listed species and these plans must be implemented and sustained in a comprehensive manner for NMFS to consider them "reasonably foreseeable" in its analysis of cumulative effects. Such future state, tribal, and local government actions would likely be in the form of legislation, administrative rules, or policy initiatives, and land-use and other types of permits, and that government actions are subject to political, legislative, and fiscal uncertainties. Habitat restoration within the Stillaguamish River Basin has been conducted by several entities, including the Stillaguamish Tribe of Indians, Tulalip Tribes, Salmon Recovery Funding Board through the Washington State Recreation and Conservation Office, Snohomish Conservation District, and the U.S. Forest Service, among others (NWIFC 2016). Past restoration projects restored riparian vegetation, removed invasive plants and bank hardening, replaced or removed fish-blocking culverts and other aquatic barriers, installed log jams, and helped to increase habitat value in the Stillaguamish River Basin (NWIFC 2016). Altogether, since 1998, salmon recovery funding for the Stillaguamish River Basin has included 102 completed projects, 22 active projects, 2 conceptual projects, and 2 proposed projects focused on protecting and/or increasing salmon habitat and removing salmon migration barriers (NWIFC 2016). Past contributors to habitat restoration will likely continue to be active in the Stillaguamish River Basin.

The types of habitat restoration projects to be implemented in the future are likely to be similar to those implemented since 1990 and may include land acquisition and preservation, road decommissioning, water quality improvements, and initiation of a valley protection initiative. For the years 2018 to 2022, Snohomish County identified 15 habitat restoration projects intended to increase fish habitat and access within the river basin. Aquatic habitat restoration is also expected as local transportation entities and the Washington State Department of Transportation repair or replace culverts that have blocked fish passage in the Stillaguamish River Basin.

Statewide, the Department is required to correct passage at over 400 culverts by 2030 to provide access to 90 percent of the habitat blocked by Department-owned(NWIFC 2016). Restoration plans and funding processes that are on-going within the action area are discussed in the Environmental Baseline section (Section 2.3.2).

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 (Section 2.3.2).

2.6. Integration and Synthesis

The Integration and Synthesis section is the final step in our assessment of the risk posed to species and critical habitat as a result of implementing the Proposed Action. In this section, we add the effects of the Proposed Action (Section 2.4) to the environmental baseline (2.3) and to cumulative effects (Section 2.5) to formulate the agency's opinion as to whether the Proposed 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. This assessment is made in full consideration of the status of the species and critical habitat and the status and role of the affected population(s) in recovery (Sections 2.2.1.1 through 2.2.2.2).

In assessing the overall risk of the Proposed Action on each species, NMFS considers the risks of each factor discussed in Section 2.4.1, above, in combination, considering their potential additive effects with each other and with other actions in the area (environmental baseline and cumulative effects). This combination serves to translate the positive and negative effects posed by the Proposed Action into a determination as to whether the Proposed Action as a whole would appreciably reduce the likelihood of survival and recovery of the listed species and their designated critical habitat.

2.6.1. Puget Sound Chinook Salmon ESU

When the effects of the Proposed Action are added to the effects of all human activities in the action area, including any anticipated Federal, state, or private projects, NMFS concludes that the Proposed Action will not appreciably reduce the likelihood of survival and recovery in the wild of the Puget Sound Chinook Salmon ESU.

Based on a review of the proposed hatchery actions (Section 1.3), the status of affected Stillaguamish River watershed Chinook salmon populations (Section 2.2.1), and consideration of environmental baseline conditions (Section 2.3) and cumulative effects (Section 2.5), the assigned effects of the proposed salmon hatchery actions on Puget Sound Chinook salmon range from negative to beneficial (Section 2.4.2.).

The viability status of both of the Stillaguamish River watershed Chinook salmon populations are low. Spawner abundance is currently depressed, but stable at levels above the critical threshold for the summer population, and near the critical threshold for the fall population. The remaining population diversity, spatial structure, and productivity are below desired levels required for these populations to recover to a self-sustaining condition (Section 2.2.1). Neither population in the basin currently assumes a primary role for recovery of the Puget Sound Chinook Salmon ESU (Section 2.2.1.1). Due to the poor condition of habitat, both of the Stillaguamish River watershed Chinook salmon populations remain in the preservation phase of restoration (HSRG 2014), and best management practices at hatchery programs are necessary to maintain the recoverability of these two native Chinook salmon populations. Of the effects categories evaluated, four take pathways evaluated under two hatchery–related factors were assigned as potentially having negative effects on listed Chinook salmon in the Stillaguamish River watershed (see Section 2.4.2):

- broodstock collection effects (factor 2)
- genetic and ecological (competition) effects (factor 2)
- salmon predation effects (coho hatchery program) (factor 3)
- in-hatchery losses (factor 3)

Removal of fish from the naturally spawning population is typically considered a negative effect as analyzed in Factor 1 (2.4.2.1). However, in the action area, the in-river survival of the listed population is typically very low, averaging 8.5% from 2002-2014, as reported in Factor 2 (2.4.2.2.3). In the context of the low in-river survivals, the removal of natural-origin fish highlights that the overall effect is beneficial to the survival of the out-migrating population. The proposed hatchery programs can pose both genetic and ecological risks—there are abundance and diversity benefits to the listed species from these integrated programs, designed to supplement the natural populations, providing an overall beneficial effect to viability. The ecological effects through competition in the adult life stage are limited by the proportion of hatchery-origin fish spawning naturally, which is measured as nearly equal annually for the Chinook salmon programs. Overall, these programs are small, and produce a limited number of adults, which return as adults to the action area, and pose limited ecological risks to ESA-listed salmon and steelhead through predation and competition.

The hatchery-related factors identified that would have beneficial impacts are genetic diversity (2.4.2.2.1), through the increased abundance and diversity of the integrated listed Chinook salmon returns, and RM&E (2.4.2.4), by providing fisheries impact data and population data at the genetic level annually.

Effects of facility operation are small and localized, and negligible in magnitude (Section 2.4.2). Lastly, fisheries effects (2.4.2.6) are not applicable to this proposed action.

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 Puget Sound Chinook Recovery Plan describes the on-going and proposed state, tribal, and local government actions that are targeted to reduce known threats to ESA-listed salmon. Such actions are improving habitat conditions, and hatchery and harvest practices to protect listed salmon ESUs, and NMFS expects this trend to continue, potentially leading to increases in abundance, productivity, spatial structure, and diversity.

Increasing peak flows in the Stillaguamish River Basin related to reduced snowpack and increased rain has reduced Chinook salmon productivity. Low riparian forest cover has contributed to increased water temperatures, which also correspond to low survival. Despite these realities, the Stillaguamish Tribe continues to protect and restore the estuary and river habitat by engineering log jams, planting riparian vegetation, and restoring tidal influence to previously diked lands (NWIFC 2016). These actions may support improved returns of Chinook salmon to this basin. In addition, the existence of the hatchery programs ensures that fish will still exist in the Stillaguamish River Basin even if natural-origin returns continue to. The operators genetic monitoring programs will ensure that the distinct genetic background of these populations will be maintained and propagated by the hatchery programs. Because the proposed action is likely to lead to improvements in the current genetic and demographic status of the population, and considering the status of the Stillaguamish as a tier 2 population in NMFS Population Recovery Approach out of 22 total populations in the ESU, the Proposed Action will not appreciably reduce the likelihood of survival and recovery of the Puget Sound Chinook Salmon ESU.

2.6.2. Puget Sound Steelhead DPS

Based on a review of the proposed hatchery actions (Section 1.3), the status of affected Stillaguamish River basin steelhead populations (Section 2.2.2), and consideration of environmental baseline conditions (Section 2.3) and cumulative effects (Section 2.5), the assigned effects of the proposed salmon hatchery actions on Puget Sound steelhead range from not applicable to low negative (Section 2.4.2). The viability status of the three Stillaguamish River basin steelhead populations is poor. Spawner abundance is currently depressed, and remaining population diversity, spatial structure, and productivity are also below desired levels required for the population to recover to a self-sustaining condition (Section 2.2.2.1). However, the Northern Cascades MPG is a stronghold for diversity, abundance, and viability, with a relatively lower extinction risk than the other two MPG's in the Puget Sound DPS.

Of the effects categories evaluated, two hatchery-related factors – broodstock collection and ecological (competition) effects – were assigned a potential to pose low negative effect on abundance and productivity of listed steelhead in the Stillaguamish River watershed (see Section 2.4.2). The remaining hatchery-related factors identified would have impacts that were not applicable, or negligible in magnitude (Section 2.4.2) and would not affect the overall viability status of the listed Stillaguamish River watershed steelhead populations.

This analysis has considered limiting factors, as described in the recent status review update, and the effects of the proposed action on the Puget Sound Steelhead DPS, combined with other past and ongoing activities inside the action area, including implementation of conservative harvest management actions (Section 2.3.4), and the effects of past hatchery operations (Section 2.3.3). At this time and for the near future, habitat conditions in the action area are not favorable to steelhead rearing and migration (2.3.2).

Our environmental baseline analysis considers the effects of changes in habitat (both beneficial and adverse), fisheries, and hatcheries on this DPS. Although all may have contributed to the listing of this DPS, all factors have also seen improvements in the way they are managed/operated. As we continue to deal with a changing climate, management of these factors may also alleviate some of the potential adverse effects (e.g., through hatcheries serving as a genetic reserve for natural populations).

The negative effects of our Proposed Action on this DPS are through broodstock collection and ecological interactions. Broodstock collection effects have been evaluated to have low negative effect through safe handling and release of all non-target smolts captured. The ecological effects through competition for resources on the juvenile life stage are limited by the size of the programs and timing of releases. For these four salmon programs, this is managed through the sizing of the programs, which are small and produce a limited number of adults that return as adults to the action area. RM&E does not lead to additional effects that were not already permitted. Effects of facility operation are small and localized.

Taken together, the proposed actions are expected to have unsubstantial negative effects on the Puget Sound steelhead DPS. As discussed above, some low negative effects to steelhead populations in the action area are expected; however, none are expected to rise to the level at which they would have more than very minor effects on population viability or more than negligible effects on DPS survival and recovery. This analysis leads to a determination that the subject salmon hatchery programs will have negative but very limited impacts on ESA-listed steelhead and that they will not appreciably reduce the likelihood of survival and recovery in the wild by reducing the reproduction, number, or distribution of the Puget Sound Steelhead DPS.

The recovery plan for Puget Sound Steelhead DPS is in development, and will describe the on-going and proposed state, tribal, and local government actions that should be targeted to reduce known threats to the DPS. Such actions are likely to be improving habitat conditions and hatchery and harvest practices to protect listed steelhead DPSs, and NMFS expects this trend to continue.

2.6.3. Critical Habitat

The hatchery water diversion and discharge pose a negligible effect on designated critical habitat in the action area (Section 2.4.2.5). Existing hatchery facilities have not contributed to altered channel morphology and stability, reduced and degraded floodplain connectivity, excessive sediment input, or the loss of habitat diversity. The operation of traps and other hatchery facilities may impact migration PBFs due to delay at these structures and possible rejection. There are no expected delays of natural-origin adults due to facility operations. Thus, the impact on the spawning, rearing, and migration PBFs will be small in scale, and will not appreciably diminish the capability of the critical habitat to satisfy the essential requirements of the species.

Climate change may have some effects on critical habitat as discussed in Section 2.3.1. With continued losses in snowpack and increasing water temperatures, it is possible that increases in the density and residence time of fish using cold-water refugia could result in increases in ecological interactions between hatchery and natural-origin fish of all life stages. However, the continued restoration of habitat may also provide additional refugia for fish.

Predicted increases in rain-on-snow 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-origin listed fish species. The proposed Stillaguamish River watershed programs for Chinook salmon are expected to help attenuate these impacts on the listed summer and fall Chinook populations over the short term by providing a refuge from adverse effects for the propagated species through circumvention of potentially adverse migration, natural spawning, incubation, and rearing conditions.

2.7. Conclusion

After reviewing and analyzing the current status of the listed species and critical habitat, the environmental baseline within the action area, the effects of the Proposed Action, any effects of interrelated and interdependent activities, and cumulative effects, it is NMFS' biological opinion that the Proposed Action is not likely to jeopardize the continued existence of the Puget Sound Chinook Salmon ESU or the Puget Sound Steelhead DPS, or destroy or adversely modify their designated critical habitat.

2.8. Incidental Take Statement

Section 9 of the ESA and Federal regulation 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" (16 U.S.C. 1532). "Harm" is further defined by regulation to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering (50 CFR 17.3). "Incidental take" is defined by regulation as "takings that result from, but are not the purpose of, the carrying out of 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 the ITS.

2.8.1. Amount or Extent of Take

NMFS analyzed six factors applicable to the proposed hatchery salmon actions. Four take pathways, discussed under two factors (Factor 2 and Factor 3), are expected to result in some level of take (from individual fish to larger numbers of fish) of ESA-listed Puget Sound Chinook salmon: Chinook salmon hatchery program effects through broodstock collection; program effects on genetic diversity; disease (in hatchery losses); Chinook and coho salmon predation effects.

Two factors are likely to result in take of listed Puget Sound steelhead: handling during collection of Chinook salmon for broodstock, and competition and predation effects (coho) on steelhead survival and migration.

Factor 1: **Hatchery program does or does not remove natural fish for broodstock**

The number of adult Chinook salmon collected annually in the Stillaguamish River for broodstock will be limited to 160 total adults. This includes 65 pairs for the summer program and up to 15 pairs for the fall program. Seining may occur 4 to 12 times during the broodstock collection period from July through September. The Chinook salmon transferred to Harvey Creek in a fish transport truck shall be transported as described in the HGMPs. To reduce the risk of harm to broodstock procured using seine-nets, operators collect Chinook in early morning hours, when water temperatures are lowest. The operators shall curtail collection at noon each day to avoid increased stress due to elevated water temperatures. The application of these measures is intended to ensure the negative effects from broodstock collection on Stillaguamish Chinook salmon remain low. Estimated mortality has ranged from 3% – 32% annually over the past twenty years of operations. During years with average water temperatures that do not exceed 55°F (13°C), operators report 3% - 8% pre-spawn mortality (Stillaguamish Tribe of Indians 2017a).

Annually, up to 900 Chinook salmon smolts will be captured, and up to 450 obtained via seining in the South Fork Stillaguamish River annually for captive broodstock for the fall Chinook salmon program. The number obtained for captive brood is limited currently by genetic screening at the assignment likelihood of greater than 90% to the fall population (Small et al. 2017b) as discussed in 2.4.2.1. The additional 450 smolts captured, but not retained for broodstock, will be released unharmed back into the river, with an incidental mortality of up to 3.5%, although not expected to exceed 1% (or approximately 5-16 smolts killed), as analyzed in 2.4.2.2.3.

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**

Effects of hatchery fish on the genetics of natural-origin fish can occur through a reduction in genetic diversity, outbreeding depression, and hatchery-influenced selection. Of these three effects, only a reduction in genetic diversity as analyzed was a non-negligible effect. Take, which occurs in the form of reduced genetic diversity, cannot be directly measured. Thus, NMFS will use a gene flow surrogate that can be measured through the annual evaluation of the proportion of marked and tagged hatchery fish and unmarked and untagged natural-origin fish that are collected in-river for broodstock and spawned, and through the estimation of the composition spawners reported as pHOS, pNOB, and the resulting PNI values on an annual basis.

Based on the 2010 NMFS PRA, a Tier-2 population should target a PNI value of 0.50 or greater to ensure the composite population is maintaining the current genetic diversity. If annually reported data indicates that the pHOS continues to increase, in conjunction with a decrease in natural-origin returns such that the PNI would drop below 0.40 over a measured five-year rolling average for more than two consecutive brood cycles, ten years, NMFS will need to reevaluate the levels of potential reduction in genetic diversity of the programs to listed populations.

Natural population fluctuations are expected, as reflected in the composition of hatchery and natural spawners on the spawning grounds annually. Thus, the five-year rolling average is expected to adequately describe the overall effect without being unduly complicated by year-to-year variation.

Factor 3: Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas

Ecological Interactions

Ecological interactions—that is, for this proposed action, competition with and predation by hatchery-origin Chinook and coho salmon—could result in take of natural-origin Chinook salmon and steelhead, resulting in some combination of mortality (through predation) and injury or harm or wounding (competition). Take through ecological interactions between juvenile natural-origin salmon and steelhead and hatchery-origin salmon smolts released from these programs can occur. This type of take is difficult to quantify because it cannot be observed, and, therefore, cannot be directly or reliably measured. However, as described in section 2.4.2.3.1, ecological interactions are the direct result of hatchery releases and so anticipated ecological effects can be evaluated using the PCDRisk Model.

Thus, for take through ecological interactions, NMFS uses, as a take surrogate, the number of hatchery smolts released. This surrogate has a rational connection to the amount of take expected from competition and predation, as more of these events will occur as more fish are released from the hatchery. NMFS expects some annual variability in release numbers based on normal hatchery operations. Therefore, NMFS adopts as a surrogate take metric for ecological interaction effects hatchery releases of the current goal. NMFS will consider this take exceeded if the five-year running geometric mean of hatchery releases exceeds the proposed release numbers. If this occurs, NMFS would need to re-evaluate competition and predation risks to natural Chinook populations. NMFS will annually determine whether take has been exceeded when final release data become available, unless the number of smolts released after one or two years is so high that attainment of the proposed release numbers across five years is not a reasonable expectation, in which case NMFS will consider the take limit to have been exceeded at that time.

Because NMFS considers ecological effects on steelhead resulting from these programs to be negligible, NMFS is not describing take for ESA-listed steelhead.

In-Hatchery Losses

Under Factor 3, we analyze losses that occur within the hatchery (Section 2.4.2.3.3). Loss rates of 20 to 36 percent have been reported for the captive brood portion of the fall Chinook salmon program over the 2014-2016 timeframe. Based on the analysis in Section 2.4.2.3.3., should in-hatchery losses exceed 40 percent annually over three consecutive years, NMFS will need to reevaluate the effect of this loss on the natural fall Chinook salmon population.

2.8.2. Effect of the Take

In Section 2.7, NMFS determined that the level of anticipated take, coupled with other effects of the Proposed Action, is not likely to jeopardize the continued existence of the Puget Sound Chinook Salmon ESU or Puget Sound steelhead DPS, or result in the destruction or adverse modification of their designated critical habitat.

2.8.3. Reasonable and Prudent Measures

"Reasonable and prudent measures" are those actions necessary to minimize the amount or extent of incidental take (50 CFR 402.02). These measures are nondiscretionary.

NMFS concludes that the following reasonable and prudent measures are necessary and appropriate to minimize incidental take. The Action Agencies (NMFS and the Bureau of Indian Affairs) shall ensure that:

1. The applicants implement the hatchery programs and operate the hatchery facilities as described in the Proposed Action (Section 1.3) and in the submitted HGMPs.
2. The applicants monitor activities and provide reports to SFD annually for all hatchery programs described in the Proposed Action, and associated RM&E.

2.8.4. Terms and Conditions

The terms and conditions described below are non-discretionary, and NMFS, the BIA, and the applicants must comply with them in order to implement the reasonable and prudent measures (50 CFR 402.14). Action Agencies and any applicant 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 incidental take statement (50 CFR 402.14). If the entity to whom a term and condition is directed does not comply with the following terms and conditions, protective coverage for the proposed action would likely lapse.

1. The action agencies (NMFS and the Bureau of Indian Affairs) shall assure that the applicants implement the Stillaguamish Basin Hatchery Programs as described in the Proposed Action (Section 1.3) and the submitted HGMPs, including:
    a. NMFS is authorizing the annual capture of up to 160 adult Stillaguamish Chinook salmon, of which 65 pairs will be retained for the summer program and up to 15 pairs will be retained for the fall program. The Chinook salmon shall be transferred in a fish transport truck at no more than 50 fish per trip, using therapeutics as described in the HGMPs, to reduce the risk of harm to broodstock procured in-river using seine-nets. Operators shall collect Chinook salmon in early morning hours, when water temperatures are lowest and cease broodstock collection activities at noon daily. The operators shall monitor collected fish and note when an increased stress response is observed during handling.
    b. NMFS is authorizing the annual capture of up to 900 Stillaguamish Chinook salmon smolts, with 450 obtained annually for captive broodstock for the fall Chinook salmon program and the remainder to be released unharmed back into the Stillaguamish River, with an expected mortality of 1%. Juvenile steelhead captured during this activity shall be immediately returned to the river unharmed.
    c. If the five-year running geometric mean of hatchery releases exceeds the proposed release numbers, unless the number of smolts released after one or two years is so high that attainment of the proposed release numbers across five years is not a reasonable expectation, NMFS will consider the take limit to have been exceeded at that time.the applicants and action agencies will re-evaluate competition and predation risks to natural Chinook salmon populations.

d. Should adult in-hatchery losses for the fall Chinook salmon captive brood stock program exceed 40 percent annually over a period of three consecutive years, the applicants and action agencies will re-evaluate the effect of this loss on the natural fall Chinook salmon population. The operators will report losses associated with the captive brood program in their annual report.
e. Providing advance notice to NMFS of any change in hatchery program operation that potentially increases the amount or extent of take, or results in an effect of take not previously considered.
f. Allowing NMFS to accompany any employee or representative field personnel while they conduct activities described in the biological opinion.

2. The applicants shall provide reports to NMFS SFD annually for all hatchery programs, and associated RM&E.
    a. All reports/notifications be submitted electronically to the NMFS SFD point of contact for this opinion: Allyson Purcell (503)736-4736; *Allyson.purcell@noaa.gov*
    b. Reports shall be submitted to NMFS SFD by October 31st of the year following release (e.g., brood year 2016, release year 2017, report due October 2018).
    c. Applicants will notify NMFS SFD within 48 hours after exceeding any authorized take, and shall submit a written report detailing why the authorized take was exceeded within two weeks of the event.
    d. Annual reports to NMFS SFD for the Stillaguamish Basin Hatchery programs should include:
        i. A calculation of quantifiable encounter and mortality take for each species as recorded through each of the activities included in the Proposed Action
        ii. *Hatchery Environment Monitoring Reporting*
            - Number and composition of broodstock, and dates of collection
            - Numbers, total pounds, dates, locations, and tag/mark information of released fish
            - Average size of released juveniles and standard deviation
            - Egg-to-smolt survival rate
            - Disease occurrence and duration and proportion of production lost at hatcheries and the acclimation sites
            - Any unforeseen effects on ESA-listed fish

2.9. 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 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" (50 CFR 402.02). NMFS has identified three conservation recommendations appropriate to the Proposed Action:

1. Improve estimates of natural-origin juvenile population abundance and productivity for listed species in the Stillaguamish Basin.
2. Continue to pursue population-specific escapement estimates for the fall and summer Chinook salmon populations in the Stillaguamish basin, as proposed through tGMR.
3. Consider whether the effect of elevated water temperature increases the adverse effects of handling fish during broodstock collection activities.

2.10. Re-initiation of Consultation

This concludes formal consultation for Stillaguamish Salmonid Hatchery Operations.

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

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

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

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

3.1. Essential Fish Habitat Affected by the Project

The Proposed Action is the implementation of four salmon hatchery programs, as described in Section 1.3. The action area (Figure 2) of the Proposed Action includes habitat described as EFH for Chinook salmon and steelhead. As described by PFMC (2003), the freshwater EFH for Chinook salmon has five habitat areas of particular concern (HAPCs): (1) complex channels and floodplain habitat; (2) thermal refugia; (3) spawning habitat; (4) estuaries; and marine and estuarine submerged aquatic vegetation. HAPC 3 is potentially affected by the Proposed Action.

3.2. Adverse Effects on Essential Fish Habitat

The Proposed Action has small effects on the major components of EFH. As described in Section 2.4.2, water withdrawal for hatchery operations can adversely affect salmon by reducing streamflow, impeding migration, or reducing other stream-dwelling organisms that could serve as prey for juvenile salmonids. Water withdrawals can also kill or injure juvenile salmonids through impingement upon inadequately designed intake screens or by entrainment of juvenile fish into the water diversion structures. The proposed hatchery programs include designs to minimize each of these effects. In general, water withdrawals are small enough in scale that changes in flow would be undetectable, and impacts would not occur.

The PFMC (2003) recognized concerns regarding the "genetic and ecological interactions of hatchery and wild fish… [which have] been identified as risk factors for wild populations." The biological opinion describes in considerable detail the impacts hatchery programs might have on natural populations of Chinook salmon (Section 2.4.2.2); the effects on steelhead are typically much smaller, due to the species-specific nature of many of the interactions and relatively small overlap in habitat usage by the two species. Ecological effects of juvenile and adult hatchery-origin fish on natural-origin fish are discussed in Sections 2.4.2.2 and 2.4.2.3. Hatchery salmon returning to the Stillaguamish River watershed are expected to largely spawn with natural-origin salmon in similar proportions, due to the small program sizes, in order to maintain or increase the native populations hindered by degraded natural habitat productivity. Some salmon from the programs would stray into other rivers but not in numbers that would exceed the carrying capacities of natural production areas, or that would result in increased incidence of disease or predators. Predation by adult hatchery salmon on juvenile natural-origin Chinook salmon or steelhead is unlikely due to timing differences and because adult salmon typically stop feeding by the time they reach spawning areas. Predation and competition by juvenile hatchery Chinook salmon on juvenile natural-origin Chinook or steelhead is small because these fish outmigrate relatively quickly, and at sizes that limit these types of interactions.

Because of the consequence of potential genetic effects during spawning and the predation and competition effects during juvenile outmigration stage, the NMFS has determined that the proposed action would adversely affect EFH for Pacific salmon.

3.3. Essential Fish Habitat Conservation Recommendations

For each of the potential adverse effects by the Proposed Action on EFH for Chinook salmon and steelhead, NMFS believes that the Proposed Action, as described in the HGMPs and the ITS (Section 2.8), includes the best approaches to avoid or minimize those adverse effects. Thus, NMFS provides, as its EFH conservation recommendations, that the agencies ensure that the terms and conditions of the ITS, both operational and monitoring, be carried out to manage the genetic and ecological effects and to ensure that the program effects continue to occur as expected.

3.4. Statutory Response Requirement

As required by section 305(b)(4)(B) of the MSA, an action 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 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 if the Proposed Action is substantially revised by the applicants 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

Section 515 of the Treasury and General Government Appropriations Act of 2001 (Public Law 106-554) ("Data Quality Act") specifies three components contributing to the quality of a document. They are utility, integrity, and objectivity. This section of the opinion addresses these DQA components, document compliance with the Data Quality Act, and certifies that this opinion has undergone pre-dissemination review.

4.1. Utility

Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable, and beneficial to the intended users. The intended users of this opinion are the NMFS (permitting entity), and the BIA (funding entity). The scientific community, resource managers, and stakeholders benefit from the consultation through the anticipated increase in returns of salmonids to the Stillaguamish River, and through the collection of data indicating the potential effects of the operation on the viability of natural populations of Stillaguamish Chinook salmon and steelhead. This information will improve scientific understanding of hatchery-origin Chinook salmon effects 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 (https://repository.library.noaa.gov/) 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 600.920(j).

Best Available Information: This consultation and supporting documents use the best available information, as referenced in the references section. The analyses in this biological 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.

5. References

Anderson, J. H., P. L. Faulds, W. I. Atlas, and T. P. Quinn. 2012. Reproductive success of captively bred and naturally spawned Chinook salmon colonizing newly accessible habitat. Evolutionary Applications 6:165-179.

Araki, H., W. R. Ardren, E. Olsen, B. Cooper, and M. S. Blouin. 2007. Reproductive success of captive-bred steelhead trout in the wild: Evaluation of three hatchery programs in the Hood River. Conservation Biology 21(1):181-190.

Araki, H., B. A. Berejikian, M. J. Ford, and M. S. Blouin. 2008. Fitness of hatchery-reared salmonids in the wild. Evolutionary Applications 1:342-355.

Ayllon, F., J. L. Martinez, and E. Garcia-Vazquez. 2006. Loss of regional population structure in Atlantic salmon, *Salmo salar* L., following stocking. ICES Journal of Marine Science 63:1269-1273.

Bachman, R. A. 1984. Foraging behavior of free-ranging wild and hatchery brown trout in a stream. Transactions of the American Fisheries Society 113(1):1-32.

Beacham, T. D., and C. B. Murray. 1990. Temperature, egg size, and development of embryos and alevins of five species of pacific salmon: A comparative analysis. Transactions of the American Fisheries Society 119(6):927-945.

Beamer, E., and coauthors. 2005. Delta and Nearshore Restoration for the Recovery of Wild Skagit River Chinook Salmon: Linking Estuary Restoration to Wild Chinook Salmon Populations. 97p.

Beamish, R. J., and D. R. Bouillon. 1993. Pacific salmon production trends in relation to climate. Canadian Journal of Fisheries and Aquatic Sciences 50:1002-1016.

Beamish, R. J., C. Mahnken, and C. M. Neville. 1997. Hatchery and wild production of Pacific salmon in relation to large-scale, natural shifts in the productivity of the marine environment. ICES Journal of Marine Science 54:1200-1215.

Beauchamp, D. A. 1990. Seasonal and diet food habit of rainbow trout stocked as juveniles in Lake Washington. Transactions of the American Fisheries Society 119:475-485.

Beechie, T. J., E. Buhle, M. Ruckelshaus, A. Fullerton, and L. Holsinger. 2006. Hydrologic regime and the conservation of salmon life history diversity. Biological Conservation 130(4):560-572.

Beechie, T. J., B. D. Collins, and G. R. Pess. 2001. Holocene and Recent Geomorphic Processes, Land Use, and Salmonid Habitat in two North Puget Sound River Basins. Geomorphic Processes and Riverine Habitat 4:37-54.

Behnke, R. J., and American Fisheries Society. 1992. Native Trout of Western North America. American Fisheries Society, Bethesda, Maryland. 275p.

Bell, E. 2001. Survival, Growth and Movement of Juvenile Coho Salmon (*Oncorhynchus kisutch*) Over-wintering in Alcoves, Backwaters, and Main Channel Pools in Prairie Creek, California. September, 2001. A Thesis presented to the faculty of Humboldt State University. 85p.

Berejikian, B. A., and M. J. Ford. 2004. Review of Relative Fitness of Hatchery and Natural Salmon. December 2004. U.S. Dept. Commer., NOAA Technical Memorandum NMFS-NWFSC-61. 43p.

Berntson, E. A., R. W. Carmichael, M. W. Flesher, E. J. Ward, and P. Moran. 2011. Diminished reproductive success of steelhead from a hatchery supplementation program (Little Sheep Creek, Imnaha Basin, Oregon). Transactions of the American Fisheries Society 140:685-698.

BIA. 2017a. Letter to Ryan Wulff (NMFS) from Rudy Peone (BIA). Requesting cooperation agency status in NMFS' NEPA review. December 12, 2017. Bureau of Indian Affairs, Portland, Oregon. 1p.

BIA. 2017b. Letter to Ryan Wulff (NMFS) from Rudy Peone (BIA). Requesting NMFS as the lead agency for ESA Stillaguamish. December 1, 2017. Bureau of Indian Affairs, Portland, Oregon. 1p.

Bilton, T., D. F. Alderdice, and J. T. Schnute. 1982. Influence of time and size at release of juvenile coho salmon (*Oncorhynchus kisutch*) on returns at maturity. Canadian Journal of Fisheries and Aquatic Sciences 39(3):426-447.

Bjornn, T. C., and D. W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83-138 *in* W.R. Meehan, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society. Special Publication 19.

Blankenship, S. M., M. P. Small, J. Bumgarner, M. Schuck, and G. Mendel. 2007. Genetic relationships among Tucannon, Touchet, and Walla Walla river summer steelhead (*Oncorhynchus mykiss*) receiving mitigation hatchery fish from Lyons Ferry Hatchery. WDFW, Olympia, Washington. 39p.

Bradford, M. J. 1995. Comparative review of Pacific salmon survival rates. Canadian Journal of Fisheries and Aquatic Sciences 52:1327-1338.

Bradford, M. J., B. J. Pyper, and K. S. Shortreed. 2000. Biological responses of sockeye salmon to the fertilization of Chilko Lake, a large lake in the interior of British Columbia. North American Journal of Fisheries Management 20:661-671.

Brakensiek, K. E. 2002. Abundance and Survival Rates of Juvenile Coho Salmon (*Oncorhynchus kisutch*) in Prairie Creek, Redwood National Park. January 7, 2002. MS Thesis. Humboldt State University, Arcata, California. 119p.

Brodeur, R. 1991. Ontogenetic variations in the type and size of prey consumed by juvenile coho, *Oncorhynchus kisutch*, and Chinook, *O. tshawytscha*, salmon. Environmental Biology of Fishes 30:303-315.

Brodeur, R. D., K. W. Myers, and J. H. Helle. 2003. Research conducted by the United States on the early ocean life history of Pacific salmon. North Pacific Anadromous Fish Commission 3:89-131.

Bugert, R., and coauthors. 1992. Lower Snake River Compensation Plan,Tucannon River Spring Chinook Salmon Hatchery Evaluation Program. 1991 Annual Report. Cooperative Agreement 14-16-0001-91534. Washington Department of Fisheries, Olympia, Washington. 103p.

Busack, C. 2007. The impact of repeat spawning of males on effective number of breeders in hatchery operations. Aquaculture 270:523-528.

Busack, C., and K. P. Currens. 1995. Genetic risks and hazards in hatchery operations: Fundamental concepts and issues. AFS Symposium 15:71-80.

Busack, C., and C. M. Knudsen. 2007. Using factorial mating designs to increase the effective number of breeders in fish hatcheries. Aquaculture 273:24-32.

Busby, P. J., and coauthors. 1996. Status Review of West Coast steelhead from Washington, Idaho, Oregon, and California. August 1996. U.S. Dept. Commer. NOAA Tech. Memo., NMFS-NWFSC-27. NMFS, Seattle, Washington. 275p.

California HSRG. 2012. California Hatchery Review Report. Prepared for the U.S. Fish and Wildlife Service and Pacific States Marine Fisheries Commission. June 2012. 110p.

Cannamela, D. A. 1992. Potential Impacts of Releases of Hatchery Steelhead Trout "Smolts" on Wild and Natural Juvenile Chinook and Sockeye Salmon, Appendix A. A White Paper. March 1992. Idaho Department of Fish and Game, Boise, Idaho. 26p.

CBFWA. 1996. Draft Programmatic Environmental Impact Statement. Impacts of Artificial Salmon and Steelhead Production Strategies in the Columbia River Basin. December 10, 1996. Prepared by the Columbia Basin Fish and Wildlife Authority, Portland, Oregon. 475p.

Christie, M. R., M. J. Ford, and M. S. Blouin. 2014. On the reproductive successs of early-generation hatchery fish in the wild. Evolutionary Applications 7:883-896.

Christie, M. R., M. L. Marine, R. A. French, and M. S. Blouin. 2011. Genetic adaptation to captivity can occur in a single generation. Proceedings of the National Academy of Sciences 109(1):238–242.

Climate Impacts Group. 2004. Overview of Climate Change Impacts in the U.S. Pacific Northwest. July 29, 2004. Climate Impacts Group, University of Washington, Seattle, Washington. 13p.

Crawford, B. A. 1979. The Origin and History of the Trout Brood Stocks of the Washington Department of Game. WDG, Olympia, Washington. 86p.

Crozier, L. G., and coauthors. 2008a. Potential responses to climate change in organisms with complex life histories: Evolution and plasticity in Pacific salmon.

Crozier, L. G., R. W. Zabel, and A. F. Hamlet. 2008b. Predicting differential effects of climate change at the population level with life-cycle models of spring Chinook salmon. Global Change Biology 14(2):236–249.

CTC. 2017. Pacific Salmon Commission, Joint Chinook Technical Committee Annual Report of Catch and Escapement for 2016. May 19, 2017. 225p.

Dittmer, K. 2013. Changing streamflow on Columbia basin tribal lands—climate change and salmon. Climatic Change 120:627–641.

Duffy, E. J. 2003. Early Marine Distribution and Trophic Interactions of Juvenile Salmon in Puget Sound. A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science. University of Washington. 186p.

Edmands, S. 2007. Between a rock and a hard place: Evaluating the relative risks of inbreeding and outbreeding for conservation and management. Molecular Ecology 16:463-475.

Eldridge, W. H., and K. Killebrew. 2008. Genetic diversity over multiple generations of supplementation: An example from Chinook salmon using microsatellite and demographic data. Conservation Genetics 9(1):13-28.

Emlen, J. M., R. R. Reisenbichler, A. M. McGie, and T. E. Nickelson. 1990. Density-dependence at sea for coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 47:1765-1772.

Fiumera, A. C., B. A. Porter, G. Looney, M. A. Asmussen, and J. C. Avise. 2004. Maximizing offspring production while maintaining genetic diversity in supplemental breeding programs of highly fecund managed species. Conservation Biology 18(1):94-101.

Flagg, T. A., and coauthors. 2000. Ecological and behaviorial impacts of artificial production strategies on the abundance of wild salmon populations. A review of practices in the Pacific Northwest. NOAA Technical Memorandum NMFS-NWFSC-41. NMFS, Seattle, Washington. 98p.

Flagg, T. A., C. V. W. Mahnken, and R. N. Iwamoto. 2004. Conservation hatchery protocols for Pacific salmon. AFS Symposium 44:603-619.

Ford, M., A. Murdoch, and S. Howard. 2012. Early male maturity explains a negative correlation in reproductive success between hatchery-spawned salmon and their naturally spawning progeny. Conservation Letters 5:450-458.

Ford, M. J. 2002. Selection in captivity during supportive breeding may reduce fitness in the wild. Conservation Biology 16(3):815-825.

Ford, M. J., and coauthors. 2011. Status Review Update for Pacific Salmon and Steelhead Listed Under the Endangered Species Act: Pacific Northwest. November 2011. U.S. Dept. Commer., NOAA Tech. Memo., NMFS-NWFSC-113. 307p.

Francis, R. C. 2002. Essay: Some thoughts on sustainability and marine conservation. Fisheries 27:18-21.

Fresh, K. L. 2006. Juvenile Pacific Salmon in Puget Sound. Puget Sound Nearshore Partnership Report No. 2006-06. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington. 28p.

Fukushima, M., T. J. Quinn, and W. W. Smoker. 1998. Estimation of eggs lost from superimposed pink salmon (*Oncorhynchus gorbuscha*) redds. Canadian Journal of Fisheries and Aquatic Sciences 55:618-625.

Gharrett, A. J., and S. M. Shirley. 1985. A genetic examination of spawning methodology in a salmon hatchery. Aquaculture 47:245-256.

Goodman, D. 2005. Selection equilibrium for hatchery and wild spawning fitness in integrated breeding programs. Canadian Journal of Fisheries and Aquatic Sciences 62(2):374-389.

Grant, W. S. 1997. Genetic Effects of Straying of Non-Native Hatchery Fish into Natural Populations. Proceedings of the workshop, June 1-2, 1995, Seattle, Washington. U.S. Department of Commerce, NOAA Tech. Memo., NMFS-NWFSC-30. 157p.

Gresh, T., J. Lichatowich, and P. Schoonmaker. 2000. An estimation of historic and current levels of salmon production in the Northeast Pacific Ecosystem: Evidence of a nutrient deficit in the freshwater systems of the Pacific Northwest Fisheries Habitat. Fisheries 25(1):15-21.

Griffith, J., and R. V. Arman. 2010. Annual Report- 2009: Stillaguamish River Smolt Trapping Project. December 2010. Stillaguamish Tribe of Indians, Arlington, Washington. 30p.

Griffith, J., R. V. Arman, and J. Drotts. 2009. Annual Report- 2008: Stillaguamish River Smolt Trapping Project. November 2009. Stillaguamish Tribe of Indians, Arlington, Washington. 31p.

Griffith, J., and C. Scofield. 2012. 2010 Annual Report: Stillaguamish River Smolt Trapping Project. February 2012. Stillaguamish Tribe of Indians, Arlington, Washington. 27p.

Groot, C., and L. Margolis. 1991. Pacific Salmon Life Histories. UBC Press. Vancouver, British Columbia, Canada. 588p.

Hager, R. C., and R. E. Noble. 1976. Relation of size at release of hatchery-reared coho salmon to age, size, and sex composition of returning adults. The Progressive Fish-Culturist 38(3):144-147.

Haggerty, M. 2018. Stillaguamish Dispersions Summary Tables 2018 excel report.

Harbeck, J., and C. Hurst. 2017. 4-component PNI model_J. Harbeck_Little Sheep Creek Steelhead_January 2017 excel report.

Hard, J. J., and coauthors. 2015. Viability Criteria for Steelhead within the Puget Sound Distinct Population Segment. May 2015. U.S. Dept. Commer., NOAA Tech. Memo., NMFS-NWFSC-129. 367p.

Hard, J. J., and coauthors. 2007. Status review of Puget Sound steelhead (*Oncorhynchus mykiss*). June 2007. NOAA Technical Memorandum NMFS-NWFSC-81. 137p.

Hard, J. J., R.P. Jones Jr., M. R. Delarm, and R. S. Waples. 1992. Pacific Salmon and Artificial Propagation under the Endangered Species Act. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-2. 64p.

Hargreaves, N. B., and R. J. LeBrasseur. 1985. Species selective predation on juvenile pink (*Oncorhynchus gorbuscha*) and chum salmon (*O. keta*) by coho salmon (*O. kisutch*) Canadian Journal of Fisheries and Aquatic Sciences 42:659-668.

Hartman, G. F., and J. C. Scrivener. 1990. Impacts of forestry practices on a coastal stream ecosystem, Carnation Creek, British Columbia. Canadian Bulletin of Fisheries and Aquatic Sciences 223. 80p.

Hartt, A. C., and M. B. Dell. 1986. Early Oceanic Migrations and Growth of Juvenile Pacific Salmon and Steelhead Trout. Bulletin number 46. 111p.

Hawkins, S. 1998. Residual Hatchery Smolt Impact Study: Wild Fall Chinook Mortality 1995-97. Columbia River Progress Report #98-8. WDFW, Vancouver, Washington. 24p.

Hawkins, S. W., and J. M. Tipping. 1999. Predation by juvenile hatchery salmonids on wild fall Chinook salmon fry in the Lewis River, Washington. California Fish and Game 85(3):124-129.

Healey, M. C. 1991. Life History of Chinook Salmon (*Oncorhynchus tshawytscha*). *In* C. Groot and L. Margolis (eds.), Life history of Pacific Salmon, pages 311-393. University of British Columbia Press. Vancouver, B.C. 89p.

Healey, M. C., and W. R. Heard. 1984. Inter- and intra-population variation in the fecundity of Chinook salmon *(Oncorhynchus tshawytscha*) and its relevance to life history theory. Canadian Journal of Fisheries and Aquatic Sciences 41(3):476-483.

Hess, M. A., and coauthors. 2012. Supportive breeding boosts natural population abundance with minimal negative impacts on fitness of a wild population of Chinook salmon. Molecular Ecology 21:5236-5250.

Hillman, T. W., and J. W. Mullan. 1989. Effect of Hatchery Releases on the Abundance of Wild Juvenile Salmonids. Chapter 8 *in* Summer and Winter Ecology of Juvenile Chinook salmon and steelhead trout in the Wenatchee River, Washington. Report to Chelan County PUD by D.W. Chapman Consultants, Inc. Boise, Idaho. 22p.

Hixon, M. A., D. W. Johnson, and S. M. Sogard. 2014. BOFFFFs: on the importance of conserving old-growth age structure in fishery populations. ICES Journal of Marine Science 71(8):2171-2185.

Holt, C. A., M. B. Rutherford, and R. M. Peterman. 2008. International cooperation among nation-states of the North Pacific Ocean on the problem of competition among salmon for a common pool of prey resources Marine Policy 32:607-617.

Holtby, L. B. 1988. Effects of logging on stream temperatures in Carnation Creek, British Columbia, and associated impacts on the coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 45:502-515.

Horner, N. J. 1978. Survival, Densities and Behavior of Salmonid Fry in Stream in Relation to Fish Predation. July 1978. A Master's Thesis, University of Idaho, Moscow, Idaho. 132p.

HSRG. 2004a. Emerging issues - Marine carrying capacity. Hatchery Reform: Principles and recommendations. April 2004. 3p.

HSRG. 2004b. Hatchery reform: Principles and Recommendations of the Hatchery Scientific Review Group. April 2004. Available at Long Live the Kings. 329p.

HSRG. 2009a. Columbia River Hatchery Reform Project Systemwide Report. Appendix A. White Paper No. 1. Predicted Fitness Effects of Interbreeding between Hatchery and Natural Populations of Pacific Salmon and Steelhead. 38p.

HSRG. 2009b. Columbia River Hatchery Reform Project. Final Systemwide Report. Appendix C. Analytical Methods and Information Sources. 20p.

HSRG. 2009c. Columbia River Hatchery Reform System-Wide Report. February 2009. Prepared by Hatchery Scientific Review Group. 278p.

HSRG. 2014. On the Science of Hatcheries: An updated perspective on the role of hatcheries in salmon and steelhead management in the Pacific Northwest. June 2014, (updated October 2014). 160p.

HSRG, WDFW, and NWIFC. 2004. Technical Discussion Paper #2: Segregrated hatchery programs.

ICTRT. 2007. Considering alternative Artificial Propagation programs: Implications for the viability of listed Anadromous Salmonids in the Interior Columbia River. 77p.

IHOT. 1995. Policies and procedures for Columbia basin anadromous salmonid hatcheries. Annual report 1994 to Bonneville Power Administration, project No. 199204300, (BPA Report DOE/BP-60629). Bonneville Power Administration.

ISAB. 2007. Climate Change Impacts on Columbia River Basin Fish and Wildlife. May 11, 2007. Report ISAB 2007-2. Northwest Power and Conservation Council, Portland, Oregon. 146p

Johnston, N. T., C. J. Perrin, P. A. Slaney, and B. R. Ward. 1990. Increased juvenile salmonid growth by whole-river fertilization. Canadian Journal of Fisheries and Aquatic Sciences 47:862-872.

Jones, R. 2006. Memo to File - Updates to the salmonid hatchery inventory and effects evaluation report: An evaluation of the effects of artificial propagattion on the status and likelihood of extinction of West Coast salmon and steelhead under the Federal Endangered Species Act. January 19, 2006. NMFS, Portland, Oregon.

Jonsson, N., B. Johsson, and L. P. Hansen. 2003. The marine survival and growth of wild and hatcheryreared Atlantic salmon. Journal of Applied Ecology of Freshwater Fish 40:900–911.

Judge, M. M. 2011. A Qualitative Assessment of the Implementation of the Puget Sound Chinook Salmon Recovery Plan. Lighthouse Natural Resource Consulting, Inc. 45p.

Keefer, M. L., C. C. Caudill, C. A. Peery, and C. T. Boggs. 2008. Non-direct homing behaviours by adult Chinook salmon in a large, multi-stock river system. Journal of Fish Biology 72:27-44.

Kinsel, C., M. Zimmerman, L. Kishimoto, and P. Topping. 2008. Annual report. 2007 Skagit River Salmon Production Evaluation. December 2008. State of Washington Department of Fish and Wildlife. Funded by Salmon Recovery Funding Board. 74p.

Kline, T. C., Jr., J. J. Goering, O. A. Mathisen, P. H. Poe, and P. L. Parker. 1990. Recycling of elements transported upstream by runs of Pacific salmon: I, δ15N and δ13C evidence in Sashin Creek, Southeastern Alaska. Canadian Journal of Fisheries and Aquatic Sciences 47(1):136-144.

Konoski, K. 2018. Email to Christina Iverson (NMFS) from Kate Konoski (Stilly). Construction details. May 15, 2018. 3p.

Kostow, K. 2009. Factors that contribute to the ecological risks of salmon and steelhead hatchery programs and some mitigating strategies. Reviews in Fish Biology and Fisheries 19:9-31.

Lacy, R. C. 1987. Loss of genetic variation from managed populations: Interacting effects of drift, mutation, immigration, selection, and population subdivision. Conservation Biology 1:143-158.

Lande, R., and G. F. Barrowclough. 1987. Effective population size, genetic variation, and their use in population management. Pages 87-123 *in* M. E. Soule, editor. Viable Populations for Conservation. Cambridge University Press, Cambridge and New York.

LaPatra, S. E. 2003. The lack of scientific evidence to support the development of effluent limitations guidelines for aquatic animal pathogens Aquaculture 226:191–199.

Larkin, G. A., and P. A. Slaney. 1996. Trends in Marine-Derived Nutrient Sources to South Coastal British Columbia Streams: Impending Implications to Salmonid Production. Report No. 3. Watershed Restoration Program, Ministry of Environment, Lands and Parks and Ministry of Forests. 59p.

Leider, S. A., P. L. Hulett, J. J. Loch, and M. W. Chilcote. 1990. Electrophoretic comparison of the reproductive success of naturally spawning transplanted and wild steelhead trout through the returning adult stage. Aquaculture 88(3-4):239-252.

Lichatowich, J., I. S.P. Cramer & Associates, U.S. Department of Energy, Bonneville Power Administration, and Division of Fish and Wildlife. 1993. Ocean Carrying Capacity. Recovery Issues for Threatened and Endangered Snake River Salmon Technical Report 6 of 11. June 1993. Technical Report 1993. Project No. 93-013, BPA report DOE/BP-99654-6. 32p.

Lynch, M., and M. O'Hely. 2001. Captive breeding and the genetic fitness of natural populations. Conservation Genetics 2:363-378.

Mahnken, C., G. T. Ruggerone, W. Waknitz, and T. Flagg. 1998. A historical perspective on salmonid production from Pacific Rim hatcheries. North Pacific Anadromous Fish Commission Bulletin 1:38-53.

Mantua, N., I. Tohver, and A. Hamlet. 2009. Impacts of Climate Change on Key Aspects of Freshwater Salmon Habitat in Washington State. Pages 217 to 253 (Chapter 6) *in*: Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate. Climate Impacts Group, University of Washington, Seattle, Washington. 37p.

Martins, E. G., S. G. Hinch, S. J. Cooke, and D. A. Patterson. 2012. Climate effects on growth, phenology, and survival of sockeye salmon (*Oncorhynchus nerka*): a synthesis of the current state of knowledge and future research directions. Reviews in Fish Biology and Fisheries 22(4):887-914.

McClelland, E. K., and K. A. Naish. 2007. What is the fitness outcome of crossing unrelated fish populations? A meta-analysis and an evaluation of future research directions. Conservation Genetics 8:397-416.

McElhany, P., M. H. Rucklelshaus, M. J. Ford, T. C. Wainwright, and E. P. Bjorkstedt. 2000. Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-42. 174p.

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

Melnychuk, M. C., and coauthors. 2014. Marine survival difference between wild and hatchery-reared steelhead trout determined during early downstream migration. Canadian Journal of Fisheries and Aquatic Sciences 71:831-846.

Montgomery, D. R., J. M. Buffington, N. P. Peterson, D. Schuett-Hames, and T. P. Quinn. 1996. Stream-bed scour, egg burial depths, and the influecne of salmonid spawning on bed surface mobility and embryo survival. Canadian Journal of Fisheries and Aquatic Sciences 53:1061-1070.

Morrison, W. E., M. W. Nelson, R. B. Griffis, and J. A. Hare. 2016. Methodology for assessing the vulnerability of marine and anadromous fish stocks in a changing climate. Fisheries 41(7):407-409.

Mote, P. W., and coauthors. 2003. Preparing for climatic change: the water, salmon, and forests of the Pacific Northwest. Climatic change 61(1-2):45-88.

Murota, T. 2003. The marine nutrient shadow: A global comparison of anadromous fishery and guano occurrence. Pages 17-31 *in* J.G. Stockner, ed. Nutrients in salmonid ecosystems. American Fisheries Society Symposium 34, Bethesda, Maryland. AFS Symposium 34:17-31.

Myers, J. M., and coauthors. 2015. Identifying Historical Populations of Steelhead within the Puget Sound Distinct Population Segment. March 2015. U.S. Dept. Commer., NOAA Technical Memorandum NMFS NWFSC-128. 175p.

Myers, J. M., and coauthors. 1998. Status Review of Chinook Salmon from Washington, Idaho, Oregon, and California. February 1998. U.S. Dept. Commer., NOAA Tech Memo., NMFS-NWFSC-35. 476p.

Naish, K. A., and coauthors. 2008. An Evaluation of the Effects of Conservation and Fishery Enhancement Hatcheries on Wild Populations of Salmon Advances in Marine Biology in Advances in Marine Biology, Volume 53. David W. Sims, Series Editor. 318p.

Naman, S. W., and C. S. Sharpe. 2012. Predation by hatchery yearling salmonids on wild subyearling salmonids in the freshwater environment: A review of studies, two case histories, and implications for management. Environmental Biology of Fisheries 94(1):21-28.

Nelson, K., and B. Kelder. 2005. 2002 Skykomish River Chinook and coho out-migration study. Annual report No. 05-1. Tulalip Natural Resources Department, Tulalip, Washington. 64p.

Nickelson, T. E., M. F. Solazzi, and S. L. Johnson. 1986. Use of hatchery coho salmon (*Oncorhynchus kisutch*) presmolts to rebuild wild populations in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences 43:2443-2449.

NMFS. 1995. Juvenile Fish Screen Criteria. Revised February 16, 1995. NMFS, Portland, Oregon. 15p.

NMFS. 1996. Juvenile Fish Screen Criteria for Pump Intakes: Addendum. May 9, 1996. NMFS Environmental and Technical Services Division, Portland, Oregon. 4p.

NMFS. 2000. RAP - A Risk Assessment Procedure for Evaluating Harvest Mortality of Pacific salmonids. May 30, 2000. NMFS, Seattle, Washington. 34p.

NMFS. 2002a. Endangered Species Act Section 7 Consultation and Magnuson-Stevens Act Essential Fish Habitat Consultation. Biological Opinion on Artificial Propagation in the Hood Canal and Eastern Strait of Juan de Fuca Regions of Washington State. Hood Canal Summer Chum Salmon Hatchery Programs by the U.S. Fish and Wildlife Service and the Washington Department of Fish and Wildlife and Federal and Non-Federal Hatchery Programs Producing Unlisted Salmonid Species. National Marine Fisheries Service, Portland, Oregon. 285p.

NMFS. 2002b. Environmental assessment of a National Marine Fisheries Service action to determine whether eight HGMPs provided by the Washington Department of Fish and Wildlife (WDFW) and the U.S. Fish and Wildlife Service (USFWS) meet the criteria in the Endangered Species Act section 4(d) rule limit 5. 50 CFR 223.203(b)(5) and Finding of No Significant Impact. 35p.

NMFS. 2004. Salmonid Hatchery Inventory and Effects Evaluation Report (SHIEER). An Evaluation of the Effects of Artificial Propagation on the Status and Likelihood of Extinction of West Coast Salmon and Steelhead under the Federal Endangered Species Act. Technical Memorandum NMFS-NWR/SWR. May 28, 2004. U.S. Dept. of Commerce, National Marine Fisheries Service, Portland, Oregon. 557p.

NMFS. 2005a. Appendix A CHART assessment for the Puget Sound salmon evolutionary significant unit from final assessment of NOAA Fisheries' Critical Habitat Analytical Review Teams for 12 ESUs of West Coast salmon and steelhead. August 2005. 55p.

NMFS. 2005b. Endangered and Threatened Species: Designation of Critical Habitat for 12 Evolutionarily Significant Units of West Coast Salmon and Steelhead in Washington, Oregon, and Idaho. Pages 52630-52858 *in*. Federal Register, Volume 70 No. 170.

NMFS. 2005c. Policy on the consideration of hatchery-origin fish in Endangered Species Act listing determinations for Pacific salmon and steelhead. Pages 37204-37216 *in* D. o. Commerce, editor. Federal Register, Volume 70 No. 123.

NMFS. 2006a. Endangered Species Act Section 7 Consultation Biological Opinion and Section 10 Statement of Findings and Magnuson-Stevens Fishery Conservation and Managment Act Essential Fish Habitat Consultation. Washington State Forest Practices Habitat Conservation Plan. NMFS Consultation No.: NWR-2005-07225. 335p.

NMFS. 2006b. Final Supplement to the Shared Strategy's Puget Sound Salmon Recovery Plan. November 17, 2006. NMFS, Portland, Oregon. 47p.

NMFS. 2007. Report to Congress: Pacific Coastal Salmon Recovery Fund. FY 2000–2006. U.S. Department of Commerce. 56p.

NMFS. 2008a. Assessing Benefits and Risks & Recommendations for Operating Hatchery Programs consistent with Conservation and Sustainable Fisheries Mandates. Appendix C of Supplementary Comprehensive Analysis of the Federal Columbia River Power System and Mainstem Effects of the Upper Snake and other Tributary Actions. May 5, 2008. NMFS, Portland, Oregon.

NMFS. 2008b. Endangered Species Act Section 7 Biological Opinion on the Effects of the Pacific Coast Salmon Plan and U.S. Fraser Panel Fisheries on the Lower Columbia River Coho and Lower Columbia River Chinook Evolutionarily Significant Units Listed under the Endangered Species Act and Magnuson-Stevens Act Essential Fish Habitat Consultation. April 28, 2008. NMFS, Portland, Oregon. Consultation No.: NWR-2008-02438. 124p.

NMFS. 2008c. Endangered Species Act Section 7 Consultation Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation on EPA's Proposed Approval of Revised Washington Water Quality Standards for Designated Uses, Temperature, Dissolved Oxygen, and Other Revisions. February 5, 2008. NMFS Consultation No.: NWR-2007-02301. 137p.

NMFS. 2008d. Endangered Species Act Section 7 Consultation Final Biological Opinion and Magnuson-Stevens Fishery Conservation and Managment Act Essential Fish Habitat Consultation. Implementation of the National Flood Insurance Program in the State of Washington Phase One Document-Puget Sound Region. NMFS Consultation No.: NWR-2006-00472. 226p.

NMFS. 2008e. Endangered Species Act Section 7(a)(2) Consultation Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation. Consultation on Treaty Indian and Non-Indian Fisheries in the Columbia River Basin Subject to the 2008-2017 *U.S. v. Oregon* Management Agreement. May 5, 2008. NMFS, Portland, Oregon. NMFS Consultation No.: NWR-2008-02406. 685p.

NMFS. 2010. Draft Puget Sound Chinook Salmon Population Recovery Approach (PRA). NMFS Northwest Region Approach for Distinguishing Among Individual Puget Sound Chinook Salmon ESU Populations and Watersheds for ESA Consultation and Recovery Planning Purposes. November 30, 2010. Puget Sound Domain Team, NMFS, Seattle, Washington. 19p.

NMFS. 2011a. Anadromous Salmonid Passage Facility Design. July 2011. National Marine Fisheries Service, Northwest Region, Portland, Oregon. 140p.

NMFS. 2011b. Evaluation of and recommended determination on a Resource Management Plan (RMP), pursuant to the salmon and steelhead 4(d) Rule comprehensive management plan for Puget Sound Chinook: Harvest management component. Salmon Management Division, Northwest Region, Seattle, Washington.

NMFS. 2012a. Effects of Hatchery Programs on Salmon and Steelhead Populations: Reference Document for NMFS ESA Hatchery Consultations. December 3, 2012. Northwest Region, Salmon Managment Division, Portland, Oregon. 50p.

NMFS. 2012b. Streamlining Restoration Project Consultation using Programmatic Biological Opinions. NMFS Northwest Region Habitat Conservation Division, Portland, Oregon.

NMFS. 2013. Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat (EFH) Consultation - Washington State Department of Transportation Preservation, Improvement, and Maintenance Activities. January 2, 2013. NMFS Consultation No.: 2012-00293. NMFS, Seattle, Washington. 82p.

NMFS. 2014. Endangered Species Act Biological Opinion and Magnuson-Stevens Act Essential Fish Habitat Consultation. Impacts of Programs Administered by the Bureau of Indian Affairs that Support Puget Sound Tribal Salmon Fisheries, Salmon Fishing Activities Authorized by the U.S. Fish and Wildlife Service, and Fisheries. Authorized by the U.S. Fraser Panel in 2014. May 1, 2014. NMFS Consultation No.: WCR-2014-578. 156p.

NMFS. 2015. Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation. Impacts of Programs Administered by the Bureau of Indian Affairs that Support Puget Sound Tribal Salmon Fisheries, Salmon Fishing Activities Authorized by the U.S. Fish and Wildlife Service, and Fisheries. Authorized by the U.S. Fraser Panel in 2015. NMFS, Seattle, Washington. May 7, 2015. NMFS Consultaton No.: WCR-2015-2433. 172p.

NMFS. 2016a. Endangered Species Act 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 Three Hatchery and Genetic Management Plans for Early Winter Steelhead in the Dungeness, Nooksack, and Stillaguamish River basins under Limit 6 of the Endangered Species Act Section 4(d) Rule. April 15, 2016. NMFS Consultation No.: WCR-2015-2024. 220p.

NMFS. 2016b. Endangered Species Act 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 Two Hatchery and Genetic Management Plans for Early Winter Steelhead in the Snohomish River basin under Limit 6 of the Endangered Species Act Section 4(d) Rule. April 15, 2016. NMFS Consultation No.: WCR-2015-3441. 189p.

NMFS. 2016c. Final Environmental Impact Statement - Environmental Impact Statement to Analyze Impacts of NOAA's National Marine Fisheries Service Proposed 4(d) Determination under Limit 6 for Five Early Winter Steelhead Hatchery Programs in Puget Sound. March 2016. NMFS, Lacey, Oregon. 326p.

NMFS. 2017a. Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response:. Impacts of the Role of the BIA Under its Authority to Assist with the Development of the 2017-2018 Puget Sound Chinook Harvest Plan, Salmon Fishing Activities Authorized by the U.S. Fish and Wildlife Service, and Fisheries Authorized by the U.S. Fraser Panel in 2017. May 3, 2017. NMFS Consultation No.: F/WCR-2017-6766. 201p.

NMFS. 2017b. Endangered Species Act 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 Six Hatchery and Genetic Management Plans for Snohomish River basin Salmon under Limit 6 of the Endangered Species Act Section 4(d) Rule. September 27, 2017. NMFS Consultation No.: NWR-2013-9699. 189p.

NMFS. 2017c. National Marine Fisheries Service Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat (EFH) Consultation. Consultation on the "Evaluation and Recommended Determination of a Tribal Resource Management Plan Submitted for Consideration Under the Endangered Species Act's Tribal Plan Limit [50 CFR 223.204] for the Period January 1, 2017 – December 31, 2021" affecting Salmon, Steelhead, and Eulachon in the West Coast Region. April 5, 2017. NMFS Consultation No.: WCR-2016-5800. 95p.

NMFS. 2018. Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response. Impacts of the Role of the BIA Under its Authority to Assist with the Development of the 2018-2019 Puget Sound Chinook Harvest Plan, Salmon Fishing Activities Authorized by the U.S. Fish and Wildlife Service, and Fisheries Authorized by the U.S. Fraser Panel in 2018. May 9, 2018. NMFS, West Coast Region. NMFS Consultation No.: WCR-2018-9134. 258p.

Noakes, D. J., R. J. Beamish, and M. L. Kent. 2000. On the decline of Pacific salmon and speculative links to salmon farming in British Columbia. Aquaculture 183:363-386.

NRC. 1996. Upstream: Salmon and Society in the Pacific Northwest. National Academy Press: Washington, D.C. 452p.

NWFSC. 2015. Status Review Update for Pacific Salmon and Steelhead listed under the Endangered Species Act: Pacific Northwest. December 21, 2015. NWFSC, Seattle, Washington. 356p.

NWIFC. 2016. 2016 State of Our Watersheds, WRIAs 1-23. A report by the Treaty Tribes in Western Washington. Northwest Indian Fisheries Commission Member Tribes. 336p.

NWIFC, and WDFW. 2006. The Salmonid Disease Control Policy of the Fisheries Co-Managers of Washington State. Revised July 2006. 38p.

ODFW. 2003. Fish Health Management Policy, September 12, 2003. Oregon Department of Fish and Wildlife. 10p.

Ohlberger, J., E. J. Ward, D. E. Schindler, and B. Lewis. 2018. Demographic changes in Chinook salmon across the Northeast Pacific Ocean. Fish and Fisheries 19(3):533-546.

Olla, B. L., and M. W. Davis. 1989. The role of learning and stress in predator avoidance of hatchery-reared coho salmon (*Oncorhynchus kisutch*) juveniles. Aquaculture 76(3-4):209-214.

Olla, B. L., M. W. Davis, and C. H. Ryer. 1998. Understanding how the hatchery environment represses or promotes the development of behavioral survival skills. Bulletin of Marine Science 62(2):531-550.

Pearcy, W. G., and S. M. McKinnell. 2007. The ocean ecology of salmon in the Northeast Pacific Ocean - An abridged history. American Fisheries Society Symposium 57:7-30.

Pearsons, T. N., and C. A. Busack. 2012. PCD Risk 1: A tool for assessing and reducing ecological risks of hatchery operations in freshwater. Environmental Biology of Fishes 94:45-65.

Pearsons, T. N., and A. L. Fritts. 1999. Maximum size of Chinook salmon consumed by juvenile coho salmon. North American Journal of Fisheries Management 19(1):165-170.

Pearsons, T. N., and coauthors. 1994. Yakima River Species Interaction Studies. Annual report 1993. December 1994. Division of Fish and Wildlife, Project No. 1989-105, Bonneville Power Administration, Portland, Oregon. 264p.

Pelletier, G., and D. Bilhimer. 2004. Stillaguamish River Watershed Temperature Total Maximum Daily Load. Report 04-03-010. March 2004. Washington State Department of Ecology, Olympia, Washington. 119p.

PFMC. 2003. Pacific Coast Management Plan. Fishery Management Plan for Commercial and Recreational Salmon Fisheries off the coasts of Washington, Oregon and California as revised through Amendment 14. (Adopted March 1999). September 2003. PFMC, Portland, Oregon. 78p.

PFMC. 2014. Appendix A to the Pacific Coast Salmon Fishery Management Plan as modified by Amendment 18 to the Pacific Coast Salmon Plan: Identification and description of essential fish habitat, adverse impacts, and recommended conservation measures for salmon. Pacific Fishery Management Council, Portland, Oregon. September 2014. 227 pages including appendices. Appendix A is available online at: http://www.pcouncil.org/wp-content/uploads/Salmon_EFH_Appendix_A_FINAL_September-25.pdf.

Piorkowski, R. J. 1995. Ecological effects of spawning salmon on several south central Alaskan streams. Ph.D. dissertation, University of Alaska, Fairbanks, Alaska. 191p.

Piper, R. G., and coauthors. 1986. Fish Hatchery Management, 5th edition. US Dept. of Interior, USFWS.

PNFHPC. 1989. Model Comprehensive Fish Health Protection Program. Approved September 1989, revised February 2007. PNFHPC, Olympia, Washington. 22p.

PSC. 2006a. 2004/2005 Twentieth Annual Report, Vancouver, B.C. Canada. August 2006.188p.

PSC. 2006b. Chinook Technical Committee Report Report of the Joint Chinook Technical Committee Workgroup on the October 19, 2005 Assignment Given to the Chinook Technical Committee by the Pacific Salmon Commission Regarding the Conduct of Canadian AABM Fisheries Report TCCHINOOK (06)-1. July 28, 2006. 166p.

PSC. 2016. Pacific Salmon Commission Joint Chinook Technical Committee Report. Chapter 3 Performance Evaluation Report. TCCHINOOK (16)-02. Revised November 14, 2016. 135p.

PSIT, and WDFW. 2010. Comprehensive Management Plan for Puget Sound Chinook: Harvest Management Component. April 12. 2010. Puget Sound Indian Tribes and the Washington Department of Fish and Wildlife. 237p.

PSIT, and WDFW. 2013. Puget Sound Chinook Harvest Management Performance Assessment 2003-2010. July, 2013. Puget Sound Indian Tribes and Washington Department of Fish and Wildlife, Olympia, Washington. 111p.

PSIT, and WDFW. 2017. Draft Comprehensive Management Plan for Puget Sound Chinook: Harvest Management Component. December 1, 2017. Puget Sound Indian Tribes and the Washington Department of Fish and Wildlife. 338p.

PSP. 2013. Puget Sound Partnership and Recovery Implementation Technical Team (RITT), 2013 Three Year Work Plan Review for the Stillaguamish Watershed. 13p.

PSSTRT. 2013. Viability Criteria for Puget Sound Steelhead. Final Review Draft. April 2013. 372p.

PST, and WDFW. 2015. 2015-2016 Puget Sound Chinook Harvest Plan. Submitted to the National Marine Fisheries Service to Initiate Consultation and Authorization of Fisheries under Section 7 of the Endangered Species Act. April 28, 2015. Puget Sound Tribes and WDFW, Olympia, Washington. 44p.

PSTRT. 2002. Planning Ranges and Preliminary Guidelines for the Delisting and Recovery of the Puget Sound Chinook Salmon Evolutionarily Significant Unit. April 30, 2002. Puget Sound Technical Recovery Team, NMFS-NWFSC, Seattle, Washington. 20p.

Puget Sound Partnership. 2018. The 2018-2022 Action Agenda for Puget Sound. December 2018. 295p.

Quamme, D. L., and P. A. Slaney. 2003. The relationship between nutrient concentration and stream insect abundance. American Fisheries Society Symposium 34:163-175.

Quinn, T. P. 1993. A review of homing and straying of wild and hatchery-produced salmon. Fisheries Research 18:29-44.

Quinn, T. P. 1997. Homing, Straying, and Colonization. Genetic Effects of Straying of Non-Native Fish Hatchery Fish into Natural Populations. NOAA Tech. Memo., NMFS-NWFSC-30. 13p.

Quinn, T. P., and N. P. Peterson. 1996. The influence of habitat complexity and fish size on over-winter survival and growth of individually marked juvenile coho salmon (*Oncorhynchus kisutch*) in Big Beef Creek, Washington. Canadian Journal of Fisheries and Aquatic Sciences 53:1555-1564.

Reisenbichler, R. R., and J. D. McIntyre. 1977. Genetic differences in growth and survival of juvenile hatchery and wild steelhead trout, *Salmo gairdneri*. Journal of the Fisheries Research Board of Canada 34:123-128.

Rensel, J., and coauthors. 1984. Evaluation of Potential Interaction Effects in the Planning and Selection of Salmonid Enhancement Projects. J. Rensel, and K. Fresh editors. Report prepared by the Species Interaction Work Group for the Enhancement Planning Team for implementation of the Salmon and Steelhead Conservation and Enhancement Act of 1980. WDFW, Olympia, Washington. 90p.

Ruckelshaus, M. H., and coauthors. 2006. Independent Populations of Chinook Salmon in Puget Sound. July 2006. U.S. Dept. Commer., NOAA Technical Memorandum NMFS-NWFSC-78. 145p.

Ruggerone, G. T., and F. A. Goetz. 2004. Survival of Puget Sound Chinook salmon (*Oncorhynchus tshawytscha*) in response to climate-induced competition with pink salmon (*Oncorhynchus gorbuscha*). Canadian Journal of Fisheries and Aquatic Sciences 61:1756-1770.

Ryman, N. 1991. Conservation genetics considerations in fishery management. Journal of Fish Biology 39 (Supplement A):211-224.

Ryman, N., P. E. Jorde, and L. Laikre. 1995. Supportive breeding and variance effective population size. Conservation Biology 9(6):1619-1628.

Ryman, N., and L. Laikre. 1991. Effects of supportive breeding on the genetically effective population size. Conservation Biology 5(3):325-329.

Saisa, M., M.-L. Koljonen, and J. Tahtinen. 2003. Genetic changes in Atlantic salmon stocks since historical times and the effective population size of a long-term captive breeding programme. Conservation Genetics 4:613–627.

Sandercock, F. K. 1991. The Life History of Coho Salmon (*Oncorhynchus kisutch*) *in* C. Groot and L. Margolis (eds.), Life history of Pacific Salmon. Univ. of British Columbia Press, Vancouver, B.C.

Scheuerell, M. D., P. S. Levin, R. W. Zabel, J. G. Williams, and B. L. Sanderson. 2005. A new perspective on the importance of marine-derived nutrients to threatened stocks of Pacific salmon (*Oncorhynchus* spp.). Canadian Journal of Fisheries and Aquatic Sciences 62(5):961-964.

Scheuerell, M. D., and J. G. Williams. 2005. Forecasting climate-induced changes in the survival of Snake River spring/summer Chinook salmon (*Oncorhynchus tshawytscha*). Fisheries Oceanography 14(6):448-457.

Scofield, C., and J. Griffith. 2012. 2011 Annual Report: Stillaguamish River Smolt Trapping Project. August 2012. Stillaguamish Tribe of Indians, Arlington, Washington. 30p.

Scofield, C., and J. Griffith. 2013. 2012 Annual Report: Stillaguamish River Smolt Trapping Project. September 2013. Stillaguamish Tribe of Indians, Arlington, Washington. 35p.

Scofield, C., and J. Griffith. 2014. 2013 Annual Report: Stillaguamish River Smolt Trapping Project. October 9, 2014. Stillaguamish Tribe of Indians, Arlington, Washington. 36p.

Scofield, C., and J. Griffith. 2015. 2014 Annual Report: Stillaguamish River Smolt Trapping Project. May 2015. Stillaguamish Tribe of Indians, Arlington, Washington. 35p.

Scofield, C., and J. Griffith. 2016. 2015 Annual Report: Stillaguamish River Smolt Trapping Project. January 2016. Stillaguamish Tribe of Indians, Arlington, Washington. 32p.

Shapovalov, L., and A. C. Taft. 1954. The Life Histories of the Steelhead Rainbow Trout (*Salmo gairdneri*) and Silver Salmon (*Oncorhynchus kisutch*) with special reference to Waddell Creek, California, and Recommendations Regarding Their Management. California Department of Fish and Game Fish Bulletin 98.

Sharpe, C. S., P. C. Topping, T. N. Pearsons, J. F. Dixon, and H. J. Fuss. 2008. Predation of Naturally-produced Subyearling Chinook by Hatchery Steelhead Juveniles in Western Washington Rivers. June 2008. FPT 07-09. WDFW Fish Program, Science Division. 68p.

SIRC. 2005. Stillaguamish Watershed Chinook Salmon Recovery Plan. June 2005. Published by Snohomish County Department of Public Works, Surface Water Management Division. Everett, Washington. 187p.

Small, M. P., and coauthors. 2017a. 2015 Broodyear Report: Abundance Estimates for Stillaguamish River Chinook Salmon using Trans-Generational Genetic Mark Recapture, Year 2. May 2017. 42p.

Small, M. P., and coauthors. 2017b. 2017 Summary report of genetic analyses of summer- and fall-run Chinook salmon in the North and South Fork Stillaguamish River. 2017 Summary report draft, November 2017. 29p.

Small, M. P., and coauthors. 2016. 2016 Summary Report of Genetic Analyses of Summer- and Fall-run Chinook Salmon in the North and South Fork Stillaguamish River. WDFW Molecular Genetics Lab, Olympia, Washington. 44p.

SNRD. 2005. Analysis of Stillaguamish Estuary Use by Juvenile Chinook Salmon: A Pilot Study.

Sosiak, A. J., R. G. Randall, and J. A. McKenzie. 1979. Feeding by hatchery-reared and wild Atlantic salmon (*Salmo salar*) parr in streams. Journal of the Fisheries Research Board of Canada 36:1408-1412.

Spence, B. C., G. A. Lomnicky, R. M. Hughes, and R. P. Novitzki. 1996. An Ecosystem Approach to Salmonid Conservation. December 1996. TR-4501-96-6057. Corvallis, Oregon. 206p.

SSPS. 2005. Stillaguamish Watershed Profile, WRIA 5. Shared Strategy Development Committee, Seattle, Washington.

SSPS. 2007. Puget Sound Salmon Recovery Plan. Volumes I, II and III. Plan Adopted by the National Marine Fisheries Service (NMFS) January 19, 2007. Submitted by the Shared Strategy Development Committee. Shared Strategy for Puget Sound. Seattle, Washington. 503p.

Steward, C. R., and T. C. Bjornn. 1990. Supplementation of Salmon and Steelhead Stocks with Hatchery Fish: A Synthesis of Published Literature. Technical Report 90-1. Idaho Cooperative Fish and Wildlife Research Unit, Moscow, Idaho. 132p.

Stillaguamish Tribe of Indians. 2015. Stillaguamish fall Coho HGMP. December 17, 2015. Stillaguamish Tribe, Arlington, Washington. 40p.

Stillaguamish Tribe of Indians. 2016. Stillaguamish fall Chum Program HGMP. July 26, 2016. Stillaguamish Tribe, Arlington, Washington. 38p.

Stillaguamish Tribe of Indians. 2017a. Stillaguamish fall Chinook Natural Stock HGMP. June 21, 2017. Stillaguamish Tribe, Arlington, Washington. 42p.

Stillaguamish Tribe of Indians. 2017b. Stillaguamish summer Chinook Natural Stock HGMP. June 21, 2017. Stillaguamish Tribe, Arlington, Washington. 41p.

Stillaguamish Tribe of Indians. 2017c. Stillaguamish Tribe of Indians Natural Resources Climate Change Adaptation Plan. May 2017. 107p.

Tatara, C. P., and B. A. Berejikian. 2012. Mechanisms influencing competition between hatchery and wild juvenile anadromous Pacific salmonids in fresh water and their relative competitive abilities. Environmental Biology of Fishes 94(1):7-19.

Theriault, V., G. R. Moyer, L. S. Jackson, M. S. Blouin, and M. A. Banks. 2011. Reduced reproductive success of hatchery coho salmon in the wild: Insights into most likely mechanisms. Molecular Ecology 20:1860-1869.

Topping, P., L. Kishimoto, J. Holowatz, D. Rawding, and M. Groesbeck. 2008a. 2006 Juvenile Salmonid Production Evaluation Report: Green River, Dungeness River, and Cedar Creek. Washington Department of Fish and Wildlife. FPA 08-05. August 2008. 136p.

Topping, P., M. Zimmerman, and L. Kishimoto. 2008b. Juvenile Salmonid Production Evaluation Report: Green River and Dungeness River Chinook Monitoring Evaluations in 2007. FPA 08-09. WDFW, Olympia, Washington. 97p.

Tynan, T. 1997. Life History Characterization of Summer Chum Salmon Populations in the Hood Canal and Eastern Strait of Juan De Fuca Regions. Washington Department of Fish and Wildlife Hatchery Program. Report # H97-06. 112p.

USFWS. 1994. Programmatic Biological Assessment of the Proposed 1995-99 LSRCP Program. Lower Snake River Compensation Plan Office and USFWS, Boise, Idaho. 68p.

USFWS. 2004. U.S. Fish & Wildlife Service handbook of aquatic animal health procedures and protocols.

Vasemagi, A., R. Gross, T. Paaver, M. L. Koljonen, and J. Nilsson. 2005. Extensive immigration from compensatory hatchery releases into wild Atlantic salmon population in the Baltic sea: Spatio-temporal analysis over 18 years. Heredity 95(1):76-83.

Volkhardt, G., D. Seiler, S. Neuhauser, and L. Kishimoto. 2006a. 2004 Skagit River Wild 0+ Chinook Production Evaluation. Annual Report. Washington Department of Fish and Wildlife Fish Program, Science Division. FPA 05-15. May 2006. 58p.

Volkhardt, G., P. Topping, and L. Kishimoto. 2006b. 2005 Juvenile Salmonid Production Evaluation Report – Green River, Dungeness River, and Cedar Creek. FPA 06-10. WDFW, Olympia, Washington. 101p.

Wainwright, T. C., and L. A. Weitkamp. 2013. Effects of climate change on Oregon Coast coho salmon: habitat and life-cycle interactions. Northwest Science 87(3):219-242.

Waples, R. S. 1991. Genetic interactions between hatchery and wild salmonids: Lessons from the Pacific Northwest. Canadian Journal of Fisheries and Aquatic Sciences 48(Supplement 1):124-133.

Waples, R. S. 1999. Dispelling some myths about hatcheries. Fisheries 24(2):12-21.

Waples, R. S., and C. Do. 1994. Genetic risk associated with supplementation of Pacific salmonids: Captive broodstock programs. Canadian Journal of Fisheries and Aquatic Sciences 51 (Supplement 1):310-329.

Ward, B. R., and P. A. Slaney. 1988. Life history and smolt-to-adult survival of Keogh River steelhead trout (*Salmo gairdneri*) and the relationship to smolt size. Canadian Journal of Fisheries and Aquatic Sciences 45:1110-1122.

Ward, L., and coauthors. 2008. Elwha River Fish Restoration Plan. Developed Pursuant to the Elwha River Ecosystem and Fisheries Restoration Act, Public Law 102-495. U.S. Dept. Commer., NOAA Tech. Memo., NMFS-NWFSC-90. 191p.

Warheit, K. I. 2014a. Measuring reproductive interaction between hatchery-origin and Wild steelhead (*Oncorhynchus mykiss*) from northern Puget Sound populations potentially affected by segregated hatchery programs. November 10, 2014. Unpublished Final Report. WDFW, Olympia, Washington. 14p.

Warheit, K. I. 2014b. Probability_PEHC_Greater_02 excel spreadsheet. November 21, 2014. WDFW, Olympia, Washington.

Washington Fish and Wildlife Commission. 2009. Policy POL-C3619: Hatchery reform. Olympia, Washington.

Washington, U. S. v. 1974. 384 F. Supp 312 (W.D. Wash.), aff'd, 500F.2nd 676 (9thCr. 1975, cert. denied), 423 U.S. 1086 (1976). Seattle, Washington.

WDFW. 2002. 2002 Washington State Salmon and Steelhead Stock Inventory (SASSI). Available on-line at: http://wdfw.wa.gov/fish/sasi/index.htm. Washington Department of Fish and Wildlife, Olympia, Washingtion. 724p.

WDFW. 2005. Whitehorse Pond Summer Steelhead Program HGMP. Draft. August 4, 2005. 49p.

WDFW. 2014. Whitehorse Ponds (Stillaguamish River) Winter Steelhead (*Oncorhynchus mykiss*) Hatchery Program (Segregated) HGMP. July 28, 2014. WDFW, Mill Creek Washington. 65p.

WDFW. 2018a. SCORE_WDFW_2018_Winter SthdEscapement_Stillaguamish excel report.

WDFW. 2018b. Stock Status and Harvest Management Plan for Winter and Summer-run Steelhead Returning to the Snohomish and Stillaguamish rivers in 2017-18. 36p.

WDFW. 2019. Stock Status and Harvest Management Plan for Winter and Summer-run Steelhead Returning to the Snohomish and Stillaguamish rivers in 2018-19. 33p.

WDFW, and PNPTT. 2000. Summer Chum Salmon Conservation Initiative. An Implementation Plan to Recover Summer Chum in the Hood Canal and Strait of Juan de Fuca Region. April 2000. 797p.

WDFW, and PSTIT. 2005. Comprehensive Management Plan for Puget Sound Chinook: Harvest Management Component Annual Postseason Report, 2004-2005 Fishing Season. June 28, 2005. 115p.

WDFW, and PSTIT. 2006. 2005-2006 Chinook Management Report. March 2006. 114p.

WDFW, and PSTIT. 2007. 2006-2007 Chinook Management Report.

WDFW, and PSTIT. 2008. Puget Sound Chinook Comprehensive Harvest Management Plan Annual Report Covering the 2007-2008 Fishing Season. Olympia, Washington. 58p.

WDFW, and PSTIT. 2009. Puget Sound Chinook Comprehensive Harvest Management Plan Annual Report Covering the 2008-2009 Fishing Season. May 11, 2009. Olympia, Washington. 136p.

WDFW, and PSTIT. 2010. Puget Sound Chinook Comprehensive Harvest Management Plan Annual Report Covering the 2009-2010 Fishing Season. June 21, 2010. Olympia, Washington. 152p.

WDFW, and PSTIT. 2011. Puget Sound Chinook Comprehensive Harvest Management Plan Annual Report Covering the 2010-2011 Fishing Season. August 1, 2011. Olympia, Washington. 125p.

WDFW, and PSTIT. 2012. Puget Sound Chinook Comprehensive Harvest Management Plan Annual Report Covering the 2011-2012 Fishing Season. October 3, 2012. Olympia, Washington. 125p.

WDFW, and PSTIT. 2013. Puget Sound Chinook Comprehensive Harvest Management Plan Annual Report Covering the 2012-2013 Fishing Season. Revised August 13, 2013. Olympia, Washington. 114p.

WDFW, and PSTIT. 2014. Puget Sound Chinook Comprehensive Harvest Management Plan Annual Report Covering the 2013-2014 Fishing Season. June 2014. Olympia, Washington. 78p.

WDFW, and PSTIT. 2016. Puget Sound Chinook Comprehensive Harvest Management Plan Annual Report Covering the 2015-2016 Fishing Season. November 2016. Olympia, Washington. 122p.

WDFW, and WWTIT. 1994. 1992 Washington State Salmon and Steelhead Stock Inventory (SASSI). Appendix one. Puget Sound Stocks. Hood Canal and Strait of Juan de Fuca Volume. December 1994. Washington Department of Fish and Wildlife and Western Washington Treaty Indian Tribes, Olympia, Washington. 432p.

WDOE. 1981. Draft Stillaguamish River Basin Instream Resources Protection Program Including Proposed Administrative Rules. March 1981. State Water Program W.W.I.R.P.P. Series - No. 10. 66p.

Whitlock, M. C. 2000. Fixation of new alleles and the extinction of small populations: Drift, load, beneficial alleles, and sexual selection. Evolution 54(6):1855-1861.

Willi, Y., J. V. Buskirk, and A. A. Hoffmann. 2006. Limits to the adaptive potential of small populations. Annual Review of Ecology, Evolution, and Systematics 37:433-458.

Williams, R. W., R. M. Laramie, and J. J. Ames. 1975. A Catalog of Washington Streams and Salmon Utilization. Volume 1. November 1975. Washington Department of Fisheries, Olympia, Washington. 814p.

Williamson, K. S., A. R. Murdoch, T. N. Pearsons, E. J. Ward, and M. J. Ford. 2010. Factors influencing the relative fitness of hatchery and wild spring Chinook (*Oncorhynchus tshawytscha*) in the Wenatchee River, Washington. Canadian Journal of Fisheries and Aquatic Sciences 67:1840-1851.

Wipfli, M. S., J. Hudson, and J. Caouette. 1998. Influence of salmon carcasses on stream productivity: response of biofilm and benthic macroinvertebrates in southeastern Alaska, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences 55:1503-1511.

Withler, R. E. 1988. Genetic consequences of fertilizing chinook salmon (*Oncorhynchus tshawytscha*) eggs with pooled milt. Aquaculture 68:15-25.

WSCC. 1999. Salmon Habitat Limiting Factors Final Report. Water Resource Inventory Area 5, Stillaguamish Watershed. July 1999. Washington State Conservation Commission. 83p.

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

Appendix A:

We evaluated freshwater spawning ground and hatchery CWT recoveries for total of 2.734 million CWT Chinook salmon (brood years 2000-2011) released from the Whitehorse Ponds. A total of 104 tags were recovered out-of-population, or 0.004% of the total number of CWT fish released, whereas 0.078% of released tags were recovered within the North Fork. Adjusting tag recoveries for sampling rates by recovery location resulted in 551 estimated tags in out-of-population sites, and 5,675 estimated tags in the North Fork Stillaguamish. For every 10.3 estimated CWTs within the basin, one tag was recovered out-of-basin, suggesting an out-of-basin stray rate of 8.8%.

NMFS must also consider the effects of fish which stray from this integrated recovery program into non-target ESA-listed populations. Table 24 displays the results from a retrospective coded wire tag (CWT) analysis (Haggerty 2018) performed in order to evaluate the dispersion of hatchery releases from Puget Sound Chinook salmon programs.

Between the return years 2006-2015 a total of 18 North Fork Stillaguamish CWT's were recovered from the natural spawning grounds in the Skagit Basin. When expanded for sampling effort and the proportion of released fish tagged it was estimated that there were 181 estimated CWT fish and 200 expanded adults. Thus, out of the 127,661 natural spawners in the Skagit basin over these recovery years, 0.16% identified as releases from the North Fork Stillaguamish Chinook salmon program.

In the Snohomish basin over the same return years, approximately 41 North Fork Stillaguamish CWT's were recovered, five in the Skykomish and 36 in the Snoqualmie. For the Skykomish population, when expanded for sampling effort and the proportion of released fish tagged, it was estimated that there were 29 estimated CWT fish and 31 expanded adults. When further adjusting for the proportion of hatchery fish with known origin it was estimated 85 of 31,338 (0.27%) naturally spawning fish were from the North Fork Stillaguamish hatchery program. For the Snoqualmie population when the 36 observed CWTs were expanded for sampling effort and the proportion of released fish tagged it was estimated that there were 216 estimated CWT fish and 241 expanded adults. When further adjusting for the proportion of hatchery fish with known origin it was estimated 463 of 13,830 (3.35%) naturally spawning fish were from the North Fork Stillaguamish hatchery program.

Thus, the potential effects of Chinook salmon produced by the Snohomish Basin hatchery programs straying into adjacent basins, and genetic risks to the adjacent Skagit and Snohomish PRA tier 1, 2 and 3 natural populations, as assessed, are not meaningful or measurable.

Table 24 Estimated Total Adult Equivalents Using Coded Wire Tag Recoveries from Return Years 2006- 2015 from Stillaguamish Basin Hatchery Releases for All Recipient Populations.

	Recipient Chinook Populations		
Donor Program	**All Six Skagit Basin Populations (Upper and Lower Skagit, Upper and Lower Sauk, Cascade, Suaittle)**	**Skykomish within the Snohomish Basin**	**Snoqualmie within the Snohomish Basin**
N.F. Stillaguamish Adult Equivalents Estimated Via CWT Recovered[1]	200/127,661 = 0.16%	85/31,338=0.27%	463/13,830 = 3.35%
NMFS PRA Tier for Recipient Pop	1	2	3

[1]See (Haggerty 2018) for adult equivalent estimation methodology. Due to the limited number of fall Chinook salmon program recoveries to date the CWT analysis was based on a vast majority of North Fork summer Chinook program releases and recoveries as reported in RMIS 2018.