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

NMFS Consultation Number: WCR-2020-02561

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

Affected Species and Determinations:

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

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

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

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1. INTRODUCTION

The Proposed Actions are: (1) the National Marine Fisheries Service's (NMFS) determination under limit 6 of the ESA 4(d) rules for Puget Sound Chinook salmon and Puget Sound steelhead (50 CFR § 223.203(b)(6)) concerning the Tulalip Tribes and the Washington Department of Fish and Wildlife (WDFW) hatchery programs in the Snohomish River basin; and, (2) the Bureau of Indian Affairs' (BIA) ongoing disbursement of funds for operation and maintenance of the Tulalip tribal hatchery programs listed in Table 1. Collectively, NMFS and the BIA are the "Action Agencies." Pursuant to the letter received by NMFS from the BIA, NMFS is the designated lead agency for the conduct of this consultation (Speaks 2013).

The Tulalip Tribes and WDFW propose to operate seven hatchery programs that release Chinook, coho, and fall chum salmon into the Snohomish River basin (Table 1). As described in section 1.8 of the Hatchery and Genetics Management Plans (HGMP) (Tulalip Tribes 2012; Tulalip Tribes 2013a; Tulalip Tribes 2013b; WDFW 2013a; WDFW 2013b; WDFW and Everett Steelhead and Salmon Club (ESSC) 2013), all of the hatchery programs are operated for fisheries harvest augmentation purposes.

Chinook salmon propagated through these hatchery programs are included as part of the ESA-listed Puget Sound Chinook salmon Evolutionarily Significant Unit (ESU). "Hatchery programs with a level of genetic divergence relative to the local natural population(s) that is no more than what occurs within the ESU are considered part of the ESU and will be included in any listing of the ESU" (NMFS 2005c). For a detailed description of how NMFS evaluates and determines whether to include hatchery fish in an ESU or Distinct Population Segment (DPS), see Section 2.2 (NMFS 2005c). NMFS considers the Chinook salmon from these hatchery programs to be integrated[1] because they are derived from the ESA-listed natural Skykomish River ("Skykomish") population that is native to the Snohomish River basin, contain genetic resources that represent the ecological and genetic diversity of the Skykomish Chinook salmon population, and because the hatchery programs collect natural origin fish for hatchery broodstock.

Coho and fall chum salmon in Puget Sound, including the coho and fall chum salmon from the hatchery programs considered in this opinion, are not listed under the ESA. NMFS considers the coho salmon from the hatchery programs to be integrated[1] with the natural populations of coho salmon in the Snohomish Basin because they are derived from stocks native to the Snohomish River basin. The chum salmon from the Tulalip Hatchery chum salmon program are not derived from the local natural population and are considered segregated/isolated[1]. Adult chum salmon produced by this program are not intended to spawn naturally and are not intended to establish, supplement, or support any chum salmon populations occurring in the natural environment. The co-managers initiated an integrated recovery program for Snohomish fall chum salmon with an initial, small experimental release in 2019. The purpose is to help rebuild the depleted status of Snohomish chum salmon to a harvestable level that would enable the eventual transition from an integrated recovery[1] program to an integrated harvest program. As with the regional Chinook and coho hatchery programs, NMFS also considers this chum hatchery program to be integrated[1] with the natural population of chum salmon in the Snohomish because they are also derived from stocks native to the basin.

[1] These terms are defined in Section 2.4.1.

Table 1. Hatchery programs associated with the Proposed Action, including program operator and primary funding agency.

Hatchery and Genetics Management Plan (HGMP)	Program Operator	Funding Agency
Bernie Kai-Kai Gobin Salmon Hatchery "Tulalip Hatchery" Summer Chinook Salmon (Tulalip Tribes 2012)	Tulalip Tribes	BIA
Tulalip Bay Hatchery Coho Salmon (Tulalip Tribes 2013a)	Tulalip Tribes	BIA
Tulalip Bay Hatchery Fall Chum Salmon (Tulalip Tribes 2013b)	Tulalip Tribes	BIA
Wallace River Hatchery Summer Chinook Salmon (WDFW 2013b)	WDFW	WDFW
Wallace River Hatchery Coho Salmon (with the Eagle Creek Hatchery cooperative program) (WDFW 2013a)	WDFW	WDFW
Everett Bay Net-Pen Coho Salmon (WDFW and Everett Steelhead and Salmon Club (ESSC) 2013)	WDFW	WDFW
Wallace River Hatchery Integrated Chum Salmon (WDFW 2019b)	WDFW	WDFW

1.1. Background

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

We also completed an essential fish habitat (EFH) consultation on the proposed action, in accordance with section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801 et seq.) and implementing regulations at 50 CFR 600.

We completed pre-dissemination review of this document using standards for utility, integrity, and objectivity in compliance with applicable guidelines issued under the Data Quality Act (DQA) (section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001, Public Law 106-554). The document will be available within two weeks at the NOAA Library Institutional Repository [https://repository.library.noaa.gov/welcome]. A complete record of this consultation is on file at the Sustainable Fisheries Division (SFD) of NMFS in Lacey, Washington.

1.2. Consultation History

Using a 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 six plans developed by the Tulalip Tribes and WDFW describing hatchery programs for Chinook salmon, coho salmon, and fall chum salmon in the Snohomish Basin. On December 20, 2012, NMFS received one HGMP for the Tulalip Tribal hatchery Chinook salmon program on Tulalip Creek, a tributary to Tulalip Bay, with a request to process the HGMP under limit 6 of the 4(d) rule as a joint co-manager plan (Tulalip Tribes 2012). The Tulalip Tribes subsequently submitted two additional HGMPs for review under 4(d) rule, limit 6 on June 20, 2013, describing programs for coho salmon and fall chum salmon that would release juvenile fish into Tulalip Bay (Tulalip Tribes 2013a; Tulalip Tribes 2013b). On February 19, 2013, NMFS received an HGMP for the WDFW Chinook salmon hatchery program at Wallace River Hatchery, with a cover letter requesting review of the plan under limit 6 (WDFW 2013b). On June 27, 2013, NMFS received WDFW's HGMP for the Everett Bay Net-pen coho program (WDFW and Everett Steelhead and Salmon Club (ESSC) 2013), and on October 14, 2013, WDFW's HGMP for the Wallace River Hatchery coho salmon program (WDFW 2013a) was received. The Wallace River Hatchery coho salmon HGMP was revised and resubmitted on September 19, 2016. Both of the WDFW coho salmon HGMPs were also submitted for NMFS review under 4(d) rule limit 6. This biological opinion is based on information provided in these HGMPs and in memos submitted by the co-managers to revise the six salmon HGMPs and evaluate an additional seventh chum salmon HGMP as well as increased Chinook production proposed by the co-managers.

On December 15, 2017, NMFS published in the Federal Register notification of the availability of its ESA 4(d) Rule proposed evaluation and pending determination (PEPD) for the six joint salmon HGMPs for public review and comment (81 FR 90784). A draft Environmental Assessment (EA), assembled by NMFS to evaluate compliance of any NMFS ESA 4(d) Rule determination regarding the HGMPs with the NEPA, was made available for public review at the same time, as announced in the same notice. During the public review period, NMFS received comments from one commenter – WDFW. WDFW's substantive comments applicable to Snohomish River basin salmon hatchery actions and effects were reviewed and considered in this opinion.

The Snohomish HGMP permit under the ESA was signed on November 17, 2017. On February 23, 2018, WDFW contacted NMFS to request an additional release of up to 7,000 coho salmon sub-yearling smolts at 150 fpp marked with an adipose clip from a pond located on private property off Woods Creek, a tributary to the Skykomish River in cooperation with Monroe Rod & Gun Club. On April 17, 2018 NMFS sent a letter to the Snohomish co-managers explaining that as this proposed additional coho salmon release would not contribute any additional effects to listed species that were not considered in the consultation evaluating the effects of seven Hatchery and Genetic Management Plans for Snohomish River Basin salmon and because this proposed additional coho salmon release does not change the scope, magnitude, or duration of effects considered in the consultation re-initiation of the consultation was not needed.

On September 27, 2018, NMFS received a letter co-signed by the Tulalip Tribes and WDFW jointly requesting NMFS re-initiate the ESA consultation to consider increased production of all hatchery programs and include a 7th HGMP for the Wallace River Hatchery integrated chum salmon program (WDFW and Tribes 2018). The co-managers are proposing a phased approach to increasing Chinook salmon production.

Since the 2017 evaluations were completed, the Snohomish basin co-managers submitted a seventh HGMP for Skykomish chum salmon for ESA and NEPA consultation (WDFW 2019b) and proposed Chinook salmon production increases to provide increased prey available for Southern Resident Killer Whales (SRKW) in a two-phased approach that is described in more detail below in Section 1.3.1. The phased approach is taken with respect to incremental facilities and operations improvements proposed in the effort to improve water quality, quantity and holding conditions to increase in-hatchery survival. The Snohomish hatchery consultation was reopened in 2018 to evaluate the additional chum salmon HGMP and increased hatchery Chinook production as proposed by the co-managers in this updated Biological Opinion.

In addition to the proposed phased production increases and accompanying facilities improvements to improve in-hatchery survival, the co-managers propose to evaluate experimental rearing and release groups to monitor and identify methods to adaptively manage interactions with natural-origin fish while maximizing survival and contribution to SRKWs. Thermally-otolith-marked and coded-wire tagged sub-yearling Chinook experimental rearing and release groups will be evaluated to investigate how spreading out the release window and varying rearing and release strategies affects contribution to the SRKW key prey base and potential ecological and genetic interactions with ESA-listed, natural-origin juvenile and adult Chinook salmon in the Snohomish river, estuary, and nearshore marine habitats.

In later years, when adults recruit to fisheries and return to natural and hatchery escapements from the increased production experimental releases, survivorship and size at age will be examined to infer contribution to the SRKW prey as well as potential genetic and ecological interactions among adult fish. The overall goals of the proposed production increase and monitoring approach is therefore to increase hatchery production and optimize survival to increase the contribution of early returning Skykomish River summer Chinook salmon during the SRKW reduced body condition-diversified diet period, while identifying optimal rearing and release strategies that minimize ecological and genetic effects to ESA-listed Chinook salmon and steelhead.

1.3. Proposed Federal Action

Under the ESA, "action" means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies (50 CFR 402.02).

The Proposed Actions are: (1) NMFS' determination under limit 6 of the ESA 4(d) rules for listed Puget Sound Chinook salmon and listed Puget Sound steelhead (50 CFR § 223.203(b)(6)) concerning the Tulalip Tribes and the WDFW hatchery salmon programs in the Snohomish River basin; and, (2) the BIA's ongoing disbursement of funds for operation and maintenance of the three Tulalip Tribal hatchery salmon programs listed in Table 1.

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

NMFS describes a hatchery program as a group of fish that have a separate purpose and that may have independent spawning, rearing, marking and release strategies (NMFS 2008c). The operation and management of every hatchery program is unique in time and specific to an identifiable stock and its native habitat (Berejikian et al. 2004). In this specific case, the proposed hatchery salmon programs described in the Tulalip Tribes (Tulalip Tribes 2012; Tulalip Tribes 2013a; Tulalip Tribes 2013b) and WDFW (WDFW 2013a; WDFW 2013b; WDFW 2019b; WDFW and Everett Steelhead and Salmon Club (ESSC) 2013) HGMPs were determined sufficient for formal consultation (Jones 2013). Two of the hatchery programs release ESA-listed Chinook salmon, and the other five release non-ESA listed coho and fall chum salmon into, or in the immediate vicinity of, the Snohomish River basin. All of the programs are currently operating. The Chinook and coho salmon hatchery programs and the integrated Skykomish chum salmon program raise fish native to the Snohomish River basin. The fall chum salmon propagated at Tulalip Bay were transferred from Hood Canal and Deep South Sound (Tulalip Tribes 2013b).

The primary purpose for these hatchery programs is to help meet adult fish loss mitigation responsibilities, partially off-setting adverse impacts to natural-origin salmon abundances that historically sustained tribal and State fisheries. In meeting this purpose, the hatchery programs would be implemented applying actions designed to minimize risks of adverse effects on listed fish species. Key premises of the programs are that habitat that once sustained abundant natural salmon populations has been lost and degraded by past and on-going human developmental activities in the Snohomish River basin, and natural salmon and their habitat are furthered threatened by climate change. The goals for the six initial programs are therefore, lacking natural salmon in abundance, to provide Chinook, coho, and chum salmon for harvest to support regional fisheries, provide values associated with Treaty-reserved fishing rights recognized by the Federal courts, and help to meet Pacific Salmon Treaty harvest sharing agreements with Canada (Tulalip Tribes 2012; WDFW 2013b). The Wallace River Hatchery integrated chum salmon program is a conservation program to rebuild the depleted Snohomish chum salmon population to a harvestable level and enable the eventual transition from an integrated recovery program to meet the needs discussed above. All of the programs would implement salmon population monitoring activities in marine and freshwater areas that are important for tracking the status of ESA-listed fish populations and the effects of the hatchery programs.

The fishing seasons and regulations developed specifically to harvest salmon produced by the programs have previously been reviewed under the ESA, and NMFS's authorization for 'take' from fisheries is part of an already completed consultation (NMFS 2020). The co-managers propose fishery management plans for Puget Sound and associated freshwater areas on either an annual or multi-year basis, and NMFS generally consults on these plans and addresses the take effects of Snohomish River basin salmon-directed recreational and commercial fisheries through an ESA section 7 consultation for the duration of the relevant plan. Most recently, NMFS issued a biological opinion for a 2020 Puget Sound harvest plan assembled by the co-managers that found that the harvest plan for 2020 fisheries did not jeopardize ESA-listed species. The harvest plans submitted by the co-managers have remained relatively similar over the past several years and are expected to continue to do so in 2021 and beyond.

Finally, the proposed action includes funding by the U.S. Fish & Wildlife Service (USFWS) provided to WDFW through its Sportfish Restoration Act grants program. USFWS provides grants to WDFW for hatchery facility operations, which include at least a portion of the funding for operation of the Wallace River hatchery facility. Because the funding of the programs under consideration does not result in any actions or effects not already under consideration as part of NMFS' review of the programs themselves, this Opinion will not separately discuss the funding action other than to note its inclusion in the consultation. USFWS has no other active role in the proposed action.

1.3.1. Proposed action for Chinook salmon hatchery programs

Due to large fluctuations in within-hatchery adult holding survival at Wallace River Hatchery and in post-release marine survival for production originating from both facilities, the Snohomish co-managers have proposed bookends for hatchery production for evaluation as "Phase 1 and Phase 2" under this Proposed Action. These large fluctuations substantially affect the likelihood of the co-managers meeting their combined hatchery production goals and salmon recovery viability targets, as well as how they affect projected surrogate take indicators (e.g., PNI_D, $pHOS_D$) as evaluated in this Biological Opinion. A typical indicator used to describe the influence of hatchery-origin spawners based on demographic carcass-based surveys on the natural population is the demographic proportionate natural influence (PNI_D). The proportion of hatchery-origin fish on the spawning grounds based on demographic carcass-based surveys ($pHOS_D$) and the proportion of natural-origin fish used in the broodstock (pNOB) are used to calculate demographic based PNI_D. NMFS calculates PNI_D according to Ford (2002) and Busack (2015). A PNI_D exceeding 0.5 is an indicator that natural selection may outweigh hatchery-influenced selection, which incorporates the assumption that demographic spawner estimates are the same as the number of genetically effective spawners. In other words, the natural environment has the propensity to influence the total population (hatchery- and natural-origin fish) genetic diversity more than the hatchery environment. Genetic methods more directly estimate gene flow are not often relied on as much as demographic CWT based methods as the data is more readily available.

The water supply and facilities improvements (see section 2.5.2.5) associated with the phased production approach are being done to benefit summer Chinook, which are the most affected species due to their relatively earlier return timing when water quality and quantity at Wallace River Hatchery are depleted, as compared to coho and chum that return after water temperatures have dropped and flows have greatly increased.

1.3.1.1. Proposed Chinook salmon hatchery broodstock collection and mating protocol

Table 2. Description of Skykomish River summer Chinook salmon broodstock collection and mating protocols for Phases 1 and 2.

Program	Phase	Collection Location	Collection Duration	Collection Method	Hatchery Escapement Needed	Mating Protocol	NOB
Wallace River Hatchery Summer Chinook Salmon	Phase 1	Wallace River Hatchery, Wallace River, Sunset Falls Fishway	May-Sept	Volunteer to traps, Seining River	2,964[1]	Matrix Spawning	Up to 400/sliding scale
Tulalip Hatchery Summer Chinook Salmon		Wallace River Hatchery, Tulalip Hatchery, Wallace River	May-Oct	Volunteer to trap	4,344[1]	Matrix Spawning	0
Wallace River Hatchery Summer Chinook Salmon	Phase 2	Wallace River Hatchery, Wallace River, Sunset Falls Fishway	May-Sept	Volunteer to traps, Seining River	1,662[2]	Matrix Spawning	Up to 400/sliding scale
Tulalip Hatchery Summer Chinook Salmon		Wallace River Hatchery, Tulalip Hatchery, Wallace River	May-Oct[3]	Volunteer to trap	3,320[2]	Matrix Spawning	0

[1] Assumes the following parameters: hatchery escapement 38.4 percent females, female holding mortality rate of 29.7 percent, average fecundity of 4,393, survival of green egg-to-sub-yearling release of 85.4 percent, and survival of green egg-to-yearling release of 63.9 percent.
[2] Same as above with the exception of female holding mortality rate, which is assumed to be 8 percent in Phase 2.
[3] In years when there may be short-falls in the number of available broodstock returning before October 1st, late-returning fish would be collected to augment egg-takes up to the annual egg collection objective for the Tulalip Hatchery program.

Natural-origin Chinook salmon collected at the Wallace River Hatchery trap and Sunset Falls Fishway are incorporated as broodstock for the Wallace River Hatchery program. Chinook salmon adults collected at the Sunset Falls Fishway will be transferred by truck for holding and spawning at Wallace River Hatchery. During Phase 1, on average, of 7,308 Chinook salmon needed for the combined program, 2,964 will be collected for the Wallace River Hatchery integrated program and 4,344 will be collected for the Tulalip Hatchery program which is integrated one generation out. During Phase 2, on average, of 4,982 Chinook salmon needed for the combined program, 1,662 will be collected for the Wallace River Hatchery integrated program and approximately 3,320 will be collected for the Tulalip Hatchery program.

Of the 400 natural-origin Chinook salmon broodstock that may be collected for broodstock integration for the on-station release, up to 225 may be collected at the Sunset Falls Fishway with the remainder collected from returns to Wallace River Hatchery (Tulalip Tribes 2012; WDFW 2013b). Use of NOR Chinook salmon at Wallace River Hatchery will initially be prioritized for broodstock integration to contribute toward a highly integrated release of 300,000 AD+CWT yearlings; any NORs that remain available in addition to those needed for this group will be used for integration of the remaining Wallace River Hatchery on station releases. If any additional NORs remain after the on-station releases, they will be used to meet upstream passage goals in the Wallace River. Fewer natural-origin fish may be collected for broodstock at the co-managers discretion when the run is forecasted to be under the Low Abundance Threshold (LAT; currently 2,015 Chinook salmon) or when water temperatures at Wallace River Hatchery or the Sunset Falls Fishway are likely to lead to increased mortality.

Returns from the highly integrated Chinook production will be prioritized for use as broodstock to meet the remaining amount of the eggtake goal for the highly integrated yearling program if it cannot be met solely with natural-origin broodstock. Remaining highly integrated fish will next be used to meet eggtake goals needed for limited integration sub-yearling releases at Wallace River Hatchery. Any remaining highly integrated fish will be prioritized for use as broodstock to help meet the Tulalip Hatchery egg-take goal. All returns from the highly integrated program will be identified by an adipose fin clip and the presence of a CWT (see Table 4). Some Chinook salmon originating from the limited integration sub-yearling production may be inadvertently misidentified and used as highly integrated broodstock because they will also have a clip and a CWT. The incidence of adult returns spawned for the highly integrated program that result from highly-integrated yearling vs limited-integration sub-yearling releases will be assessed post-season based upon the relative contribution of their unique tag codes in the integrated broodstock, which is incorporated in the analysis later in this biological opinion.

The annual number of natural-origin Chinook salmon collected at Sunset Falls Fishway is limited to 225 fish or 20 percent of the total natural-origin Chinook salmon adults returning to the trap, whichever is lower. Additionally, removal of natural-origin fish at Sunset Falls will be curtailed or adjusted downward when best available pre- or in-season estimates of natural-origin escapement to the Skykomish basin is estimated to be below the Lower Abundance Threshold (PSIT and WDFW 2017) for the Skykomish Chinook salmon population (PSIT and WDFW 2017). These limits will help safeguard ESA-listed Skykomish Chinook salmon from additional removals from the natural escapement for broodstock integration when they are estimated to be in critical status during low abundance return years.

Natural-origin fish will not be collected for use as broodstock for the Tulalip Chinook salmon program. All eggs provided for this program will be taken from hatchery-origin returns to Wallace River Hatchery that are integrated one generation out when there are sufficient returns to meet the egg transfer goal to Tulalip Hatchery. When broodstock shortfalls occur at Wallace River Hatchery, Chinook salmon may be collected from adult returns to Tulalip Bay at the lower Tulalip Creek pond. Adult returns after September 30th are not prioritized for broodstock spawned for the Wallace River Hatchery on-station release to reduce the risk of collecting remnant Green River-lineage fall Chinook salmon adults that were previously propagated at Wallace River Hatchery before the program transitioned to using 100 percent native Skykomish River-origin summer Chinook in broodyear 1997. Post October 1st adults returning to Wallace River Hatchery may be used to fulfill egg-take needs for the Tulalip Hatchery program in years when there are shortfalls in collections of earlier spawning Skykomish stock.

In years when adults do not volunteer to the WDFW traps at required broodstock collection levels, hatchery-origin Chinook salmon broodstock may be collected by seining below the Wallace River weir. When in place to collect broodstock (early June through September annually), the Wallace River weir blocks upstream migration for adult Chinook and coho salmon returning to the river. Adult Chinook salmon collected at Wallace River Hatchery that are surplus to the combined egg-take goal for Wallace River and Tulalip Hatchery programs would be released into the Wallace River to help meet co-manager-established "Minimum Spawner Guidelines" (MSG) of 303 male and 202 female spawners in the lower Wallace River, and 224 and 149 males and females in the upper river.

Broodstock spawned for the Tulalip Hatchery Chinook salmon program would be selected randomly from hatchery-origin fish returning to Wallace River Hatchery. Chinook salmon broodstock used to provide gametes for the on-station release at Wallace River Hatchery, as well as used to meet the egg transfer goal to Tulalip Hatchery, would be selected randomly as the fish mature to ensure the summer Chinook salmon broodstock are representative of the maturation period for the native Skykomish River summer Chinook salmon population (WDFW 2013b). All male summer Chinook salmon collected, including jacks, would be considered for spawning. Males would be chosen randomly from the held population, and jacks would be incorporated into spawning at a rate of 2 percent of spawned males. Matrix spawning will be conducted by equally dividing pooled eggs from five females into five buckets and fertilizing the eggs in each bucket with milt from a different male.

Weirs and traps will be operated in Battle Creek from November to January to collect returning adult fall chum salmon for broodstock. The Wallace River and May Creek weirs will be operated from June through September to collect Chinook salmon broodstock. Natural-origin adult Chinook be collected at the Sunset Falls Fishway for transport to Wallace River Hatchery from July 1 through September each year. Adult broodstock collection activities will occur from summer through early fall when adult summer Chinook salmon return to the basin to ensure that they are representative of the natural return timing of the extant native population.

1.3.1.2. Proposed Chinook salmon incubation, rearing, and release protocols

All Wallace River Hatchery Chinook salmon will be incubated, reared, and released at Wallace River Hatchery (River Mile 4.0). Unfertilized eggs and sperm, or eyed eggs will be transferred to Tulalip Hatchery Chinook salmon will be incubated and reared at Tulalip Hatchery and released for final incubation, hatching, rearing and release directly into Tulalip Bay at the mouth of Tulalip Creek (RM 0.0).

Table 3. Proposed release protocols for the two Snohomish basin Chinook salmon hatchery programs.

Program	Release Duration	Current Release	Maximum Release*	Size and Life Stage at Release	Acclimation; Release Strategy
Wallace River Hatchery Summer Chinook Salmon	April-Oct	1.0 Million	2.2 Million†	Sub-yearling; 19-70 fpp	Yes; Volitional (1 week) then forced
	April	500,000	750,000	Yearling; 10 fpp	Yes; Forced
Tulalip Hatchery Summer Chinook Salmon Program	April-Oct	2.4 Million	4.4 Million†	Sub-yearling; 30-80 fpp	Yes; Volitional (1 week) then forced

†The co-managers will vary timing of egg-takes, feeding rates, and temperature regimes to manipulate growth rates and timing of smoltification to optimize rearing and release strategies for these programs, predicated on funding made available for these studies. Goals include increasing production for SRKWs (testing experimental rearing and release strategies to increase survival and the abundance, timing and size of available prey) while monitoring post-release juveniles from the experimental groups to monitor ecological and/or genetic interactions with juvenile and adult natural-origin fish in the effort to identify strategies that minimize these interactions while maximizing survival.

Wallace River Hatchery will use a phased approach to increasing production. Phase 1 is a limited time interim phase where production of sub-yearlings is elevated until additional capacity is available for yearling production and female holding mortality can be improved as described when facility improvements described in section 2.5.2.5 can be completed. Detailed Phase 1 and 2 release group information is included below in Table 4.

Table 4. Summary of Chinook salmon production at Wallace River Hatchery under Phase 1 and Phase 2, including mark type and level of integration. Natural origin Chinook salmon will be prioritized as broodstock for the highly integrated yearling group. Any remaining natural origin Chinook salmon will be used as broodstock for the limited integration groups.

Hatchery Phase	**Hatchery Program**	**Number**	**Release Phase**	**Mark**	**CWT**	**Integration Type**	**Note**
PHASE 1[1,2]	Wallace	370,000	Sub-yearling	Ad-Clip + Otolith	Yes	Limited	Standard CWT Group
	Wallace	200,000	Sub-yearling	No Ad-Clip + Otolith	Yes	Limited	Standard DIT Group
	Wallace	100,000	Sub-yearling	Ad-Clip + Otolith	Yes	Limited	Early Release
	Wallace	100,000	Sub-yearling	Ad-Clip + Otolith	Yes	Limited	Late Release
	Wallace	1,430,000	Sub-yearling	Ad-Clip + Otolith	No	Limited	Standard Release
	Wallace	300,000	Yearling	Ad-Clip + Otolith	Yes	High	Standard Release
	Wallace	300,000	Yearling	Ad-Clip + Otolith	No	Limited	Standard Release
	Tulalip	100,000	Sub-yearling	Ad-Clip + Otolith	Yes	One generation out	Standard Release
	Tulalip	100,000	Sub-yearling	No Ad-Clip + Otolith	Yes	One generation out	Standard Release
	Tulalip	100,000	Sub-yearling	Ad-Clip + Otolith	Yes	One generation out	Early Release
	Tulalip	100,000	Sub-yearling	Ad-Clip + Otolith	Yes	One generation out	Late Release
	Tulalip	4,000,000	Sub-yearling	Ad-Clip + Otolith	No	One generation out	Standard Release
	Total Release	**7,200,000**					
PHASE 2[1,3]	Wallace	370,000	Sub-yearling	Ad-Clip + Otolith	Yes	Limited	Standard CWT Group
	Wallace	200,000	Sub-yearling	No Ad-Clip + Otolith	Yes	Limited	Standard DIT Group
	Wallace	630,000	Sub-yearling	Ad-Clip + Otolith	No	Limited	Standard Release
	Wallace	300,000	Yearling	Ad-Clip + Otolith	Yes	High	Standard Release
	Wallace	450,000	Yearling	Ad-Clip + Otolith	No	Limited	Standard Release
	Tulalip	100,000	Sub-yearling	Ad-Clip + Otolith	Yes	One generation out	Standard Release
	Tulalip	100,000	Sub-yearling	No Ad-Clip + Otolith	Yes	One generation out	Standard Release
	Tulalip	4,200,000	Sub-yearling	Ad-Clip + Otolith	No	One generation out	Standard Release
	Total Release	**6,350,000**					

All juvenile fish released through the programs will be otolith marked, and the remainder will also be tagged and/or fin clipped (100% less clip and tag retention that typically average >99%) to allow for their differentiation from natural-origin salmon after their release as juveniles from the hatcheries, and when the fish return as adults to Snohomish River basin marine and freshwater areas. Reporting and control of specific fish pathogens will be conducted in accordance with the Salmonid Disease Control Policy of the Fisheries Co-managers of Washington State (WDFW and NWIFC 1998).

1.3.1.3. Proposed Chinook salmon adult management

Broodstock used for the Chinook salmon hatchery programs at both hatcheries are derived from the native Skykomish Chinook salmon population. Hatchery-origin Chinook salmon produced for harvest augmentation purposes that escape to the hatcheries in excess of broodstock needs (primarily surplus males) would be passed upstream to meet MSG targets, distributed to tribal members for food, sold to fish buyers, donated to food banks, or dispersed within the Snohomish River basin for marine-derived nutrient enhancement purposes.

With 100 percent thermal otolith marking reinitiated at Wallace River Hatchery in broodyear 2013 and continuing at Tulalip Hatchery, it was recently possible to reinitiate estimation of demographic (carcass-based) pHOS directly attributable to the Snohomish region hatchery-origin Chinook programs from 2017 through 2019. During this period, total pHOS (all hatchery-origin fish) within the naturally spawning Skykomish Chinook population averaged 32.0 percent, while averaging 24.4 percent for all hatchery-origin Chinook salmon spawning outside of the Wallace River, 25.4 percent for all HORs spawning within the Snoqualmie population, and 32.4 percent for the entire basin. Excluding the small number of non-thermally marked, five-year-old Wallace River Hatchery-origin fish in 2017, it was possible to estimate pHOS attributable to the Snohomish region hatchery programs and “Other” (non-Snohomish region) Chinook HORs that year and afterward because all regional hatchery production was 100% marked by hatchery of origin (i.e. all two- through five-year-old returns from Wallace River Hatchery since 2017 have been 100% thermally marked and identifiable along with 100% of Tulalip Hatchery Chinook production). Total pHOS attributable to Tulalip, Wallace, and “Other” HOR Chinook spawning within the total Skykomish population, including the Wallace River, from 2017 through 2019 averaged 0.5 percent, 22.2 percent, and 9.3 percent, respectively, while it averaged 0.5 percent, 14.7 percent and 9.2 percent, respectively, outside of the Wallace River during that period. The pHOS attributable to Tulalip, Wallace, and “Other” HOR Chinook spawning within the Snoqualmie population from 2017 through 2019 averaged 3.0 percent, 3.6 percent, and 18.7 percent, respectively, while averaging 1.2 percent, 16.7 percent, and 14.4 percent for Tulalip, Wallace, and “Other”, respectively, across the entire basin as shown in Table 5.

Table 5. Average number and (proportion) of hatchery-origin (pHOS) Chinook salmon escapement to natural spawning areas in the Snohomish basin from 2017-2019 as determined using thermal otolith marks.

Aggregation	Average Tulalip HORs	Average Wallace HORs	Average Other HORs	Average All Snohomish HORs
Skykomish Population (excluding Wallace)	12 (0.5%)	354 (14.7%)	221 (7.6%)	587 (24.4%)
Skykomish Population (including Wallace)	14 (0.5%)	640 (22.2%)	269 (7.9%)	923 (36.2%)
Snoqualmie Population	36 (3.0%)	43 (3.6%)	224 (12.3%)	303 (19.3%)
Snohomish Basin Total	50 (1.2%)	683 (16.7%)	587 (11.4%)	1,320 (31.4%)

With a smolt-to-adult recruit rates (SAR) averaging 0.37 percent, 0.31 percent, and 1.35 percent, respectively, for Tulalip Hatchery sub-yearlings (broodyears 2000-2005 and 2007-2011), Wallace River Hatchery sub-yearlings (broodyears 2000-2011), and Wallace River Hatchery yearlings (broodyears 2002-2008, and 2010), the proposed Wallace River and Tulalip Hatchery programs may produce an estimated 31,293 and 30,215 adults, respectively, each year in Phase 1 and Phase 2 (total contribution to all fisheries and escapement (Haggerty 2020b). A substantial proportion, 25 percent to 32 percent, of hatchery-origin Chinook salmon produced by the Wallace River Hatchery program would be harvested in Canadian and U.S. pre-terminal and - terminal area fisheries (WDFW 2013b). Fishery harvest rates on hatchery-origin Chinook salmon returning to Tulalip would be managed to be as close to 100 percent as possible through implementation of targeted terminal area fisheries in Tulalip Bay, where hatchery-origin adult returns concentrate. No Chinook salmon would generally be reserved in Tulalip Bay for broodstock collection in years when Wallace River Hatchery can meet the egg transfer goal to Tulalip Hatchery, allowing for harvest (and removal rates) of hatchery-origin Chinook salmon in Tulalip Bay to be maximized. The effects of these fisheries on ESA-listed natural-origin Chinook salmon were evaluated and authorized through a separate ESA consultation (NMFS 2019a). The majority of Wallace River Hatchery Chinook salmon adults recruit back to their hatchery release locations; approximately 69 percent of sub-yearling-origin adults and 62 percent of yearling adults (CWT recovery data from WDFW 2013b); however, escapement to natural spawning areas in the Snohomish River basin does occur. The average hatchery-origin Chinook salmon proportions, or pHOS, of all hatchery-origin fish encountered within the total naturally spawning Skykomish and Snoqualmie Chinook populations for the most recent twelve years (2008-2019) were 31.6 percent, and 23.0 percent, respectively. The basin-wide annual average pHOS for 2009-2017 was 29.4 percent (Mike Crewson, Tulalip Tribes, and Pete Verhey, WDFW). Annual Chinook salmon broodstock collection will lead, on average, to the spawning of ~3,944 effective spawners at a 1:1 male to female ratio comprised of ~3,544 hatchery-origin adults and up to 400 natural-origin adults in Phase 1 and ~3,518 effective spawners in Phase 2. Up to 1,987 natural-origin adults may be incidentally encountered that escape to Wallace River Hatchery and up to 300 that return to the Sunset Falls Fishway may be incidentally encountered (Mike Crewson, Tulalip Tribes).

1.3.2. Proposed Action for Coho and Chum Salmon Hatchery Programs

1.3.2.1. Proposed hatchery broodstock collection and mating protocol for coho and chum salmon hatchery programs

Coho salmon returning to Wallace River Hatchery are used as broodstock to provide eggs or fish for the three coho salmon programs in the Snohomish River basin as well as for South Sound Net-Pen programs and educational cooperative ventures that are not part of the proposed actions considered in this consultation. Coho broodstock collected for the Wallace River Hatchery release and fish transfers to Eagle Creek) and the Everett Bay Net-pen programs would be integrated with up to 500 viable natural-origin coho salmon collected from returns to Wallace River Hatchery and/or from adults collected at the Sunset Falls Fishway. In years when coho salmon broodstock returns to Wallace River Hatchery are not sufficient to meet the egg-take goals for these programs, adult coho salmon may be collected from returns to Tulalip Bay to augment annual egg-takes for the Tulalip Hatchery program.

Table 6. Description of broodstock collection and mating protocols for three coho and two chum salmon hatchery programs.

Program	Origin	Collection Location	Collection Duration	Collection Method	Number of Broodstock Needed	Mating Protocol	NOB
Wallace River Hatchery Coho Salmon	Skykomish River	Wallace River Hatchery, Sunset Falls Fishway	Sept-Nov	Volunteer to traps	4,125	Matrix Spawning	500
Wallace River Hatchery Integrated Chum Salmon[1]	Skykomish/ Wallace River	Skykomish River, Wallace River, May Creek	Oct-Dec	Volunteer to trap, Seine	2,100	Matrix Spawning	Up to 2,500
Tulalip Bay Hatchery Fall Chum Salmon	Hood Canal/ Deep South Sound	Battle Creek, Tulalip Bay	Nov-Jan	Volunteer to trap	9,000	Matrix Spawning	0

[1] Provides eggs to support the Tulalip Bay Coho Salmon Hatchery program.

Weirs and traps will be operated in Battle Creek (also known as Mission Creek) from November to January annually to collect returning adult fall chum salmon for broodstock. The Wallace River weir will be operated from June through September 30 and the May Creek weir at Wallace River Hatchery will be operated from June through December as conditions permit to collect coho salmon broodstock. Chinook salmon predominate during the early portion of weir operation at both locations as described in Section 1.3.1.1. Natural-origin adult coho salmon may be collected at the Sunset Falls fishway for transport to Wallace River Hatchery from July 1 through early November each year. Wallace River Hatchery chum salmon will be collected primarily in side channels of the Skykomish River using seining and hook-and-line methods. After initially founding the startup broodstock from the natural-origin Skykomish River population, the source of adult chum salmon broodstock will be from adult returns to Wallace River Hatchery that voluntarily enter the hatchery traps, which will be integrated with natural-origin collections from the Skykomish River basin.

Adult broodstock collection activities will occur across the breadth of the fall when coho and chum salmon return to the basin (late-September through December) to ensure that salmon collected as broodstock are representative of the natural return timing of the extant native populations.

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

1.3.2.2. Proposed incubation, rearing, and release protocols for coho and chum salmon hatchery programs

Table 7. Proposed incubation, rearing, and release protocols for coho and chum salmon hatchery programs operated and Wallace River and Tulalip Hatcheries.

Program	Incubation Location	Rearing Location	Release Location	Release Duration	Current Release	Maximum Release	Size and Life Stage at Release	Acclimation; Release Strategy
Tulalip Hatchery Fall Chum Salmon	Tulalip Hatchery	Tulalip Hatchery	Battle Creek Pond, RM 0.1	April-May	12 Million	12 Million	Fry; 300-550 fpp	Yes; Volitional (~3 weeks) then forced
Wallace River Hatchery Integrated Chum Salmon	Wallace River Hatchery	Wallace River Hatchery	Wallace River Hatchery	April-May	0	2 Million	Fry; 450-500 fpp	Yes; Volitional (~3 weeks) then forced
Wallace River Hatchery Coho Salmon	Wallace River Hatchery	Wallace River Hatchery	Wallace River RM 4.0	May-June	150,000	300,000	Yearling; 17 fpp	Yes; Volitional (~3 weeks) then forced
			Pond near Woods Creek		7,000	7,000	Sub-yearling; 150 fpp	Yes, Volitional
		Eagle Creek Hatchery	Eagle Creek RM 0.4		54,000	54,000	Yearling; 15 fpp	Yes; Forced
Tulalip Bay Hatchery Coho Salmon	Tulalip Hatchery	Tulalip Hatchery	Tulalip Bay	May-June	2 Million	2 Million	Yearling; 17 fpp	Yes; Volitional (~3 weeks) then forced
Everett Bay Net-Pen Coho Salmon	Wallace River Hatchery	Wallace River Hatchery /Everett Bay	Everett Bay	May-June	20,000	40,000	Yearlings; 15 fpp	Yes; Forced

Table 8. Hatchery-origin salmon marking and/or tagging strategies applied to coho and chum salmon produced by the Wallace River Hatchery and Tulalip Hatchery programs. Marking and tagging proportions may vary annually. DOF = Depending on funding available.

Program	Release Stage	Otolith	Ad-Clip Only	CWT Only	Ad-Clip and CWT
Tulalip Bay Hatchery Fall Chum Salmon	Fry	100%	0%	0%	0%
Wallace River Hatchery Chum Salmon	Fry	100%	0%	0%	0%
Wallace River Hatchery Coho Salmon	Wallace River Hatchery Yearling	0%	40%	30%	30%
	Eagle Creek Hatchery Yearling	0%	100%	0%	0%
Tulalip Hatchery Coho Salmon	Yearling	100%	95%	0%	5%
Everett Bay Net-Pen Coho Salmon	Yearling	0%	100%	0%	0%

1.3.3. Proposed research, monitoring, and evaluation

The seven HGMPs include monitoring and evaluation (M&E) actions designed to identify the performance of the programs in meeting their fisheries harvest augmentation and listed fish risk minimization objectives. Monitoring the harvest benefits of the programs to fisheries from production of returning adult hatchery-origin fish is an important objective (e.g., smolt-to-adult survival rate and fishery contribution level monitoring). All of the Snohomish River basin hatchery programs include extensive monitoring, evaluation, and adaptive management programs for Snohomish region fisheries, hatcheries, and escapements designed to monitor and reduce incidental effects on natural-origin fish populations. The adult Chinook salmon monitoring program in the Snohomish basin natural escapement (stream surveys and biological sampling) would be conducted annually to document HOR/NOR ratios, spawning contribution and straying rates, and to develop estimates of gene flow and relative productivity (calculated from genetic and demographic data), spatial structure, diversity, age, sex, and size of natural- and hatchery-origin Chinook escaping to natural spawning areas and regional hatcheries in the basin. Contribution rates of hatchery-origin Chinook, coho, and chum salmon to regional fisheries will be monitored annually.

The co-managers will use this information to inform and advise adaptive management of hatchery actions to meet HGMP performance criteria. Specific actions described in the HGMPs include monitoring of Chinook salmon escapement to Snohomish River basin natural spawning areas to estimate the number of clipped, tagged, and thermally-marked fish in the natural escapement each year. Foot and boat spawning ground surveys would be conducted to estimate redds, live fish counts, and sample Chinook salmon carcasses for scales, otoliths, adipose-fin clips, CWT's, and tissues for genetic analysis.

Annual adult Chinook, coho, and chum salmon escapement monitoring in the Snohomish River watershed to gauge hatchery program performance and effects (stream surveys and biological sampling) may lead to encounters (take) of ESA-listed Chinook salmon. Effects would potentially include harassment (disturbance) of naturally-spawning fish during the course of spawning ground surveys and biological sampling of carcasses.

The same general types of biological sampling would be implemented for fish sampled in fisheries and hatcheries. Fish sampled in Snohomish region salmon fisheries are sexed, measured for fork length, wanded for CWTs (Chinook and coho salmon only), and checked for adipose fin clip status, while subgroups are sampled for scales and otoliths (tribal fisheries only) and other demographic data is recorded. However, while all hatchery returns are sexed and checked for adipose fin clip and CWT status, only a select subset are measured for fork length or sampled for scales and otoliths (some broodstock depending on the year and purpose, e.g. all fish bearing CWTs or that are part of research projects). As one example, since 2014, operculum tissues have been collected from all Chinook salmon spawned at Wallace River Hatchery, which has been tracked separately for broodstock spawned for the Tulalip and WDFW Chinook hatchery programs noting sex, clip and CWT status and measuring fork lengths of all spawners to enable Parental-Based Tagging (PBT).

Specific M&E actions for the seven HGMPs affecting juvenile salmon are described in section 1.10 and section 11.0 of each HGMP, and in section 12.0 of the Tulalip Hatchery Chinook salmon HGMP (Tulalip Tribes 2012). Although the results of these juvenile fish M&E actions would be used to guide implementation of the proposed salmon hatchery programs, juvenile salmon sampling occurring outside of the hatchery locations has been previously authorized through a separate ESA consultation process (NMFS 2017). The co-managers propose to continue to monitor interactions between juvenile hatchery- and natural-origin salmon in freshwater, estuarine, and marine areas within the region to evaluate and manage program ecological effects. Continued juvenile outmigrant trapping by the Tulalip Tribes is also proposed, using rotary screw traps in the Skykomish and Snoqualmie systems, seines and fyke nets in the estuary, and beach seines in nearshore marine areas, augmented with offshore purse seining when funding allows, to provide important information on the co-occurrence, out-migration timing, relative abundances and sizes, growth indices and diets of hatchery-origin fish, ESA-listed natural-origin Chinook salmon and steelhead, and non-listed natural-origin coho, chum, and pink salmon. Up to 32,000 hatchery-origin adipose fin clipped sub-yearling Chinook salmon would be retained from the hatcheries each year for conducting juvenile outmigrant trap efficiency trials.

Table 9. Research, monitoring, and evaluation associated with the seven hatchery programs and any existing ESA coverage.

Activity	Associated Program	ESA Coverage
Monitor adult collection, numbers, origins, sex, adipose fin clip and CWT status and record fork length, and collect scales, otoliths, tissues for genetic analysis and record other demographic data from select groups of representative fish at weirs, traps, and hatchery facilities	All	This Opinion
Operate rotary screw traps to estimate the abundance, timing, and age composition of hatchery- and naturally-produced migrants	All	4(d) Tribal Research Plan 2017-2021, This Opinion (efficiency trials)
Monitor relative numbers of hatchery- and natural-origin fish captured in freshwater, estuarine, and marine areas to collect basic life history information (i.e., length, maturity, migration status, marks/tags, sex, age and growth via scale samples and/or otoliths, genetic identity, and condition)	All	This Opinion; existing 10(a)(1)(A) via Permit 16702-3R
Genetic mark-recapture study	Wallace River and Tulalip Hatchery Chinook salmon	4(d) Tribal Research Plan 2017-2021
Sample terminal area fisheries, spawning grounds, and hatcheries for CWTs, otoliths, scales, tissues for DNA analysis, demographic and morphometric data	All	This Opinion
Within hatchery monitoring of fish health and survival	All	This Opinion

The Tulalip Tribes and WDFW will continue to conduct genetic mark recapture studies in the Snohomish basin when funding for this work is made available to evaluate the relative contribution of hatchery-origin Chinook salmon to natural production from genetic data. Genetic mark recapture research is authorized by NMFS for effects on ESA listed fish (NMFS 2015; NMFS 2017). Augmenting sampling, genotyping, and analysis results already completed (12,169 juvenile fish samples from 2012-2014 and 604 adult fish from 2011-2013) (Crewson et al. 2017), these studies continue, predicated on funding. Since these previous collections, the Snohomish co-managers have continued to annually collect juvenile and adult tissue samples and have accumulated a considerable number of samples to conduct another comprehensive estimate of relative reproductive success between hatchery- and natural-origin Chinook salmon but are seeking funding for laboratory analysis. Through these studies, tissues collected from natural-origin Chinook salmon juveniles captured at the Tulalip Tribes' Skykomish and Snoqualmie traps and estuary and marine sampling efforts, combined with tissues collected from hatchery- and natural-origin adult Chinook sampled on the spawning grounds, would be analyzed to determine contributions to natural production by origin, location, size and sex through parentage analysis.

Research to assess the effectiveness and impacts of increasing hatchery salmon releases will be conducted in the Snohomish estuary and adjacent marine areas. Increased hatchery releases may support Southern Resident Killer Whales (SRKW), which feed primarily on Fraser River Chinook salmon stocks during the summer but are increasingly observed in Puget Sound and along the

Washington coast from October to April based on sightings in the 'Orca Master' database (Whale Museum, Friday Harbor, WA, U.S.A (2016). Estuary and marine juvenile fish monitoring studies estimate the effects of release strategy on survivorship, time-area fishery contributions that overlap with SRKW sightings per above, size at recruitment, and ongoing GSI analyses conducted by NOAA Fisheries of SRKW fecal samples and fish tissues collected during predation events; collectively to infer contribution to the SRKW prey base. Monitoring will also allow operators to identify potential ecological and genetic impacts to ESA-listed natural-origin juvenile and adult salmonids to enable strategies to reduce and mitigate such impacts to be developed. Sub-yearling Chinook salmon will be released in one of three, uniquely otolith marked and/or coded-wire tagged experimental "Early" mid- to late-April/early-May, "Normal" early-June, and "Late" October rearing and release groups from each hatchery, contingent upon available funding for this work. Yearling Chinook salmon will also be uniquely thermally marked and/or coded-wire tagged and released from Wallace River Hatchery in early-April prior to the sub-yearling treatment groups and included in the studies. Capture numbers, lengths, scales, otoliths, and stomach content samples will be collected from fish originating from each experimental release along with recording release numbers, lengths, and weights. Scales and otoliths will be collected from each group prior to each release and compared to samples collected from experimental hatchery groups and coinciding natural-origin juvenile Chinook salmon encountered before and after the releases. This sampling will be conducted in marine and estuarine areas to compare relative growth and residence times along with the collection of additional environmental conditions (e.g. temperature, salinity, dissolved oxygen). Chinook salmon will be monitored and collected from the Snohomish estuary as shown in Table 10 and Figure 1 as part of this research. A maximum of 900 juvenile Chinook salmon will be collected annually for this research program.

Table 10. Snohomish estuary and nearshore marine juvenile Chinook salmon sampling sites included in intensive monitoring efforts before and after releases of hatchery Chinook salmon. Approximately thirty samples per site will be collected over two to three weeks preceding and following each release event. The number of samples indicated below will be collected annually predicated on funding availability.

Site	Target Samples Off Channel Area	Target Samples Marine/Distributary Area	Sampling Events Off Channel Spring/Summer	Sampling Events Marine Spring/Summer	Sampling Events Off Channel Spring/Summer	Sampling Events Marine Spring/Summer	Habitat Type
Fields Riffle	60	60	38	38	12	12	Forested Riverine Tidal
Langus	0	60	38	38	12	12	Estuarine Forest Transitional
North Jetty Island	N/A	60	N/A	38	N/A	12	Unconsolidated Shoreline
Old Barge/Dead Water	60	60	38	38	12	12	Estuarine Forest Transitional
Big Tree	N/A	60	N/A	38	N/A	12	Forested Riverine Tidal
Priest Point	N/A	60	N/A	38	N/A	12	Unconsolidated Shoreline
Tulalip Bay	60	60	N/A	38	N/A	12	Unconsolidated Shoreline
Mission Beach	N/A	60	N/A	38	N/A	12	Unconsolidated Shoreline
Quilceda Off Channel	60	N/A	38	N/A	12	N/A	Estuarine Emergent Marsh
Lower Steamboat	N/A	60	N/A	38	N/A	12	Estuarine Emergent Marsh
Otter Island	60	60	38	38	12	12	Estuarine Forest Transitional

Figure 1. Snohomish estuary and nearshore juvenile Chinook salmon beach seine sampling sites. Numbers denote the number of sets at each site (two if there is a distributary and an off-channel site).

The Terms and Conditions of this Biological Opinion require the completion of annual reports as stated in the HGMPs and in this section describing annual M&E activities involving juvenile and adult salmon in the Snohomish basin as well as the results of research and monitoring activities.

1.3.4. Facilities

Table 11. Water source, water withdrawal amount, NPDES and water rights permits, and screening information for facilities associated with the seven programs presented in the Snohomish Basin HGMPs.

Facility	Water Source	Withdrawal (cfs)	Instream Structures	Discharge Location	Water Rights Permit*	NPDES	Screening
Wallace River Hatchery	Wallace River	16 cfs	Water Intake; Weir	Pollution abatement pond	S1-00108C WRIS	WAG 13-3006	Meets NMFS 1995 Standards
		24 cfs			S1-00109 WRIS		
	May Creek	10 cfs	Water Intake; Trap and Weir		S1-05617C WRIS		Meets NMFS 1995 Standards
		4 cfs			S1-23172C WRIS		
Tulalip Hatchery	Well	1.6 cfs	None	Tulalip Creek	-	WAG 13-0012	Not Applicable
Tulalip Creek Ponds	East Fork Tulalip Creek	16 cfs	None	Tulalip Bay	-	WAG 13-0013	Not Applicable
	West Fork Tulalip Creek	16 cfs	None	Tulalip Bay	-		Not Applicable
	Tulalip Creek	41 cfs	None	Tulalip Bay	-		Not Applicable
Battle Creek Pond	Battle Creek	15 cfs	None	Tulalip Bay	-	WAG 13-0014	Not Applicable
Eagle Creek Hatchery	Spring	0.9 cfs	Water Intake	Eagle Creek	S1*16290C WRIS/08040	Not Required	Meets NMFS 2011 standards
Everett Bay Net-Pen	Marine	N/A	None	Marine	N/A	Not Required	Not Applicable

*There is no requirement that the State issue water rights permits for the Tribes' use of ground or surface water on the Reservation.

Screening of water diversions at Wallace River Hatchery does not meet NMFS (2011a) screen criteria. WDFW plans to modify screening at Wallace River Hatchery to comply with NMFS screening requirements to protect natural-origin fish from entrainment and impingement that may lead to injury and mortality (WDFW 2013b). Although the hatchery water intake screens on the Wallace River and in May Creek are protective of fish and in compliance with State and Federal guidelines (NMFS 1995; NMFS 1996), they do not meet updated NMFS Anadromous Salmonid Passage Facility Design Criteria (NMFS 2011a). However, under NMFS (2011a) criteria, screening currently in compliance with (NMFS 1995) and (NMFS 1996) guidelines are grandfathered in as acceptable, with the requirement that the screening be upgraded to meet the most recent NMFS standards when the next screen retrofit is scheduled. Design and permitting to bring the screens in compliance with NMFS (2011a) fish passage and screening criteria is projected to be completed as soon as 2025 and annual reports will provide updates to this process until the work is completed. This work will also include construction of a new, two-bay pollution abatement pond. Screening at the Tulalip Tribes' hatchery facilities and at Eagle Creek Hatchery are not risk factors as there are no salmon or other ESA-listed fish populations present in the small tributaries where the facilities are located. NMFS screening criteria are not applicable for the Everett Bay Net-Pens program.

Hatchery weirs on the Wallace River at RM 4.0 (June through September) and near to the mouth of May Creek (Chinook salmon collected June through September; coho salmon through December) are operated seasonally as conditions permit to collect broodstock. During these times, they act as temporary barriers to upstream and downstream adult fish passage. Trapping protocols applied at the Wallace River weir minimize the duration of migration delay and prospects for fish injury during trapping. Adult Chinook salmon collected at Wallace River Hatchery that are surplus to production needs after hatchery spawning requirements are met would be available for release into the upper and lower Wallace River to allow the fish to spawn naturally toward meeting co-manager-established "Minimum Spawner Guidelines" as previously described under Chinook salmon hatchery broodstock collection in section 1.3.1.1. Fish migration is not impeded by any structures used for fish rearing at Eagle Creek Hatchery and the Everett Bay Net-Pens. The ponds used to rear, imprint, and release coho and fall chum salmon for the Tulalip Hatchery programs are all instream structures.

1.4. Activities Caused By the Proposed Action

In determining whether there are other actions that should be considered in this consultation, NMFS has considered whether fisheries impacting Snohomish River basin hatchery program-origin salmon are caused by the proposed action.

Within the action area, tribal commercial, ceremonial and subsistence, and non-Indian recreational fisheries occur, targeting salmon produced by the proposed hatchery programs and commingled natural-origin salmon. These fisheries are managed by the WDFW and Tulalip Tribes and occur within the Snohomish, Skykomish, and Wallace River watersheds as well as within Puget Sound terminal area marine waters of Tulalip Bay, Port Susan, and Everett Bay. The proposed hatchery salmon programs analyzed in this opinion also contribute to pre-terminal fisheries outside of the Snohomish River watershed and marine terminal and extreme terminal fishing areas. Fisheries within and outside of the action area support values associated with Treaty-reserved fishing rights recognized by the Federal courts, support US v.Washington (1974) harvest sharing agreements between tribal and non-Indian fisheries, and help to meet Pacific Salmon Treaty salmon harvest agreements with Canada. Outside of the Snohomish River basin action area, there are no fisheries directed at salmon produced by the six salmon hatchery programs. Those salmon-directed fisheries would occur regardless of whether the proposed action continues, and are therefore not caused by the proposed action. Therefore, only those fisheries for salmon in the Snohomish River basin are caused by the proposed action. The 2019-20 fisheries were evaluated and authorized through a separate NMFS ESA consultation (NMFS 2020). 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 2020). Past effects of these fisheries are described in the environmental baseline section (Section 2.4); future effects are described in the discussion of effects of the action.

2. Endangered Species Act: Biological Opinion And Incidental Take Statement (ITS)

The ESA establishes a national program for conserving threatened and endangered species of fish, wildlife, plants, and the habitat upon which they depend. As required by section 7(a)(2) of the ESA, each Federal agency must ensure that its actions are not likely to jeopardize the continued existence of endangered or threatened species, or adversely modify or destroy their designated critical habitat. Per the requirements of the ESA, Federal action agencies consult with NMFS and section 7(b)(3) requires that, at the conclusion of consultation, NMFS provide an opinion stating how the agency's actions would affect listed species and their critical habitats. If incidental take is reasonably certain to occur, section 7(b)(4) requires NMFS to provide an ITS that specifies the impact of any incidental taking and includes non-discretionary reasonable and prudent measures (RPMs) and terms and conditions to minimize such impacts.

2.1. Analytical Approach

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

This biological opinion relies on the definition of "destruction or adverse modification," which "means a direct or indirect alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species" (50 CFR 402.02).

The designation(s) of critical habitat for (species) use(s) the term primary constituent element (PCE) or essential features. The 2016 critical habitat regulations (50 CFR 424.12) replaced this term with physical or biological features (PBFs). The shift in terminology does not change the approach used in conducting a "destruction or adverse modification" analysis, which is the same regardless of whether the original designation identified PCEs, PBFs, or essential features. In this biological opinion, we use the term PBF to mean PCE or essential feature, as appropriate for the specific critical habitat.

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

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

- Evaluate the range-wide status of the species and critical habitat expected to be adversely affected by the proposed action.
- Evaluate the environmental baseline of the species and critical habitat.
- Evaluate the effects of the proposed action on species and their habitat using an exposure-response approach.
- Evaluate cumulative effects.
- In the integration and synthesis, add the effects of the action and cumulative effects to the environmental baseline, and, in light of the status of the species and critical habitat, analyze whether the proposed action is likely to: (1) directly or indirectly reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species, or (2) directly or indirectly result in an alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species.
- If necessary, suggest a reasonable and prudent alternative to the proposed action.

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

Range-wide status of the species and critical habitat

This section describes the status of species and critical habitat that are the subject of this opinion. The status review starts with a description of the general life history characteristics and the population structure of the ESU/DPS, including the strata or major population groups (MPG) where they occur. NMFS has developed specific guidance for analyzing the status of salmon and steelhead populations in a "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" (50 CFR 402.02). In describing the range-wide status of listed species, NMFS reviews available information on the VSP parameters including abundance, productivity trends (information on trends, supplements the assessment of abundance and productivity parameters), spatial structure and diversity. We also summarize available estimates of extinction risk that are used to characterize the viability of the populations and ESU/DPS, and the limiting factors and threats. To source this information, NMFS relies on viability assessments and criteria in technical recovery team documents, ESA Status Review updates, and recovery plans. We determine the status of critical habitat by examining its PBFs. Status of the species and critical habitat are discussed in Section 2.2.

Action area

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

Describing the environmental baseline

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

Cumulative effects

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

Integration and synthesis

Integration and synthesis occurs in Section 2.7 of this opinion. In this step, NMFS adds the effects of the Proposed Action (Section 2.5.2) to the status of ESA protected populations in the Action Area under the environmental baseline (Section 2.4) and to cumulative effects (Section 2.6). Impacts on individuals within the affected populations are analyzed to determine their effects on the VSP parameters for the affected populations. These impacts are combined with the overall status of the MGP to determine the effects on the ESA-listed species (ESU/DPS), which will be used to formulate the agency's opinion as to whether the hatchery action is likely to: (1) result in appreciable reductions in the likelihood of both survival and recovery of the species in the wild by reducing its numbers, reproduction, or distribution; or (2) reduce the value of designated or proposed critical habitat.

Jeopardy and adverse modification

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

Reasonable and prudent alternative(s) to the proposed action

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

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. The species and the designated critical habitat that are likely to be affected by the Proposed Action, and any existing protective regulations, are described in Table 12. 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 helps to inform the description of the species' current "reproduction, numbers, or distribution" as described in 50 CFR 402.02. The opinion also examines the status and conservation value of critical habitat in the action area and discusses the current function of the essential physical and biological features that help to form that conservation value.

Table 12. Federal Register notices for the final rules that list species, designate critical habitat, or apply protective regulations to ESA listed species considered in this consultation that are likely to be adversely affected.

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

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

2.2.1. Status of Listed Species

For Pacific salmon and steelhead, NMFS commonly uses four parameters to assess the viability of the populations that, together, constitute the species: abundance, productivity, spatial structure, and diversity (McElhany et al. 2000). These "viable salmonid population" (VSP) criteria therefore encompass the species' "reproduction, numbers, or distribution" as described in 50 CFR 402.02. When these parameters are collectively at appropriate levels, they maintain a population's capacity to adapt to various environmental conditions and allow it to sustain itself in the natural environment. These parameters or attributes are substantially influenced by habitat and other environmental conditions.

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

"Productivity," as applied to viability factors, refers to the entire life cycle; i.e., the number of naturally spawning adults (i.e., progeny) produced per naturally spawning parental pair. When progeny replace or exceed the number of parents, a population is stable or increasing. When progeny fail to replace the number of parents, the population is declining. McElhany et al. (2000) use the terms "population growth rate" and "productivity" interchangeably when referring to production over the entire life cycle. They also refer to "trend in abundance," which is the manifestation of long-term population growth rate. "Spatial structure" refers both to the spatial distributions of individuals in the population and the processes that generate that distribution. A population's spatial structure depends fundamentally on accessibility to the habitat, on habitat quality and spatial configuration, and on the dynamics and dispersal characteristics of individuals in the population.

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

In describing the range-wide status of listed species, we rely on viability assessments and criteria in NMFS Technical Recovery Team (TRT) documents and NMFS recovery plans, when available, that describe VSP parameters at the population, 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).

2.2.1.1. Puget Sound Chinook Salmon ESU

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

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

Table 13 summarizes the available information on current abundance and productivity and their trends for the Puget Sound Chinook salmon natural populations including NMFS' critical and rebuilding thresholds and recovery plan targets for abundance and productivity (NMFS 2004a). Most Puget Sound Chinook populations are well below escapement levels and productivity goals required for recovery (Table 13). Abundance across the ESU has generally decreased since the last status review, with only five populations showing an increase in natural-origin abundance since the 2010 status review (NWFSC 2015). The remaining 17 populations showed a decline in their five-year natural-origin abundance as compared to the previous five-year period. The five-year geometric mean abundance for the entire ESU was 27,716 natural-origin adults from 2005 through 2009 and only 19,258 from 2010 through 2014;

indicating an overall decline of 31% (Table 56 in NWFSC 2015). Natural-origin escapements for five populations are above their NMFS-derived rebuilding thresholds (Table 13), while escapements for ten populations are between their critical and rebuilding thresholds, and natural-origin escapements for seven populations are below their critical thresholds (Table 13).

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

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 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 natural 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

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

Table 13. Estimates of geometric-mean escapement and productivity (1999-2014) for Puget Sound Chinook salmon.

Region	Population	Natural-origin Spawners[1]	Natural-origin Productivity[2]	Critical Escapement Threshold[3]	Rebuilding Escapement Threshold[3]	Recovery Spawner Target with High Productivity[4]
Georgia Basin	NF Nooksack	211	0.3	200	Unknown	3,800 (3.4)
	SF Nooksack	53	1.7	200	Unknown	2,000 (3.6)
Whidbey/Main Basin	Upper Skagit	7,748	1.8	967	7,454	5,380 (3.8)
	Lower Sauk	522	1.8	200	681	1,400 (3.0)
	Lower Skagit	1,932	1.4	251	2,182	3,900 (3.0)
	Upper Sauk	502	1.6	130	330	750 (3.0)
	Suiattle	319	1.2	170	400	160 (2.8)
	Upper Cascade	291	1.1	170	1,250	290 (3.0)
	NF Stillaguamish	582	0.9	300	552	4,000(3.4)
	SF Stillaguamish	104	0.7	200	300	3,600 (3.3)
	Skykomish	2,052	0.9	1,650	3,500	8,700 (3.4)
	Snoqualmie	1,142	1.5	400	1250	5,500 (3.6)
Central/South Sound	Cedar	802	1.9	200	1,250	2,000 (3.1)
	Sammamish	128	0.5	200	1,250	1,000 (3.0)
	Duwamish/Green	1,179	1.1	835	5,523	Unknown
	White[6]	1,268	0.6	200	1,100	Unknown
	Puyallup[7]	655	0.8	200	522	5,300 (2.3)
	Nisqually	522	1.0	200	1,200	3,400 (3.0)
Hood Canal	Skokomish	345	0.8	452	1,160	Unknown
	Mid-Hood Canal[8]	Not available	Not available	200	1,250	1,300 (3.0)
Strait of Juan de Fuca	Dungeness	114	0.6	200	925	1,200 (3.0)
	Elwha[9]	117	Not available	200	1,250	6,900 (4.6)

Source: (NWFSC 2015)

[1] Estimates of natural-origin escapement for Nooksack, Skagit springs, Skagit falls and Skokomish available only for 1999-2013; Snohomish for 1997-2001 and 2005-2014; Lake Washington for 2003-2014; White River 2005-2014; Puyallup for 2002-2014; Nisqually for 2005-2014; Dungeness for 2001-2014; Elwha for 2010-2014.

[2] Source 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.

[3] Thresholds under current habitat and environmental conditions (McElhany et al. 2000; NMFS 2000).

[4] Source is the final supplement to the Puget Sound Salmon Recovery Plan (NMFS 2006b); measured as recruits/spawner associated with the number of spawners at Maximum Sustained Yield under recovered conditions.

[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; WDFW and PSTIT 2005; WDFW and PSTIT 2008; WDFW and PSTIT 2009; WDFW and PSTIT 2010; WDFW and PSTIT 2011; WDFW and PSTIT 2012)and the 2010-2014 Puget Sound Chinook Harvest Management Plan (PSIT and WDFW 2010). North Fork and South Fork Nooksack estimates are through 2011 and 2010, respectively. Skagit estimates are through 2011.

[6] 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.

[7] 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).

[8] 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.

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

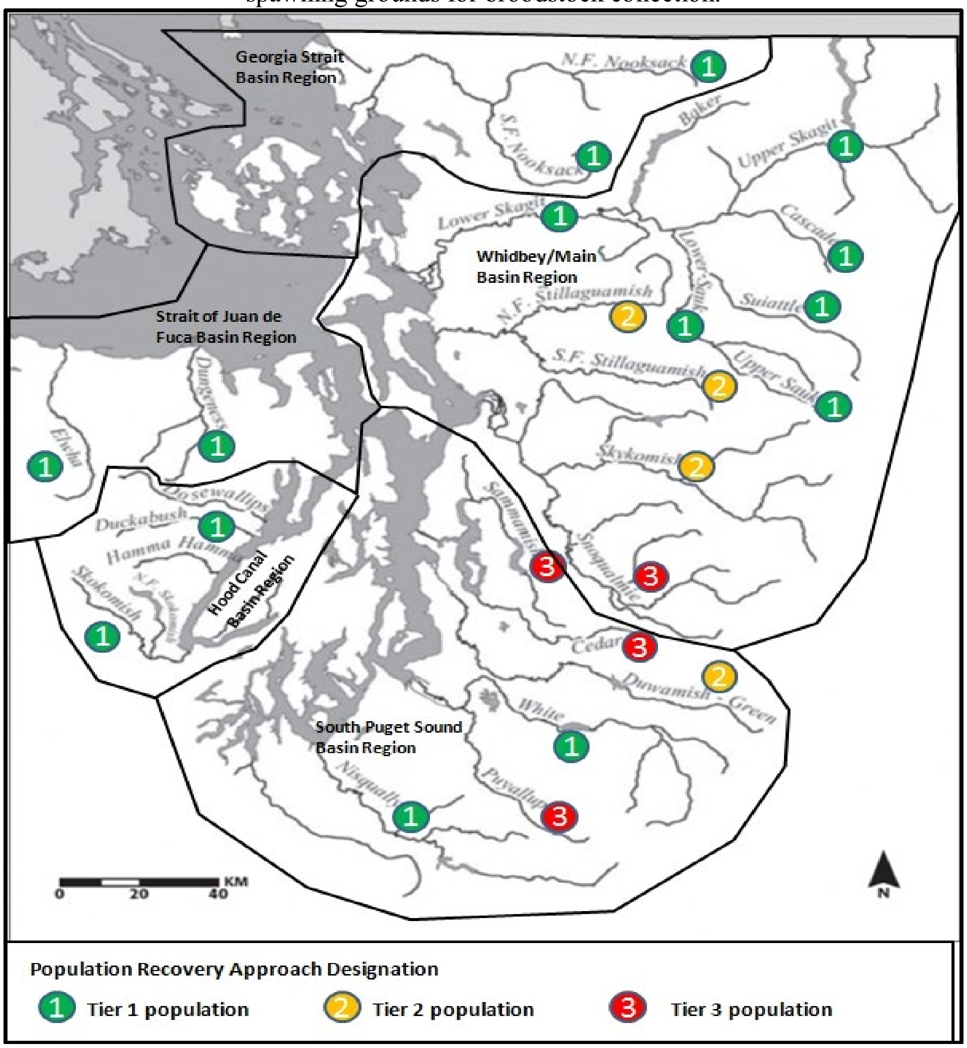

Figure 2. Populations delineated by NMFS for the Puget Sound Chinook salmon ESU (NMFS 2010b; SSPS 2007) and their assigned Population Recovery Approach tier status (NMFS 2010b; SSPS 2007)). Note: Dosewallips, Duckabush and Hamma Hamma River Chinook salmon are aggregated as the “Mid Hood Canal” population.

The limiting factors described in SSPS (2007) and NMFS (2006b) include:

- Degraded nearshore and estuarine habitat: Residential and commercial development has reduced the amount of functioning nearshore and estuarine habitat available for salmon rearing and migration. The loss of mudflats, eelgrass meadows, and macroalgae further limits salmon foraging and rearing opportunities in nearshore and estuarine areas.

- Degraded freshwater habitat: Floodplain connectivity and function, channel structure and complexity, riparian areas and large wood supply, stream substrate, and water quality have been degraded for adult spawning, embryo incubation, and rearing as a result of cumulative impacts of agriculture, forestry, and development.
- Anadromous salmonid hatchery programs: Salmon and steelhead released from Puget Sound hatcheries operated for harvest augmentation purposes can potentially pose ecological, genetic, and demographic risks to natural-origin Chinook salmon populations but can also provide benefits to viability parameters such as increased abundance and preserving genetic diversity.
- Salmon harvest management: Total fishery exploitation rates have decreased 14 to 63% from rates in the 1980s, but low natural-origin Chinook salmon population abundance in Puget Sound still requires enhanced protective measures to reduce the risk of overharvest.

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

Whidbey Basin BGR: The Whidbey Basin BGR contains 10 populations including the two Snohomish populations. 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. 2006b). 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 and it 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 (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 13) 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 (2010-2014) geometric mean abundances, two populations in the BGR are above their rebuilding thresholds (representing early and moderately early life histories) and the South Fork Stillaguamish is in critical status (WDFW Score Database; NWFSC 2015). As described above, only five populations showed an increase in abundance in the five-year geometric mean natural-origin abundance since the 2010 status review (NWFSC 2015), and three of these five are within the Whidbey Basin BGR. Long-term (1988-2019) escapement trends show the numbers of Chinook salmon returning to both the Skykomish and Snoqualmie have been highly variable but have generally declined in the most recent ten year period (Figure 3 and Figure 4). Long-term growth rates for pre-harvest abundance (return) are declining for all populations within the BGR (Haggerty 2020a; NWFSC 2015).

Snohomish River Basin Chinook - The two Snohomish River basin Chinook salmon populations – Skykomish and Snoqualmie – are grouped with eight other populations in the Whidbey Basin BGR for recovery planning purposes (NMFS 2006a; SSPS 2005b). Based on analyses of population and habitat status factors for Chinook salmon populations grouped within the Whidbey Basin BGR, under the NMFS PRA (NMFS 2010a), the populations affected by this proposed action, the Skykomish and Snoqualmie Chinook populations, are Tier 2 and Tier 3 populations, respectfully. Within the Whidbey Basin BGR, Chinook salmon populations in the Skagit River are assigned as having primary roles for Puget Sound Chinook salmon ESU recovery and are designated as Tier 1 (Figure 2). As described in Section 2.1, NMFS considers impacts to Tier 2 and 3 populations less likely to affect the viability of the ESU as a whole than similar impacts to Tier 1 populations, because of the primary importance of Tier 1 populations to overall ESU viability.

Both the Skykomish and Snoqualmie populations are ocean-type Chinook salmon with juveniles emigrating seaward in March through June. A significant proportion of adult Chinook salmon in each population, averaging 24% and 22% for the Skykomish and Snoqualmie populations, respectively (1996-2011 averages from Mike Crewson, Tulalip Tribes, and Pete Verhey, WDFW, pers. comm. 2014), is comprised by the yearling fresh water life history type (“stream type”). Adults return primarily as four-year-old fish, although both populations exhibit a relatively strong age-5 component. For the period 2005 through 2013, age-5 Chinook salmon made up 20- and 17-percent of the natural-origin spawners in the Skykomish and Snoqualmie populations, respectively (Rawson and Crewson 2017).

Adult summer Chinook salmon return to the Skykomish River watershed beginning in May and extending through September (PSIT and WDFW 2010). The Skykomish natural population has a late-summer/early-fall spawn timing (early-September to early-October) with Chinook salmon spawning in the Snohomish River mainstem, the mainstem of the Skykomish, Pilchuck, Wallace, and Sultan rivers; Woods, Elwell, Olney, Proctor, and Bridal Veil creeks; and the North and South Forks of the Skykomish River (WDFW spawning ground database). The Snoqualmie Chinook salmon population is considered a fall-run stock, migrating into the Snohomish River basin from August through October. Chinook salmon spawning occurs later than in the Snoqualmie River watershed, generally in the fall months (mid/late-September through early-November) (WDFW spawning ground database). Snoqualmie Chinook salmon spawn in the Snoqualmie River and its larger tributaries, including the Tolt and Raging rivers, and Tokul Creek (PSIT and WDFW 2010).

Abundance of Snohomish River basin Chinook salmon is a fraction of historical levels (Haggerty 2020a; SSPS 2005b). The most recent estimates of escapement, hatchery contribution, and productivity for the Snohomish basin populations are summarized in Figure 3 and Figure 4 as well as Table 14 and Table 15. Naturally-produced Chinook salmon comprise a majority of natural spawners, averaging 68.7 percent for the basin in recent years (2006-2019; see Table 14). The average hatchery-origin fraction of the naturally spawning Skykomish Chinook salmon population in the last thirteen recent years (2006-2019; 31.3%) has decreased from the level 15 years ago (1997-2001 avg. = 49.9%). The hatchery-origin fraction of the naturally spawning Snoqualmie Chinook salmon population has varied from 11.3% in 2010 to 34.4% in 2019 largely as a result in declining returns of natural-origin adults. The actual number of hatchery-origin spawners remained relatively stable during this period with 203 HOR adults escaping in 2010 and 233 escaping in 2019 (Table 14).

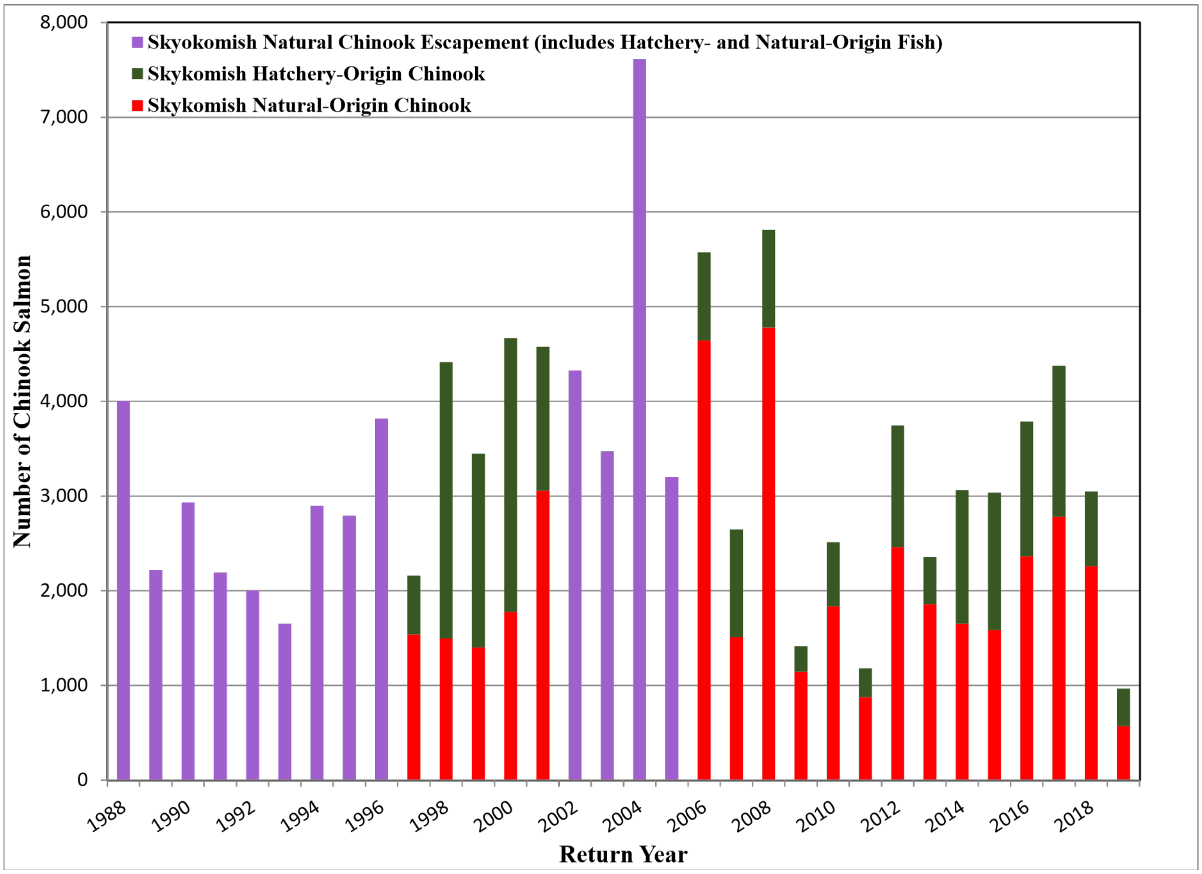

Figure 3. Estimated annual natural Chinook salmon escapement abundances in the Skykomish River for 1988 through 2019. Natural- and hatchery-origin breakouts are included for years where data are available. Source: WDFW Score database; Mike Crewson and Pete Verhey, Tulalip Tribes and WDFW unpublished escapement data 2020.

Trends in annual natural-origin spawner per natural spawner rates for the Skykomish and Snoqualmie populations indicate general declines in productivity (Table 15). For brood years 2000 through 2014, productivity of the Skykomish Chinook salmon population was less than 1:1 natural origin recruits to escapement per natural spawner in eleven of those fifteen years. For the same time period, the productivity of the Snoqualmie Chinook salmon population was less than 1:1 in ten of the years. The 2000-2010 brood year geometric mean natural origin recruit spawner per natural spawner for the Skykomish Chinook population was 0.69 and 0.65 for the Snoqualmie Chinook population (Table 15)(Haggerty 2020a).

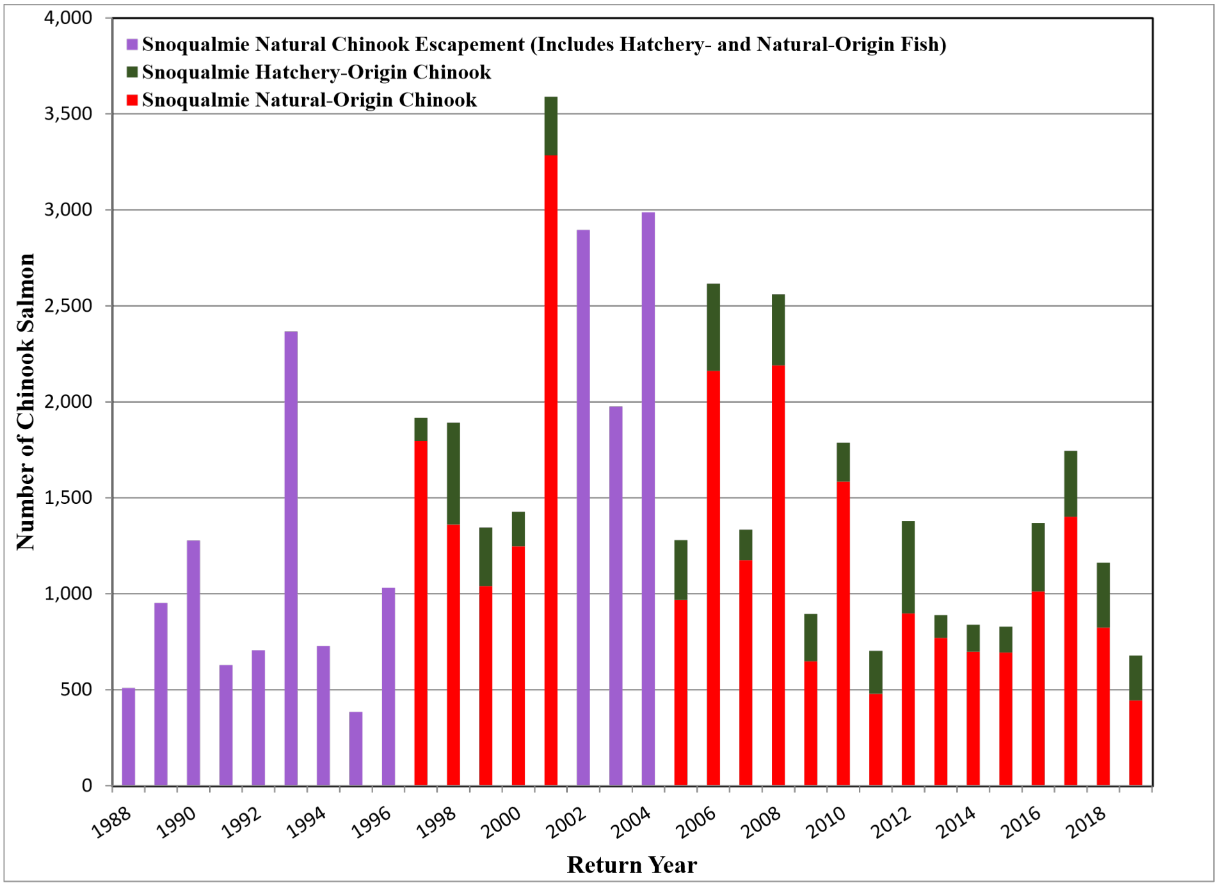

Figure 4. Estimated annual natural Chinook salmon escapement abundances in the Snoqualmie River for 1988 through 2019. Natural- and hatchery-origin breakouts are included for years where data are available. Source: WDFW Score database; Mike Crewson and Pete Verhey, Tulalip Tribes and WDFW unpublished escapement data 2020.

Table 14. Summary of Skykomish and Snoqualmie Chinook salmon populations natural escapement, natural-origin escapement, and percent of natural escapement composed of hatchery-origin spawners (pHOS) for return years 1997-2019. Source: Mike Crewson and Pete Verhey, Tulalip Tribes and WDFW unpublished escapement data 2020).

Return Year	Skykomish Total Natural Escapement	Skykomish Natural-Origin Escapement	Skykomish Percent Hatchery-Origin	Snoqualmie Total Natural Escapement	Snoqualmie Natural-Origin Escapement	Snoqualmie Percent Hatchery-Origin
1997	2,161	1,540	28.7%	1,917	1,796	6.3%
1998	4,415	1,495	66.1%	1,891	1,361	28.0%
1999	3,446	1,401	59.3%	1,345	1,040	22.7%
2000	4,668	1,775	62.0%	1,427	1,248	12.5%
2001	4,577	3,054	33.3%	3,589	3,284	8.5%
2002	4,327	NA	NA	2,896	NA	NA
2003	3,472	NA	NA	1,975	NA	NA
2004	7,614	NA	NA	2,988	NA	NA
2005	3,201	NA	NA	1,279	968	24.3%
2006	5,573	4,642	16.7%	2,615	2,161	17.4%
2007	2,648	1,510	43.0%	1,334	1,174	12.0%
2008	5,813	4,780	17.8%	2,560	2,190	14.5%
2009	1,414	1,146	19.0%	895	649	27.5%
2010	2,512	1,836	26.9%	1,788	1,585	11.3%
2011	1,181	876	25.5%	702	479	31.8%
2012	3,745	2,462	34.1%	1,379	898	34.9%
2013	2,355	1,860	21.0%	889	770	13.4%
2014	3,063	1,654	46.0%	839	698	16.8%
2015	3,034	1,585	47.8%	829	694	16.3%
2016	3,785	2,363	37.6%	1368	1013	26.0%
2017	4,374	2,783	36.4%	1745	1401	19.7%
2018	3,048	2,259	25.9%	1162	823	29.2%
2019	966	569	41.1%	678	445	34.4%
1997-2001 Skykomish pHOS			49.9%			
2006-2019 Skykomish pHOS			31.3%			
			1997-2001 Snoqualmie pHOS			15.6%
			2005-2019 Snoqualmie pHOS			22.0%
1997-2001 Basin Wide pHOS			38.9%			
2006-2019 Basin Wide pHOS			28.7%			

Table 15. Recent productivity estimates for Skykomish and Snoqualmie Chinook salmon populations as measured by the annual number of natural-origin recruits spawners (NORs) per natural spawners for the contributing brood year (Source: Rawson and Crewson 2017; Alexandersdottir and Crewson 2019; M. Alexandersdottir personal communication November 15, 2020).

Brood Year[2]	Skykomish Chinook Salmon			Snoqualmie Chinook Salmon		
	Natural Spawner Abundance	Progeny NOR Spawner Abundance[1]	Progeny NOR Spawner/Natural Spawner	Natural Spawner Abundance	Progeny NOR Spawner Abundance[1]	Progeny NOR Spawner/Natural Spawner
2000	4,668	6,274	1.34	1,427	2,361	1.65
2001	4,577	2,305	0.50	3,589	890	0.25
2002	4,327	3,760	0.87	2,896	2,209	0.76
2003	3,472	1,629	0.47	1,975	850	0.43
2004	7,614	5,568	0.73	2,988	2,244	0.75
2005	3,201	2,281	0.71	1,279	1,287	1.01
2006	5,573	1,310	0.24	2,615	1,088	0.42
2007	2,648	1,365	0.52	1,334	606	0.45
2008	5,813	2,441	0.42	2,560	744	0.29
2009	1,414	2,909	2.06	895	1,099	1.23
2010	2,511	1,060	0.42	1,788	540	0.30
2011	1,181	1,491	1.26	702	658	0.94
2012	3,744	2,216	0.59	1,379	642	0.47
2013	2,355	3,409	1.45	889	1,436	1.62
2014	3,063	1,733	0.58	838	950	1.13

[1] NOR spawner progeny of brood year natural spawners summed for all observed age classes at return.

[2] Brood year indicates the year the individual was born. This table includes data collected through 2018, which for example included 5-year-old returning adult Chinook salmon from the 2013 brood year.

The spatial structure for the Skykomish and Snoqualmie Chinook salmon natural populations has been reduced by habitat loss and degradation. Bank protection and diking of the river and major tributaries have disconnected river channels from their floodplains leading to loss of accessible river areas and habitat complexity for rearing and migrating Chinook salmon (Snohomish Basin Salmonid Recovery Technical Committee 1999). Lack of adequate in-channel large woody debris, relative to historic conditions, has decreased the amount of rearing and refuge areas available for juvenile Chinook salmon

(Snohomish Basin Salmonid Recovery Technical Committee 1999). Chinook habitat has been further reduced by loss of wetlands through draining and land conversion for human use (Snohomish Basin Salmonid Recovery Technical Committee 1999). Road construction, commercial and residential construction, and bank hardening for flood control have also impaired Chinook salmon habitat use and access and population spatial structure. Artificial barriers at locations throughout the basin, including dams, tide gates, water diversions, culverts, and pumping stations) prevent juvenile Chinook salmon from reaching rearing habitat to the further detriment of population spatial structure (Snohomish Basin Salmon 2005). Since the 1950s, the spawning distribution of the Skykomish Chinook salmon population appears to have shifted upstream. Since that time, a much larger proportion of fish spawn higher in the drainage, between Sultan and the North and South Forks of the Skykomish River, than in previous decades (Snohomish Basin Salmonid Recovery Technical Committee 1999).

Life history diversity of the Snohomish River basin Chinook salmon populations has been reduced by anthropogenic activities over the last century (Haring 2002), and is further threatened by on-going developmental actions in the watershed. Lost and degraded estuarine habitat has impaired the fry migrant components of the Skykomish and Snoqualmie populations, which need a properly functioning, braided lower river and brackish water environment to grow to a viable smolt size. Fry migrants represent a particularly important component of the life history diversity for both populations.

The Chinook salmon populations in the Snohomish River basin have been particularly affected by habitat loss in the estuary. The quantity and quality of salmon rearing habitat available to the two populations in the estuary is a small fraction of pre-development conditions (Snohomish County 2013). Historically, the Snohomish River estuary included a rich complex of tidal channels and productive marshes. Under current conditions, only one-sixth of the historical tidal marsh area downstream of the head of Ebey Slough remains intact and accessible to salmonids (Snohomish County 2013). The current lack of critical estuarine tidal marsh habitat is considered a limiting factor for Chinook salmon recovery (Snohomish Basin Salmon 2005). Greatly reduced ocean productivity coupled with drought, low flow and high temperatures followed by increased frequency and intensity of flooding are the main limiting factors that have increased in the last 20 years that cause the majority of the mortality (leDoux et al. 2017). These conditions compromise prospects for restoration of natural-origin Chinook salmon population viability, because ocean-type Chinook salmon stocks are extremely dependent on a properly functioning estuary due to their predominantly fry migrant life history.

2.2.1.2. Status of Critical Habitat for Puget Sound Chinook Salmon

Designated critical habitat for the Puget Sound Chinook ESU includes estuarine areas and specific river reaches associated with the following subbasins: Strait of Georgia, Nooksack, Upper Skagit, Sauk, Lower Skagit, Stillaguamish, Skykomish, Snoqualmie, Snohomish, Lake Washington, Duwamish, Puyallup, Nisqually, Deschutes, Skokomish, Hood Canal, Kitsap, and Dungeness/Elwha (70 FR 52630, 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, 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 (also called "primary constituent elements," or PCEs, in some designations) 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). PCEs for Puget Sound Chinook salmon (70 FR 52731, September 2, 2005), including the Snohomish 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 Snohomish River basin action area. Critical habitat includes the estuarine areas and the stream channels within the proposed stream reaches of the Snohomish sub-basin, and includes a lateral extent as defined by the ordinary high-water line (33 CFR 319.11). The Puget Sound Critical Habitat Analytical Review Team identified management activities that may affect the PCEs in the three subbasins including agriculture, grazing, channel modifications/diking, dams, forestry, urbanization, sand/gravel mining and road building/maintenance (NMFS 2005a).

2.2.2. Puget Sound Steelhead DPS

2.2.2.1. Life History and Status

Oncorhynchus mykiss has an anadromous form, commonly referred to as steelhead. 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 referred to as kelts. Averaging across all West Coast steelhead populations, 8% 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 and winter. Puget Sound steelhead are dominated by the winter life history type and typically migrate as smolts to sea at age two. Seaward emigration 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, and move southward and eastward during the fall and winter (Hartt and Dell 1986). Adults return from December to May, and peak spawning occurs from March through May. Summer steelhead adults return from May through October and peak spawning occurs the following January to May (Hard et al. 2015; 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 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 Puget Sound steelhead DPS was listed as threatened on May 11, 2007 (72 FR 26722), and the 2015 status review determined that the DPS should remain threatened (NWFSC 2015). The DPS includes all naturally spawned anadromous winter and summer steelhead populations within 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) as shown in Figure 5. Also included as part of the ESA-listed DPS are six hatchery stocks derived from local natural steelhead populations and produced for conservation purposes (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 key differences in physical, physiological, ecological, and behavioral characteristics (Hard et al. 2007). Puget Sound steelhead populations are aggregated into three extant Major Population Groups (MPGs) containing a total of 32 Demographically Independent Populations (DIPs) based on genetic, environmental, and life history characteristics (Myers et al. 2015) (Table 16).

The 2015 status review indicated some minor increases in spawner abundance and/or improving productivity over the last few years for Puget Sound steelhead; however abundance and productivity throughout the DPS remain at levels of concern. The recent increases in abundance during the 2012-2016 time period observed in a few populations are encouraging, but are within the range of variability observed in the past several years and overall trends in abundance of natural-origin spawners remain predominately negative.

Currently the recovery plan for Puget Sound Steelhead is only in draft form. However, in its status review and listing documents for the Puget Sound Steelhead DPS (76 FR 1392; 71 FR 15666), NMFS noted that the factors for decline persist as limiting factors:

- Continued destruction and modification of steelhead habitat
- Widespread declines in adult abundance (total run size), despite significant reductions in harvest in recent years
- Threats to diversity from non-local hatchery steelhead stocks
- Declining diversity in the DPS
- A reduction in spatial structure for steelhead in the DPS
- 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 have resulted in gravel scour, bank erosion, and sediment deposition, and reduced groundwater-driven summer flows
- Dikes, hardening of banks with riprap, and channelization have reduced river braiding and sinuosity, and increased the likelihood of gravel scour and dislocation of rearing juveniles

Table 16. 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 (number of fish)
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 (summer)	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[2]/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)

[2] 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.

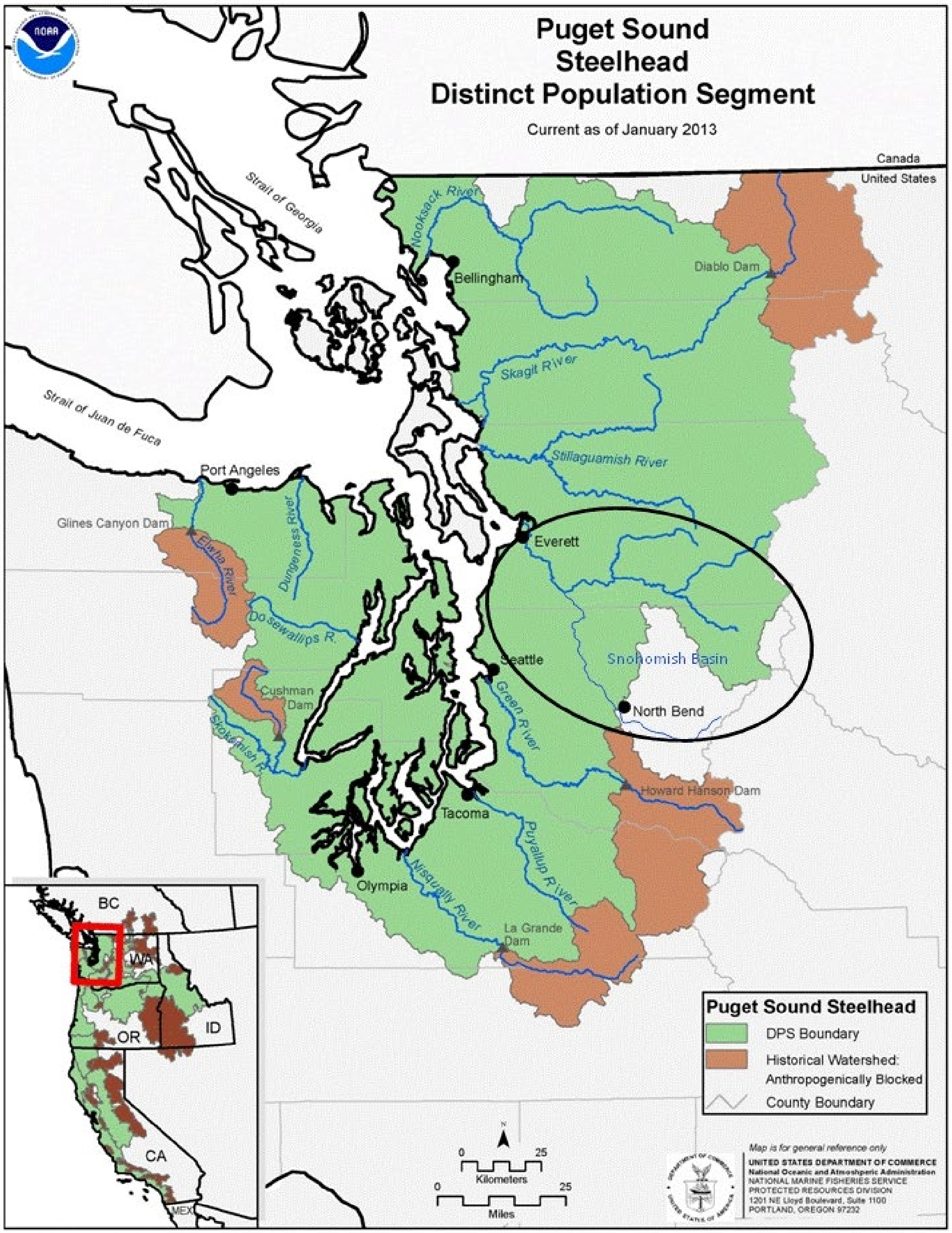

Figure 5. Location of the Snohomish River steelhead populations in the Puget Sound Steelhead DPS (generalized location indicated by black oval).

Northern Cascades MPG

The Northern Cascades MPG has 16 DIP's including eight summer or summer/winter, and eight winter DIPs (Table 16). Differences in bedrock erodibility throughout the Northern Cascades MPG create cascades and falls that may serve as isolating mechanisms for summer-and winter-run populations. This geology is likely responsible for the relatively large number of summer-run populations (PSSTRT 2013a) since returning summer steelhead tend to migrate to headwater areas in the spring and early-summer when flows are higher, making possible access to upstream areas that, in other months, are impassable due to low flow related obstacles to passage that become partial or complete barriers to migration. Eight of the 10 DIPs in the DPS with extant summer run-timing or summer components are in this MPG. The Northern Cascade MPG accounts for 75 percent of the steelhead abundance in the DPS (Hard et al. 2007). Although information on the DIPs within the Northern Cascades MPG is extremely limited, abundance varies greatly among the populations (Table 17) with the Skagit and Snohomish natural populations comprising the majority of steelhead in the MPG. Mean growth rates are declining for all populations within the MPG except for the Tolt River, and abundance for this DIP is very low. 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 10) with the Snohomish populations equally divided. However, more natural populations are at lower risk in this MPG than in the other MPGs in the DPS. In summary, the North Cascades steelhead MPG, relatively speaking, is at a lower extinction risk and is a stronghold in terms of life history diversity and abundance.

Snohomish Basin Populations

The Snohomish basin includes five steelhead DIPs: Snohomish/Skykomish winter-run; Pilchuck winter-run; Snoqualmie winter-run; Tolt summer-run; and North Fork Skykomish summer-run (PSSTRT 2013a). The DPS viability criteria developed by NMFS (Hard et al. 2015) require that at least 40 percent of the steelhead populations within each MPG achieve viability (restored to a low extinction risk), as well as at least 40 percent of each major life history type (e.g., summer-run and winter-run) historically present within each MPG achieve viability. There are no hatchery-origin steelhead produced in basin hatcheries that are included as part of the listed DPS.

Winter-run steelhead in the Snohomish River basin enter freshwater as adults between mid-October and May (Myers et al. 2015). Spawning occurs from mid-March through mid-June with peak spawning in April. Most winter-run steelhead return to spawn as four-year-old (57%), and five-year-old fish (42%) (PSSTRT 2013a citing WDFW 1994b). Juvenile out-migrant trapping data indicate that natural-origin Snohomish River basin steelhead juveniles emigrate seaward in April and May as smolts predominantly as two-year-old fish (84%) and to a lesser extent, as three-year-old smolts (15%) (PSSTRT 2013a citing WDFW 1994b).

Table 17. Naturally spawning steelhead abundances and trends for DIPs within the North Cascades MPG for which information is available. Populations within the Snohomish basin are bolded. WR=winter-run, SUR=summer run, and SWR=summer/winter run population.

Population (Run Timing)	2010-2014 Geometric Mean Escapement (Spawners)[1]	2015-2019 Geometric Mean Escapement (Spawners)[1]	Percent Change[1]
Nooksack R WR	1,745	1,906	9%
Pilchuck R WR	**626**	**638**	**2%**
Samish R WR	748	1,305	74%
Skagit R SWR[2]	6,391	7,181	12%
Snohomish/Skykomish WR	**975**	**690**	**-29%**
Snoqualmie R. WR	**706**	**500**	**-29%**
Stillaguamish R. WR[3]	386	487	26%
Tolt River SUR	**108**	**40**	**-63%**

[1]Source: (NWFSC 2015)
[2]Skagit data includes four DIPs: Skagit, Nookachamps, Baker, and Sauk.
[3]Only includes the estimated number of naturally spawning steelhead in the North Fork Stillaguamish River index segments.

In the late 1950s, WDFW began releasing summer steelhead originating from the Skamania Hatchery in the lower Columbia River, a stock that exhibits an early spawn timing. In its own examination of the subject, WDFW (Warheit et al. 2021) concluded that a mixing of local- and Skamania-origin steelhead likely continued from the late 1950s until brood year 1981. In subsequent years, WDFW used returning early summer steelhead from the Skamania program, and natural-origin individuals from the Skykomish basin, as broodstock. Over the course of decades, this broodstock management produced summer steelhead that continue to exhibit an early-spawn timing life history, as well as complex ancestry.

WDFW began operating the Sunset Falls Fishway facility in 1958 by transporting summer steelhead upstream into the upper South Fork Skykomish basin. WDFW managed steelhead passage in this way until recently, when it began limiting upstream transport to natural-origin steelhead. Management of the Sunset Falls Fishway facility, coupled with the amalgamation of hatchery- and natural-origin summer steelhead over the course of several decades, has made it challenging to make definitive conclusions about the ancestry of summer steelhead in the Skykomish basin. These challenges were exemplified in earlier studies in which researchers used allozyme (Phelps et al. 1997) and microsatellite analyses (Kassler et al. 2008) to identify steelhead ancestry within the Skykomish basin. Results from these studies suggested a substantial genetic contribution of Skamania-stock steelhead to summer steelhead native to the NF and the SF Skykomish Rivers. However, the applicability of these analyses to the current status of summer steelhead in the South Fork Skykomish River is questionable, given changes in steelhead selected for transport upstream of Sunset Falls in subsequent years. The origin (hatchery or natural) of the adults transported upstream of Sunset Falls was not recorded until 1993. From 1993 through 2008, an average of 593 unmarked, likely natural-origin steelhead were passed upstream each year, which comprised an average of 59% of the total return to Sunset Falls. Marked hatchery-origin steelhead were generally not passed upstream beginning in 2009. From 2009 through 2018, unmarked steelhead comprised 96% of the steelhead passed upstream, which averaged 315 fish (WDFW and Tulalip Tribes 2019). Subsequent to investigation by (Kassler et al. 2008), a recent, more in-depth genetic analysis by WDFW (Warheit et al. 2021) that incorporates additional samples suggests limiting passage of hatchery-origin steelhead into the upper SF Skykomish basin may have reduced the influence of the early summer hatchery program. This recent analysis includes genetic analysis of collections of putative summer steelhead from the NF Skykomish River, SF Skykomish River, and Upper SF Tolt River and has yielded a new perspective on the ancestry of the SF Skykomish population.

WDFW's recent genetic analysis found that summer-run steelhead in the SF Skykomish River were as representative of a native summer-run steelhead in the Snohomish River basin as steelhead from the NF Skykomish River and the SF Tolt River (Figure 5; Figure 11). That is, this analysis showed that the previous assumptions to consider the SF Skykomish River summer-run steelhead as being more closely related to the of out-of-basin Skamania stock than neighboring populations (Myers et al. 2015) should be re-examined. This analysis, including stepwise implementation of STRUCTURE and a rooted dendrogram, illustrated the phylogeny and genetic relationships among summer steelhead in the Snohomish River basin, showing that the NF Skykomish River, SF Skykomish River, and SF Tolt River summer-run populations were genetically similar (Warheit et al. 2021). This recent analysis and a closer examination of the history of steelhead hatchery management in the Skykomish River further supports the idea that, although it is hatchery influenced, like other populations in the basin, steelhead from the SF Skykomish River should be considered of native Puget Sound origin rather than out-of-DPS.

The analysis suggests that summer-run steelhead from the SF Skykomish and the NF Skykomish Rivers are closely related as indicated by the F_{st} value of 0.015 (Warheit et al. 2021). The population dynamics leading to this low genetic differentiation and the biological significance of the difference is uncertain. It is possible that introgression with hatchery-origin summer steelhead released from the Reiter Ponds Hatchery has occurred at different levels to fish spawning in the South- and North Forks in the past, or it may reflect the recent change in management that limited transport of returning hatchery fish to the South Fork Skykomish River upstream of Sunset Falls. To summarize, SF Skykomish steelhead may not have had as much influence from the Skamania stock because the initial hatchery program included both the natural-origin Skykomish steelhead and hatchery-origin early spawning summer steelhead. The influence was recently reduced through selective transport of natural-origin summer steelhead into the upper SF Skykomish River. Furthermore, steelhead from the SF Skykomish and the NF Skykomish may be more closely related than previously thought. Whether the North Fork and South Fork steelhead should be treated as a single population remains uncertain. The analysis here assumes steelhead in the North Fork to be considered a demographically independent population (Myers et al. 2015) that may need to reach viability for recovery of the DPS (Hard et al. 2015; NMFS 2019b) and treat it as a separate population.

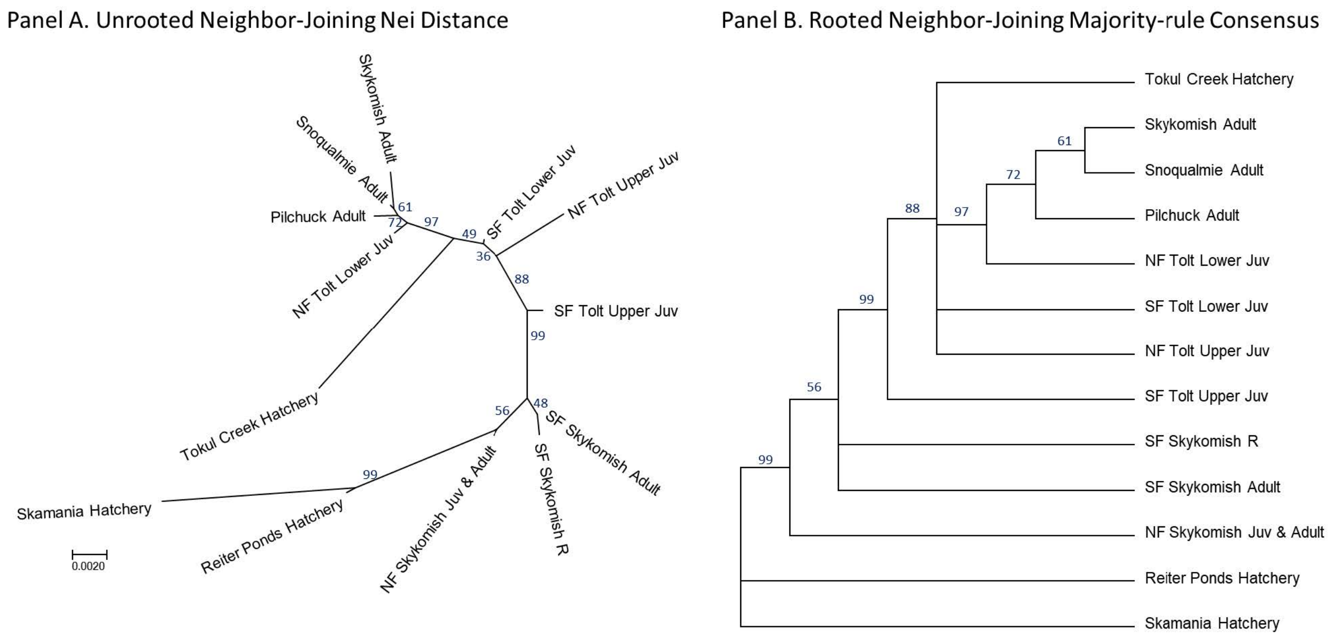

Figure 6. Unrooted neighbor-joining tree (Panel A) and majority-rule consensus tree rooted by Skamania Hatchery (Panel B). Percent support from 10,000 bootstrap trees are shown for each non-terminal branch in both trees. Branch lengths for the unrooted tree correspond to Nei's unbiased distances. The branch lengths for the rooted tree are uninformative. All branches with bootstrap values less than 50% are collapsed in the majority-rule consensus tree. The strongest support was found for separation of Skamania and Reiter Ponds Hatcheries from all other groups, separation of native winter groups from all other groups, and separation of the Skamania, Reiter Ponds, and Skykomish summer groups from all other groups (WDFW 2021).

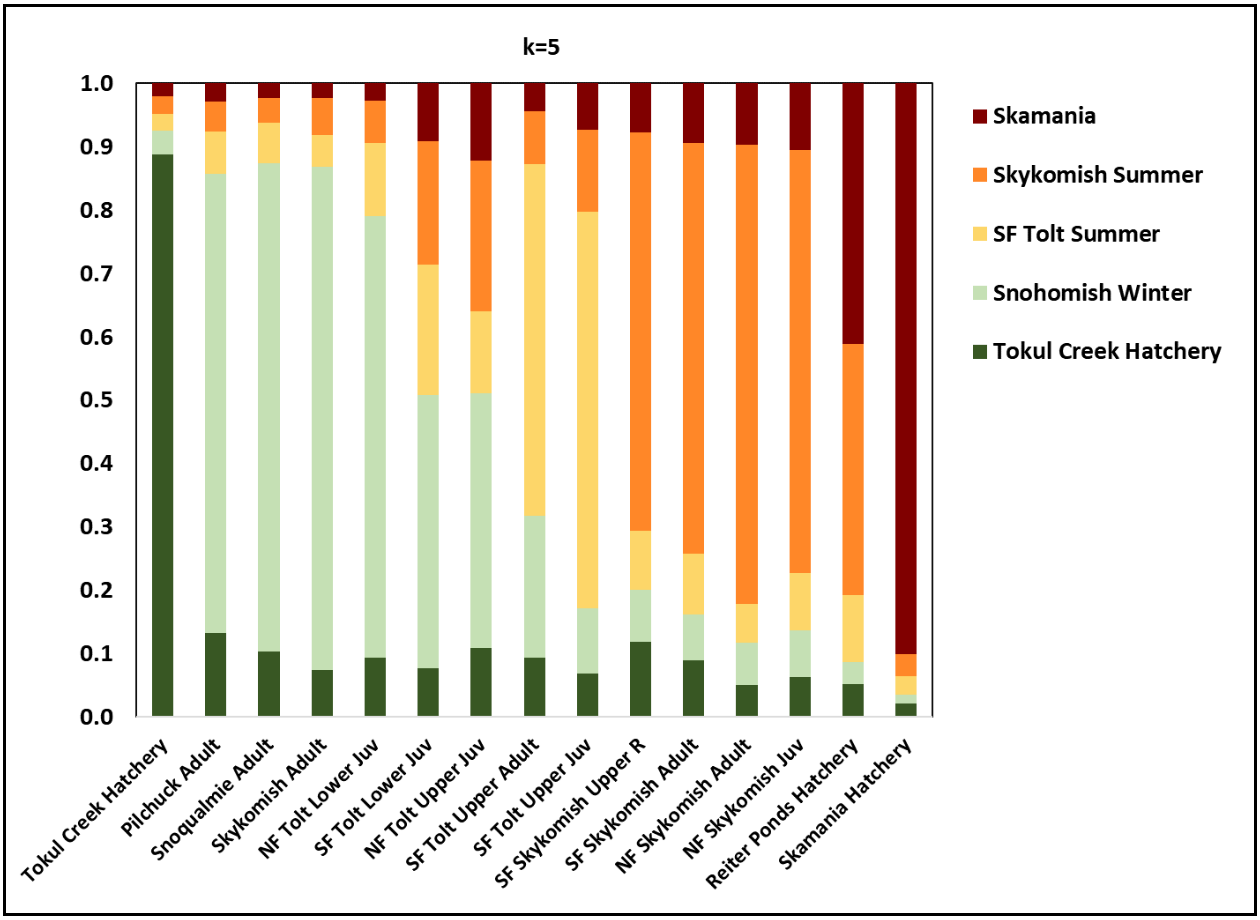

Figure 7. STRUCTURE estimates of the average genetic composition by group with k=5. The genomes of the SF and NF Skykomish are largely representative of Skykomish summer steelhead ancestry.

The implications of these findings for formal population identification (Myers et al. 2015) and recovery planning (NMFS 2019b) are being reevaluated. While previous analyses (i.e., (Kassler et al. 2008)) assumed a much larger impact from the Skamania stock, a thorough review of existing documents in light of this updated information is clearly warranted, especially regarding the genetic similarity of SF Skykomish summer steelhead and other summer steelhead in the Snohomish basin, to refine the population status and recovery role of SF Skykomish summer steelhead within the Puget Sound Steelhead DPS.

Historically, the Snohomish River basin was one of the primary producers of steelhead in Puget Sound (PSSTRT 2013a). Historical abundance estimates are lacking but county harvest levels attributed to the Snohomish in the late 1800s and early 1900s indicate that the numbers of steelhead were quite high. Harvests recorded for Snohomish County during these years were indicative of runs over 100,000 fish (PSSTRT 2013a). Escapement surveys by the Washington Department of Fish and Game in 1929 found large aggregations of steelhead in the Pilchuck, Sultan, Skykomish, and Tolt rivers, and medium aggregations in the North Fork and South Fork Skykomish, Wallace, Snoqualmie, and Raging rivers (Myers et al. 2015).

NMFS (2019b) recovery goals for the three winter-run steelhead populations in the Snohomish basin ranged from 12,000 (high productivity) to 40,200 (low productivity). NMFS (2019b) recovery goals range from 6,100 to 20,600 adults for the Snohomish/Skykomish winter-run steelhead DIP; 2,500 to 8,200 adults for the Pilchuck River DIP; and 3,400 to 11,400 adults for the Snoqualmie River DIP. The recent 5-year (2015-2019) combined geometric mean escapement for the three winter-run populations in the Snohomish River basin is 1,828 fish (Table 17, Figure 8), or 15.2% of the combined high productivity recovery plan goal. Winter-run steelhead escapements have declined significantly since the mid-1990s (Ford et al. 2011; PSSTRT 2013b; Scott and Gill 2008).

The 5-year geometric mean abundance for the Snohomish/Skykomish population was 975 natural-spawners from 2010-2014, and 690 natural-spawners from 2015-2019; this indicates an overall decline of -29 percent (NWFSC 2015). Hard et al. (2015) estimated that the probability that the population would decline to a QET of 73 steelhead was approximately 40% within 100 years; (see Table 16) based on a mean population growth rate of -0.005 (λ=0.995). The 5-year geometric mean abundance for the Pilchuck population was 626 natural-origin spawners from 2010-2014 and 638 from 2015-2019; indicating an overall increase of +2 percent. Hard et al. (2015) estimated that the probability that the population would decline to a QET of 34 steelhead was also approximately 40% within 100 years based on a mean population growth rate of -0.006 (λ=0.994). The 5-year geometric mean abundance for the Snoqualmie population was 706 natural-spawners from 2010-2014 and 500 from 2015-2019; this indicates an overall decline of 29 percent. Hard et al. (2015) estimated that the probability that the population would decline to a QET of 73 steelhead was approximately 70% within 100 years based on a mean population growth rate of -0.027 (λ=0.973).

NMFS (2019b) recovery goals for the two summer-run steelhead populations in the Snohomish basin ranged from 500 (high productivity) to 1,700 (low productivity). NMFS (2019b) recovery goals range from 300-1,200 adults for the Tolt River summer-run steelhead DIP; and 200-500 adults for the North Fork Skykomish River DIP. For Tolt River summer-run steelhead (the only summer-run population in the basin for which redd count data are available), escapements have declined since the late 1990s. The 5-year geometric mean abundance for the Tolt population was 108 natural-origin spawners from 2010 through 2014 and 40 from 2015-2019; this indicates an overall decrease of 63 percent. Hard et al. (2015) estimated that the probability that the population would decline to a QET of 25 steelhead was approximately 80 percent within 100 years (see Table 16); based on a mean population growth rate of -0.013 (λ=0.987).

Summer-run steelhead in the Snohomish basin are generally demographically depressed, with very low natural production in both the North Fork Skykomish River (82 in 2010) and South Fork Tolt River (mean of 76 from 2007 through 2018) summer-run populations (WDFW and Tulalip Tribes 2019). However, summer-run steelhead production is at a higher level in the South Fork Skykomish River, numbering in the hundreds[3]. Although this group of fish is not considered a DIP (Myers et al. 2015), it is larger than the two summer-run steelhead populations in the basin classified as DIPs. The abundance of summer steelhead in the South Fork Skykomish River is thought to have been only minimally affected

[3]Average for the last 5 years is 294 in South Fork Skykomish River vs. 49 in South Fork Tolt River; in 2010, South Fork Skykomish River escapement was about four times that of the North Fork Skykomish River.

by hatchery releases in the last decade (WDFW 2019a) due to limitations on transport of hatchery-origin early summer steelhead upstream of Sunset Falls.

Data are not available to evaluate changes in the diversity of steelhead in the Snohomish River basin. However, it is likely that the degradation and loss of habitat in the watershed, and past harvest practices that disproportionately affected the earliest returning fish, have reduced the diversity of the species relative to those prior to hatchery production using early summer steelhead from Skamania Hatchery. Genetic diversity of the winter-run natural populations has likely been adversely affected by releases of non-native early-winter steelhead from basin hatcheries, in watershed areas where spawn timings for natural and hatchery-origin fish have overlapped.

We are particularly concerned with impacts on the North Fork Skykomish summer steelhead population because (Myers et al. 2015) identified it as a DIP and NMFS maintained that either it or the South Fork Tolt summer steelhead population must be viable in order to recover the species (NMFS 2019b). The North Fork Skykomish River and the Tolt River contain populations that assure geographic spread, provide habitat diversity, reduce catastrophic risk, and increase life-history diversity of Puget Sound steelhead (NMFS 2019b) necessary for recovery of the species.

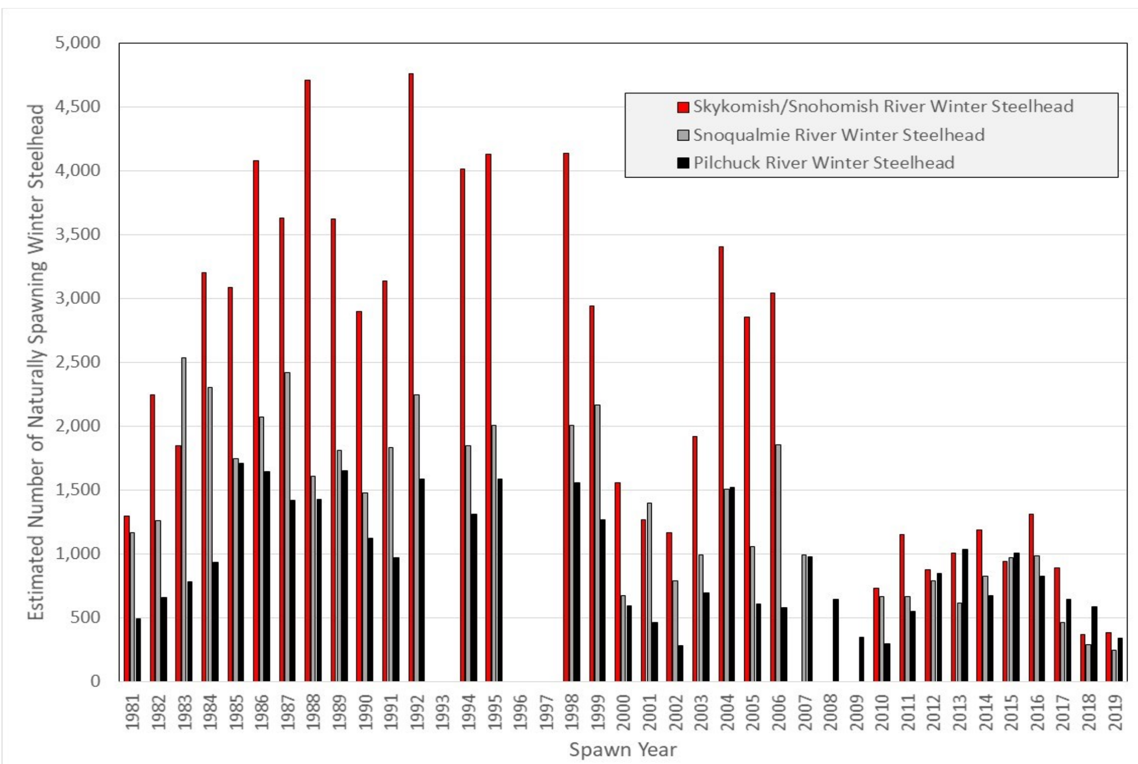

Figure 8: Snohomish Basin winter-run steelhead estimated escapement for 1980/1981 through 2018/2019. Escapement estimates based on redds enumerated on or after March 15 (source: Score database; WDFW and Tulalip Tribes unpublished data).

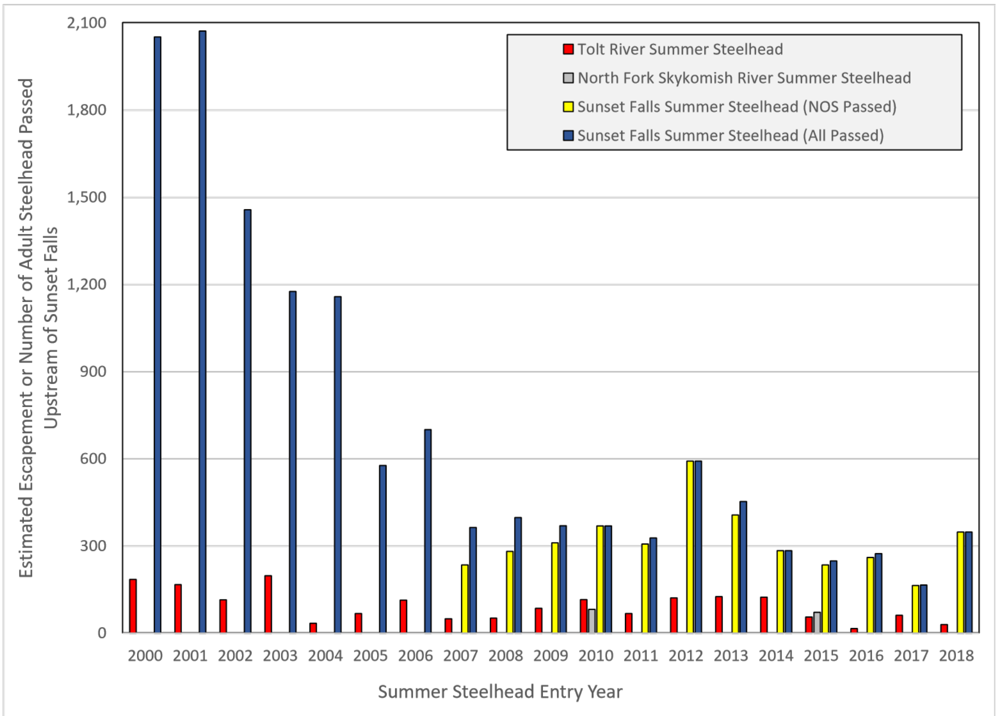

Figure 9. Snohomish Basin summer-run steelhead estimated escapement or number of fish transported upstream of Sunset Falls (Source: Score database; WDFW and Tulalip Tribes unpublished data; WDFW annual reports submitted pursuant to permit# 14433).

2.3. Action Area.

The action area resulting from this analysis includes the freshwater and estuarine areas within the Snohomish River basin and tributaries and nearshore marine areas immediately adjacent to the basin where salmon originating from the proposed hatchery programs would migrate, potentially stray, and spawn naturally. The action area also includes areas where adult salmon from the programs would be collected as broodstock and artificially spawned and where juvenile fish would be incubated, reared, acclimated, and released from the hatcheries (Figure 7).

In addition, adult hatchery origin-only Chinook salmon would be collected in the Wallace River downstream of the Wallace River Hatchery and May Creek weirs through seining in years when returning adults do not volunteer to the traps at required broodstock collection levels. Adult Chinook salmon collected at Wallace River Hatchery would be available for release into the Wallace River upstream or downstream of the hatchery weir at RM 4.0 to allow the fish to spawn naturally. Monitoring and evaluation activities would be implemented at the hatcheries and in their immediate vicinities (i.e., Tulalip Bay, Wallace River, and May Creek), and in the Snohomish River watershed extending from the mouth of the Snohomish River upstream to the limits of anadromous fish access in the Skykomish and Snoqualmie river watersheds.

As discussed in the 2017 BiOp, NMFS also considered whether the marine areas of Puget Sound outside of Tulalip Bay and in the ocean are affected by the proposed action and therefore should be included in the action area. The potential concerns are relationships between Snohomish River Basin Hatchery salmon production, and mixed stock fisheries harvest, and factors affecting salmon growth and survival in the marine environment. However, NMFS has determined that, based on best available science, it is not possible to establish any meaningful causal connection between hatchery production on the scale anticipated in the proposed action and any such effects.

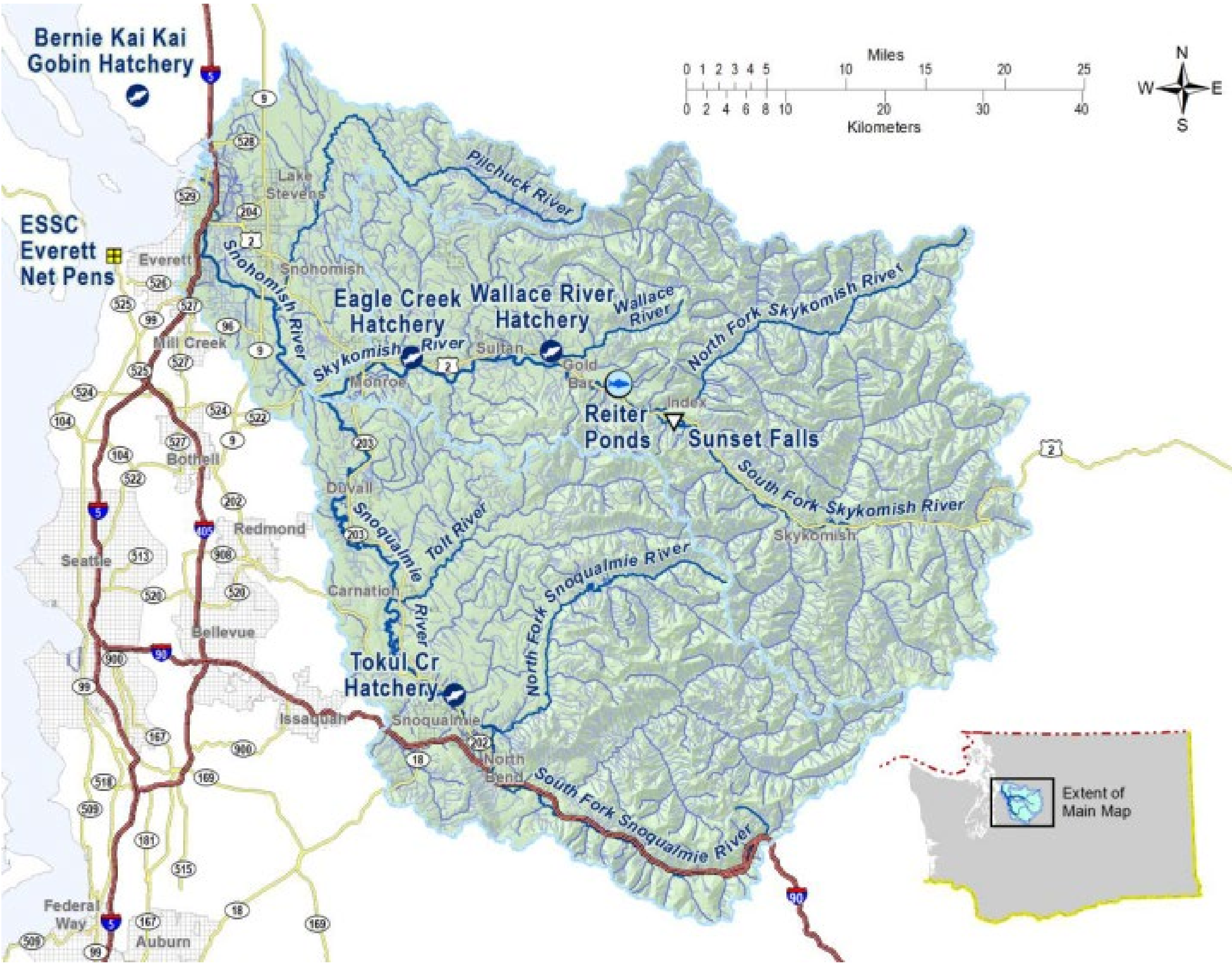

Figure 10. Action area for the proposed continued operation of Snohomish River basin salmon hatcheries. Map includes locations of all hatchery programs in the basin, two of which (Reiter Ponds and Tokul Creek Hatchery) are not operated as part of the proposed salmon hatchery actions. Source: WDFW Fish Program – September 16, 2016.

2.4. Environmental Baseline

The "environmental baseline" refers to the condition of the listed species or its designated critical habitat in the action area, without the consequences to the listed species or designated critical habitat caused by the proposed action. The environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultations, and the impact of State or private actions which are contemporaneous with the consultation in process. The consequences to listed species or designated critical habitat from ongoing agency activities or existing agency facilities that are not within the agency's discretion to modify are part of the environmental baseline (50 CFR 402.02).

The environmental baseline associated with habitat described in the 2017 BiOp remains largely the same, including land use, fish habitat, and water use in the Snohomish River basin watershed. Some habitat restoration projects described in the 2017 BiOp have been completed since that time, others are on-going while additional restoration activities have recently been initiated or are planned for upcoming years.

2.4.1. 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 (Beechie et al. 2006). Average annual Northwest air temperatures have increased by approximately 1ºC since 1900, or about 50% more than the global average over the same period (ISAB 2007). The latest climate models project a warming of 0.1 ºC to 0.6 ºC per decade over the next century. Over the next 40 years, warmer air temperatures are projected to result in diminished snowpacks and a shift to more winter/spring rain and runoff, rather than snow that is stored until the spring/summer melt season. A smaller snowpack will lead to diminished earlier in the season, resulting in lower stream-flows in the June through September period. River flows in general, and peak river flows, are likely to increase during the winter due to more precipitation falling as rain rather than snow. Water temperatures are expected to rise, especially during the summer months when lower stream-flows co-occur with warmer air temperatures. As climate change progresses and stream temperatures warm, thermal refugia will be essential to the persistence of many salmonid populations (Mantua et al. 2009). Thermal refugia are important for providing salmon and steelhead with patches of suitable habitat while allowing them to undertake migrations through, or to make foraging forays into, areas with greater than optimal temperatures. To avoid waters above summer maximum temperatures, juvenile rearing may be increasingly found only in the confluence of colder tributaries or other areas of cold water refugia (Mantua et al. 2009).

These changes will not be spatially homogeneous across the entire Pacific Northwest. Low-lying areas are likely to be more affected. Climate change may have long-term effects that include, but are not limited to, depletion of cold water habitat, variation in quality and quantity of tributary rearing habitat, alterations to migration patterns, accelerated embryo development, premature emergence of fry, and increased competition among species (ISAB 2007). In the Snohomish River basin, higher than normal air temperatures have already been observed, leading to increased surface water warming. Along with a decline in summer precipitation, snowpacks are declining as winter precipitation falls as rain instead of snow, increasing flooding and extreme low summer flows (leDoux et al. 2017). Temperature will be a concern for the entire watershed, but temperatures are likely to be more problematic for salmonids in the mainstem Snohomish, as this river section is already generally warmer than the tributaries. Increased peak flows and decreased summer base flows could also contribute to increased sedimentation and stormwater runoff. These effects could result in increased pollutant concentrations that could negatively affect fish physiology and survival. The persistence of cold water "refugia" within rivers and the diversity among salmon populations will be critical in helping salmon populations adapt to future climate conditions. Similar types of effects on salmon may occur in the marine ecosystem including warmer water temperatures, loss of coastal habitat due to sea level rise, ocean acidification, and changes in water quality and freshwater inputs (Mauger et al. 2015). Large-scale and local climate effects are implicated in food web disruptions such as changes in timing, duration, intensity (biomass and abundance), diversity, and species composition of phytoplankton and zooplankton blooms, ichthyoplankton prey abundances and densities for ocean-emigrating juvenile salmonids (Mauger et al. 2015). Although the majority of the Snohomish basin will be effected by higher winter flows and lower summer flows, the greatest effects will be observed in leveed reaches disconnected from their floodplains. Areas with a high proportion of levees include the lower Tolt and Raging Rivers, the lower Skykomish River, Snoqualmie at Fall City Reach, the Snoqualmie at Carnation Reach, the Snohomish River, middle Pilchuck River and lower Sultan River, which are expected to experience the largest impacts from the change in frequency and intensity of winter flows and these hydrologic changes will render even unleveed spawning reaches less hospitable to salmon (leDoux et al. 2017). The Snohomish basin has been characterized by low summer flow followed by peak flow events in the fall. Low flow prevents access to upstream and tributary habitats less prone to flooding and fish are forced to spawn in thalwegs that are disproportionately impacted by peak flows. This exacerbates redd scour and reduces productivity as the effective rearing area available to salmon is decreased. Productivity is decreased as salmon are forced to hold all summer in reduced flows and increased temperatures conditions where columnaris bacteria has been increasing (leDoux et al. 2017).

Productivity of salmon populations is expected to decline across life stages as climate change-induced hydrological changes become more severe, particularly low minimum summer flows as excessively high stream temperatures can be stressful or fatal to salmon (Mauger et al. 2015) and large peak flows during winter, which decrease juvenile production due to redd scour (Blum et al. 2018). Sea level rise due to climate change will inundate tidal wetlands and estuaries along the U.S. West Coast. These are especially important as rearing habitats for many fish species including juvenile Chinook salmon. Overall productivity is projected to decline as 68% of Washington tidal wetlands are expected to be submerged (Thorne et al. 2018). Increased stream temperatures will increase metabolic rates in salmon requiring increased food availability (Myrvold and Kennedy 2018). However, an overall reduction in prey availability in the Snohomish watershed will occur as beach-spawning forage fish species important for Puget Sound Chinook salmon, including Pacific sand lance and surf smelt, are impacted by narrower beaches and less available spawning habitat due to current and continued sea level rise (NWIFC 2020).

Habitat preservation and restoration actions can help mitigate the adverse impacts of climate change on salmonids. For example, restoring connections to historical floodplains and freshwater and estuarine habitats would provide fish refugia and areas to store excess floodwaters (Battin et al. 2007; ISAB 2007). For the Snohomish River basin, actions that could help mitigate climate change effects include protecting cold water refugia and restoring riparian buffers to moderate temperature effects, reducing sediment inputs, and minimizing erosion. Harvest and hatchery actions can respond to changing conditions associated with climate change by incorporating greater uncertainty in assumptions about environmental conditions, and conservative assumptions about salmon survival, in setting management and program objectives and in determining rearing and release strategies (Beer and Anderson 2013).

2.4.2. Fisheries

Hatchery-origin Chinook salmon produced through the WDFW and Tulalip Tribal programs are subject to directed harvest in terminal area net fisheries in marine waters, and recreational fisheries in marine waters, the Snohomish River, and the Skykomish River. The Tulalip Tribal fisheries that occur within Tulalip Bay, an extreme terminal fishing area referred to as the Area 8D commercial catch reporting area, and the recreational fisheries that occur in the Tulalip Bay fishery" at the head if Tulalip Bay, are the primary terminal area marine fisheries where hatchery-origin Chinook salmon produced through the Tulalip Hatchery program are harvested, with annual average harvests of 3,866 fish in tribal net fisheries (2008-2018) and 844 in recreational fisheries (1994-2017) (unpublished catch record data). There is currently no fishery (tribal, commercial or recreational) that targets natural-origin Skykomish or Snoqualmie Chinook salmon. However, natural-origin Chinook salmon from the two populations are harvested (limited to certain time, gear, and area fisheries) or are impacted incidentally in fisheries directed at hatchery-origin Chinook and coho salmon. Harvest of basin-origin natural- and hatchery-origin Chinook salmon occurs in mixed stock marine fishing areas in U.S. and Canadian waters. Exploitation rates on Skykomish and Snoqualmie natural-origin populations were nearly 80 percent for brood years 1980 through 1985, contributing to the observed decline in numbers of fish returning to the spawning grounds (PSIT and WDFW 2010). However, harvest impacts on natural-origin Snohomish have been substantially reduced over the last few decades (PSC 2018).

Fishery impact modeling by the co-managers shows a declining trend in annual fishing year exploitation rate from 1983-2000, with highs averaging 70 percent in the 1980s (PSIT and WDFW 2010). Exploitation rates have stabilized since the late 1990s, averaging 21 percent between 1997 and 2016, with a low of 12 percent in 2013 and a high of 31 percent in 2000 (2018 FRAM validation runs). These impacts occur incidentally in terminal area fisheries targeting hatchery-origin Chinook and coho salmon, and in pre-terminal marine mixed-stock fishing areas. The goal of harvest management is to maintain rebuilding exploitation rates for the Snohomish low enough (22 percent) so that natural-origin Chinook salmon escape in increasing numbers to spawn in protected or restored habitat. Prior to the Tulalip Tribes' development of an extreme terminal area fishery targeting hatchery-origin fish, the Tribes' harvest was composed of 50-60 percent natural-origin Chinook salmon. The Tribes' combined natural-origin Chinook salmon harvest during the past 20 years in Areas 8A and 8D have averaged less than 6 percent (Tulalip Tribes, unpublished Chinook salmon harvest data).

Within the action area, Tulalip Tribal commercial, ceremonial and subsistence fisheries for primarily hatchery-origin salmon and steelhead occur seasonally in Everett Bay, Port Susan, Tulalip Bay, and in the lower Snohomish River, contingent on the availability of fish surplus to escapement needs. WDFW-managed non-tribal commercial fisheries in commercial harvest areas 8A and 8D target surplus returning coho, fall chum, and pink salmon. Between 2005 and 2018, annual tribal net fishery harvests of coho salmon in the analysis area averaged 35,700 while the non-tribal coho salmon harvest averaged 440 (TOCAS with LIFT query 08/05/2019). Between 2005 and 2018, odd-year tribal and all citizen net fishery harvests of pink salmon averaged 111,600 and 216,220, respectively. Between 2005 and 2018, annual tribal and all citizen net fishery harvests of fall-run chum salmon averaged 32,200 and 29,800, respectively.

Recreational salmon fisheries that harvest coho, pink, Chinook, and chum have occurred on the Snohomish, Skykomish, and Snoqualmie rivers with regulations that vary by time, area, and species contingent on the availability of fish surplus to escapement needs. Specific catches since 2000 are presented in Table 18.

Table 18. Annual recreational catch in the Snohomish Basin action area from 2000 through 2017 (Unpublished catch record data).

Species	**Snohomish**	**Skykomish**	**Snoqualmie**
Coho	3,594	1,347	267
Pink[1]	40,508	7,196	230
Chinook	1	237	1
Chum	199	440	12

[1] Pink salmon averages are for odd years only

Within the action area, Tulalip Tribal commercial, ceremonial and subsistence fisheries targeting primarily hatchery-origin steelhead occur seasonally in Everett Bay, Port Susan, Tulalip Bay, and in the lower Snohomish River, contingent on the availability of fish surplus to escapement needs. Non-Indian commercial fishing is closed to steelhead in all areas, although there is some incidental harvest mortality in salmon-directed fisheries. Adipose fin mark-selective recreational fisheries for hatchery-origin salmon and steelhead managed by WDFW occur in the Snohomish River, Snoqualmie River, Skykomish River, and select tributaries. Between 2005 and 2018, annual tribal and non-Indian fishery harvests of non-listed early winter steelhead (EWS) in the analysis area averaged 27 and 43,541 fish, respectively. During this same period, recreational fishery harvests of non-listed Columbia River-origin Skamania early summer steelhead (ESS) averaged 2,398 fish per year (WDFW 2018). These fisheries remain as described in the 2017 BiOp and are evaluated in separate Biological Opinions (NMFS 2019a; NMFS 2020).

2.4.3. Hatcheries

Salmon and steelhead have been produced in Puget Sound hatcheries since the late 1800s. The benefit of hatcheries at the outset was to produce large numbers of fish for harvest purposes. Hatcheries have contributed 70 to 80 percent of the catch in Puget Sound and coastal salmon and steelhead fisheries. As salmon habitat was degraded by human development and activities such as dams, forest practices, and urbanization, the role of hatcheries shifted toward mitigation for lost natural production and reduced harvest opportunity. Hatchery fish have been affirmed as essential to fulfilling treaty rights and hatchery programs have largely served a mitigating function since their beginning in 1895 (US District Court, Western District of Washington, 506 F. Supp. at 198, W.D. Wash. 1980). In recent decades, the hatcheries and associated hatchery practices have evolved to support conservation and recovery of natural-origin salmon populations by preserving important genetic resources, reintroducing fish to under-utilized areas or habitats where local populations have been lost, and to guard against the catastrophic loss of naturally spawning populations at critically low abundance and productivity levels and truncated spatial distribution. Most existing state, tribal, and federal hatchery programs in Washington State with conservation and harvest augmentation objectives were originated and are currently operated to mitigate for natural production lost to impaired and declining habitat capacity and function, as well as past fisheries management practices that led to the historic decline of natural salmonid populations.

The Snohomish salmon hatchery programs were initiated because habitat in the Snohomish basin had become degraded to the degree that it could no longer provide sufficient fish for harvest. WDFW's Wallace River Hatchery summer Chinook salmon hatchery program was initiated in 1972, and the Tulalip Bay Hatchery program propagating summer-run Chinook salmon stock transferred from the WDFW hatchery commenced in 1998. Coho salmon have been released from Wallace River Hatchery since the 1920s, and releases of the species from Tulalip Hatchery began in 1981. A non-native stock-origin fall chum salmon program using stock transferred from Hood Canal and deep South Puget Sound was initiated through fry releases in Tulalip Bay beginning in 1976. Located near the mouth of the Snohomish River in the Port of Everett Marina (Port Gardner Bay), the Everett Bay Net-Pen coho salmon program was initiated in 2001 to provide recreational fishing opportunity in the Everett Bay area.

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 Skykomish and Snoqualmie river basins (WDFW 2014). During the 1960s, advances in hatchery cultural techniques led to further development of the Chambers Creek (aka "Early Winter" steelhead or "EWS") hatchery-origin stock through broodstock selection and accelerated rearing practices (Crawford 1979). The earliest maturing adult steelhead were selected in order to produce fish that smolted at one year of age, rather than, at age-2 or older as normally occurs in the wild (WDFW 2005). The Snohomish basin programs began collecting hatchery broodstock in the early-1960s (WDFW 2014). From the late-1970s to late-1990s, the Snohomish River basin EWS released at all sites in the basin were propagated from adult returns to Tokul Creek (and Whitehorse Ponds when insufficient broodstock was available). Prior to 1994, eggs collected at Tokul Creek were incubated to the eyed stage on-site and transferred to Lakewood Hatchery for further incubation, rearing, and mass-marking subsequent to dispersal of juvenile EWS for rearing and release in other Puget Sound areas, including the Snohomish Basin. The current goal for the Snohomish River basin EWS program is to manage the two programs separately. Beginning in 2015, broodstock for the Wallace/Reiter EWS program have been maintained primarily through collection of adults returning to Wallace River Hatchery and Reiter Ponds, while eggs collected for the Tokul Creek program are provided through collection of adults returning to Tokul Creek.

The Wallace River Hatchery Chinook salmon program has likely affected the diversity, spatial structure, and productivity of the Chinook salmon natural population. First or subsequent generation hatchery Chinook salmon are known to spawn in the Snohomish River watershed and it is reasonable to expect that spawning by these fish has had some effect on the genetic diversity and fitness of the aggregate Skykomish natural population and on the Snoqualmie natural population. Best management practices have been implemented for broodstock collection, selection, mating, rearing, and juvenile release strategies to limit demographic (e.g., mining), genetic and ecological effects on both of the Chinook salmon natural populations in the Snohomish watershed. In the Wallace River, Chinook salmon have been passed upstream of the Wallace River weir to seed natural habitat with naturally-spawning fish, and migration and blockage effects that the existing May Creek and Wallace River weirs have do not significantly impact spatial distribution or spawner abundances.

Genetic data for Puget Sound steelhead that reflect the patterns of genetic diversity among Puget Sound steelhead populations before the EWS programs began are not available (NMFS 2016a). It is possible that these patterns have been altered by returning EWS spawning in the wild with naturally-produced winter steelhead, but the cumulative impact of the EWS programs on genetic diversity and fitness is unknown. The early summer steelhead (ESS) stock propagated at Reiter Ponds (1974 to present) was derived from mixed Skykomish- and Skamania-origin summer steelhead (Crawford 1979). The production and release of ESS into the Snohomish basin may have potentially affected the abundance, diversity, spatial structure, and productivity of natural winter and summer steelhead populations (NMFS 2016a). Recent WDFW research involving more samples and incorporating more accurate assumptions about the origins of the Reiter Ponds hatchery stock indicate that the South Fork Skykomish population is of Skykomish origin (Warheit et al. 2021).

The six salmon hatchery programs, two non-listed, early winter steelhead hatchery programs, and one summer-run hatchery program operating within the action area, may have adversely affected listed Chinook salmon and steelhead through ecological effects, including predation on emigrating and rearing juvenile Chinook salmon by hatchery yearling Chinook and coho salmon, and steelhead in the Skykomish, Snoqualmie, and Snohomish rivers, downstream of release locations (e.g., Wallace River Hatchery, Tokul Creek Hatchery, and the Reiter Ponds facility) (NMFS 2016a). The timing of hatchery yearling releases has coincided with the out-migration timing of natural-origin Chinook salmon of an average size vulnerable to predation; however, the length of temporal overlap between natural-origin Chinook fry and rapidly outmigrating yearling hatchery smolts is relatively brief. The magnitude of predation effects is unknown. Natural-origin juvenile steelhead of sizes vulnerable to predation by the hatchery yearlings emerge from redds later in the season, and are unlikely to be encountered or preyed upon. Sub-yearling Chinook salmon produced through the Wallace River Hatchery program have been released in May or June, after the majority of natural-origin Chinook salmon have emigrated seaward. Minimal predation effects have likely occurred as a result of sub-yearling hatchery Chinook salmon releases. None of the hatchery-origin species produced in the action area are likely to have competed with natural-origin Chinook salmon and steelhead at substantial levels for food or space. All hatchery salmon and steelhead are released as smolts that will quickly emigrate seaward. For these reasons, the duration of, and opportunities for, interactions that would lead to competition with ESA-listed juvenile fish have been limited.

Wallace River Hatchery facility operations may have adversely affected the viability status of natural-origin salmon and steelhead populations in the action area. A full river-spanning weir has been operated at the Wallace River Hatchery on the mainstem Wallace River and in May Creek. The weirs seasonally block Chinook salmon access to upstream spawning areas. The May Creek weir has blocked salmonid access to upstream areas during summer and fall for several decades to enable the withdrawal of water for use in the Wallace River Hatchery, as well as to capture potential broodstock. There is limited habitat above the weir at May Creek and May Creek is no longer in its original stream channel as it has been diverted over a mile to its present location and the habitat associated with the original stream channel has been blocked by the railroad and highway and lost to human development.

Hatchery production in the Snohomish River basin watershed has remained the same as that analyzed in the 2017 BiOp,[4] which determined that those hatchery production levels do not appreciably reduce the likelihood of survival and recovery of these ESA-listed ESUs and DPSs. Since the 2017 BiOp was completed, the Biological Opinions analyzing the effects of the Green-Duwamish River basin and the Stillaguamish River basin hatcheries have been completed. Chinook salmon produced as part of these recently permitted programs escape to the Snohomish River basin as shown in Table 19 and Table 20. Chinook salmon produced by out-of-basin programs that successfully spawn in the Skykomish and Snoqualmie natural spawning areas could potentially reduce the genetic variation of these populations. Ongoing genetic sampling is proposed dependent on funding to detect genetic changes due to spawners produced by out-of-basin programs. We expect these impacts to continue in the same manner during implementation of the proposed action.

[4] Because this is a reinitiation of the prior action from the 2017 opinion with some changes, the effects of hatchery operations analyzed in that opinion are included in the environmental baseline to the extent those effects have occurred already. However, the effects which would result from the proposed action are not in the baseline, and those effects will essentially replace the future effects of the action as described in the 2017 opinion. In the effects analysis contained in this Opinion (Section 2.5), we discuss and in some cases compare the effects from the 2017 action to the proposed action. However, we wish to clarify here that NMFS considers all effects of the proposed action – not just the effects of the changes since 2017 – to be effects attributable in this Opinion to the proposed action.

Table 19. Estimated annual escapement to Chinook salmon spawning grounds in the Skykomish River by Chinook salmon produced by hatchery programs outside of the Snohomish River Basin. These returns were estimated using CWT and otolith data provided by WDFW and Tulalip Tribes based on the releases reported or proposed by the operators of each facility.

Hatchery Program	Release Number Evaluated	Estimated Escapement
Marblemount Hatchery Spring Sub-yearlings	587,500	0.5
Grovers Creek Hatchery Sub-yearlings	500,000	0.8
White River Hatchery Subyearlings	1,640,000	2.1
Marblemount Hatchery Summer Sub-yearlings	200,000	2.5
Marblemount Hatchery Fall Sub-yearlings* (projected escapement)	450,000	6.5
Whitehorse Rearing Ponds Sub-yearlings	220,000	6.7
Soos Creek Hatchery Sub-yearlings	6,800,000	193.8

*This program is proposed but not yet releasing fish. The escapement to the Skykomish River was based on data from past releases of this stock from this facility.

Table 20. Estimated annual escapement to Chinook salmon spawning grounds in the Snoqualmie River by Chinook salmon produced by hatchery programs outside of the Snohomish River Basin. Returns were projected using CWT and otolith data provided by WDFW and Tulalip Tribes. Release numbers are releases reported or proposed by the operators of each facility.

Hatchery Program	Release Number Evaluated	Estimated Escapement
Marblemount Hatchery Spring Sub-yearlings	200,000	2
Elwha Hatchery Yearlings	200,000	2
Grovers Creek Hatchery Sub-yearlings	500,000	4
White River Hatchery Subyearlings	1,640,000	6
George Adams Hatchery Sub-yearlings	3,800,000	6
Voights Creek Hatchery Sub-yearlings	1,600,000	19
Samish Hatchery Sub-yearlings	6,000,000	25
Whitehorse Rearing Ponds Sub-yearlings	220,000	45
Soos Creek Hatchery Sub-yearlings	6,800,000	164

2.5. Integration of "All H" Environmental Baseline Factors

As stated in 2.3.5 of the 2017 BiOp, consistent with Tulalip Tribe's government-to-government salmon resource management standing with the U.S. federal government through the Treaty of Point Elliot, this opinion will take into account an "All H" approach developed by the Tulalip Tribes for implementing Puget Sound basin salmon recovery plans, including the plan for WRIA 7 and the habitat, harvest, and hatchery actions included therein (SSPS 2005a). This recovery plan implementation approach - the "Snohomish Chinook Recovery Plan: Phases of Recovery and Integrated Adaptive Management Strategy" (Rawson and Crewson 2017) - harmonizes habitat actions, such as those described above, with hatchery and harvest salmon recovery actions and regulatory processes. Through the approach, a framework is applied within which "All H" actions and processes can be considered and evaluated jointly and concurrently. Emphasized in the approach is that recovery of ESA-listed Chinook salmon and steelhead will require significant management actions in all of the respective "Hs" - habitat, hydropower, harvest, and hatcheries - to recover listed fish species to a viable status.

The underlying scientific basis for this approach is that the design and execution of corrective actions is key to the conservation of species. Habitat, hydropower, harvest and hatchery management actions must be tailored to the conditions and limiting factors affecting the ESA-listed species in the watershed and then coordinated for maximum effectiveness. This is because the outcome of recovery efforts to improve the status of salmon natural populations depends on the combined and cumulative effect of "All H" actions. For example, the degree to which fish habitat is protected and restored to properly functioning conditions bears on the status of listed salmon and steelhead natural population abundance, productivity, diversity and spatial distribution. The condition of habitat, and progress in restoring it, determines the short and long-term status of the populations that may be affected by hatchery actions, and therefore the magnitude of hatchery-related effects on population and ESU viability, and the effectiveness of hatchery management actions to lessen risks.

The tribal approach for recovery plan implementation and consideration of "All H" actions is included in the Environmental Baseline section of this opinion as government-to-government guidance for considering effects of the proposed salmon hatchery actions on ESA- listed species. As such, in making determinations about the standing of proposed action effects on natural Chinook salmon and steelhead populations and ESU viability and the need for any responsive changes in the actions, NMFS will weigh the effects of implementation of concurrent habitat, harvest, and hatchery management actions to support recovery of ESA-listed fish in the Snohomish River basin.

Implementation of recovery-aimed habitat actions in isolation has failed to stem the total decline in habitat extent and condition in Puget Sound watersheds, including the Snohomish River basin (Judge 2011). Based on available population status data (Haggerty 2020a; Rawson and Crewson 2017), ESA-listed Chinook salmon and steelhead in the action area remain at low population viability levels. The ESA-listed natural Chinook salmon populations in the watershed have not progressed beyond what is described in the tribal approach as the "preservation" stage (Snoqualmie Chinook salmon) or the initial phase of the "recolonization" stage (Skykomish Chinook salmon), considering their current and recent past low viability status, and the poor to fair condition of habitat (Rawson and Crewson 2017). The current degraded condition of habitat is adversely affecting productivity for the two Chinook salmon natural populations assigned to be within these recovery stages. Productivity for the two populations continues to decline, with naturally spawning fish productivity for both the Skykomish River and Snoqualmie Chinook salmon natural populations exhibiting recruit per spawner levels substantially below the replacement level for all but two brood years over the most recent eleven brood years (Rawson and Crewson 2017). Natural steelhead populations in the watershed are also exhibiting productivity levels well below replacement (Section 2.2.2.1), with all assignable to the "preservation" phase of restoration under the tribal approach, considering the fair to poor status of habitat.

Restored habitat cannot be successfully colonized by Chinook salmon and steelhead populations that are not replacing themselves. Acknowledged is that more than a century of habitat degradation that has adversely affected ESA-listed fish species survival and productivity in the Snohomish River basin will not be reversed in just a few years. Over the long term, NMFS expects that the benefits of "All H" recovery actions will be gradually and eventually realized, if habitat essential for ESA-listed Chinook salmon and steelhead viability is protected and restored as envisioned in the watershed recovery plan, and more favorable marine survival conditions return.

Based on the environmental baseline, actions that maintain recoverability of the ESA-listed species should be implemented and coordinated with remediation of the primary limiting factors. NMFS evaluation of hatchery program effects on ESA-listed Chinook salmon and steelhead natural populations will take into account the condition of habitat in conjunction with natural fish population status to determine which management actions will be most effective in addressing hatchery-related limiting factors and threats. For the Snohomish basin, hatchery program management actions implemented in isolation are not expected to measurably help the listed salmon and steelhead populations recover to the "local adaptation" and "full restoration" phases defined in Rawson and Crewson (2017), and this Opinion does not assume any long-term beneficial changes. The "All H" recovery approach, largely focused on preserving and restoring fish habitat, is necessary to move the salmon and steelhead populations out of the initial phases of recovery.

2.6. Effects on ESA Protected Species and on Designated Critical Habitat

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

2.6.1. 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 2004b; NMFS 2005c; NMFS 2008b; 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 and then relates effects of the Proposed Action at the population scale to the MPG level and ultimately to the survival and recovery of an entire ESU or DPS.

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

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

Information that NMFS needs to analyze the effects of a hatchery program on ESA-listed species must be included in an HGMP. Draft HGMPs are reviewed by NMFS for their sufficiency before formal review and analysis of the Proposed Action can begin. Analysis of an HGMP or Proposed Action for its effects on ESA-listed species and on designated critical habitat depends on six factors[5]. These factors are:

(1) the hatchery program does or does not remove fish from the natural population and use them for hatchery broodstock

[5] Of note, seven factors were used in the 2017 BiOp. Factors 3 and 4 in the 2017 BiOp is now analyzed as one factor under Factor 3, with the subsequent factors remaining the same categories of analysis.

(2) hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds and encounters with natural-origin and hatchery fish at adult collection facilities

(3) hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas, migratory corridor, estuary, and ocean

(4) research, monitoring, and evaluation (RM&E) that exists because of the hatchery program

(5) the operation, maintenance, and construction of hatchery facilities that exist because of the hatchery program

(6) fisheries that exist because of the hatchery program, including terminal area fisheries intended to reduce the escapement of hatchery-origin fish to spawning grounds

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

2.6.2. Effects of the Proposed Action

This section discusses the effects of the proposed action on the ESA-listed species in the action area. With respect to the effects of the action on the natural-origin Puget Sound Chinook and steelhead populations in the Snohomish River basin, most of the effects remain the same as analyzed in the 2017 BiOp.

While the increased Chinook and coho salmon production may benefit SRKW diet, the degree to which SRKW would feed on this Chinook and coho salmon production is unknown. Therefore, in assessing the hatchery factors on natural-origin salmonids, we assume in this analysis that the hatchery fish would return to the Snohomish River watershed at a similar rate as in previous years.

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

The broodstock collection methods for the six programs considered in the 2017 BiOp will operate as previously discussed, and, therefore, the effects will be the same as those analyzed in the 2017 BiOp because the natural-origin broodstock collection intensity and magnitude will remain the same. To summarize, the 2017 BiOp found that there is a beneficial effect on Chinook salmon genetics and demographics because the Wallace River Hatchery Chinook Salmon program uses natural-origin Chinook salmon as broodstock to maintain the genetic diversity of the native population, while limiting the removal levels of returning natural-origin adults consistent with population needs. The 2017 BiOp also found that there are negligible effects on ESA-listed salmon and steelhead from broodstock collection of the Chinook, chum, and coho salmon because measures are applied to adequately safeguard direct and incidental encounters of listed species. The increased production will rely on collecting additional hatchery-origin Chinook salmon and using more of the hatchery-origin fish that volunteer to the Wallace River Hatchery rack. No additional natural-origin Chinook will be collected than the limit of 400 natural-origin adult Chinook salmon analyzed in the 2017 BiOp.

Consistent with the 2017 BiOp, the co-managers will continue to use their discretion in collecting NOR Chinook salmon to integrate into the broodstock in years when the stock is forecasted to be in critical status where the number of adults projected to escape to the Skykomish River natural spawning areas is below the Low Abundance Threshold (LAT). This recognizes that demographic concerns of maintaining a greater number of spawners is elevated over genetic concerns in years when low numbers of adults are expected to return to spawn. NMFS and the co-managers recognize there is some uncertainty in using forecasts or projected returns and when the run is projected to be close to the LAT, co-managers will use all available forecast information in deciding to collect natural-origin Chinook salmon. Due to the nature of run forecasts, there may be years when NOR Chinook salmon are collected when the run is actually below the LAT and vice versa. However, across years, this strategy of using the projected escapement to guide integration of NOR Chinook salmon will likely balance demographic and genetic affects.

Broodstock collection for the Wallace River Hatchery chum salmon program are expected to have negligible impact on ESA-listed salmon and steelhead. Hook-and-line broodstock collection for chum salmon will take place during the times and areas where the Skykomish River is already open to steelhead fishing and where angler volunteers can legally keep captured salmon. Barbless hooks will be used and large gear size will be utilized and fished in a manner to avoid capture of steelhead and ensure any incidentally caught fish can be released unharmed. Since Wallace River Hatchery traps are operated at the same time as adult chum broodstock collections, no additional trapping or broodstock collection operations at the hatchery will be required to facilitate chum broodstock collections and no additional fish take will occur. Care will be taken to ensure the natural run timing is represented in the broodstock that are collected. Unmarked steelhead do not recruit into the hatchery in large numbers. In-river seining for chum broodstock is unlikely to intercept Chinook due to differences in run timing between the two species. The Chinook salmon run is subsided by October and Chinook salmon are not typically present in the sloughs where chum salmon will be collected. Steelhead may be present and inadvertently intercepted, but the number of interactions is expected to be low (up to three fish). All fish captured will be handled in a safe manner and non-target fish will be released unharmed immediately upon capture. No significant delay or interruption in migration to other salmonids present in the collection area are anticipated from broodstock collection activities.

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

Genetic effects on Chinook salmon

The 2017 BiOp found that the Snohomish River basin Hatchery Chinook salmon programs have a potential to result in a negative effect on genetic diversity of Puget Sound Chinook salmon populations, including effects from within-population diversity reduction and hatchery-induced selection. Production will increase under the proposed action, which affects pHOS as discussed below, while measures identified to reduce risks to within-population diversity and measures identified to reduce hatchery-induced selection will continue to be implemented, as discussed in the 2017 BiOp. In addition, the co-managers will continue to collect genetic samples to monitor the genetic diversity status of the population and divergence between the hatchery-origin and natural-origin Chinook salmon when funding is available, as stated in the 2017 BiOp. These genetic samples may be used to detect genetic differences between hatchery- and natural-origin Chinook salmon. Previous sampling has shown Chinook salmon produced at Wallace River Hatchery are genetically indistinguishable from the Skykomish summer Chinook salmon population (Crewson et al. 2017).

The proportion of hatchery-origin fish on the spawning grounds does not necessarily equate to gene flow between hatchery- and natural-origin fish. PNI is an important surrogate indicator for evaluating genetic influence between hatchery and wild fish it is, however, an indirect estimate of gene flow based on estimates of the proportion of hatchery-origin fish on the spawning grounds (pHOS) and assumed gene flow between them and natural-origin fish in the natural environment. Genetic-based methods that measure the influence of genetically-effective breeders through genetic sampling and laboratory analyses are the most accurate method of assessing gene flow from the hatchery population to the natural population. Estimating gene flow generally uses proportions of hatchery fish on the spawning grounds determined from carcass recoveries to estimate pHOS, which do not necessarily reflect gene flow from successful spawners. DNA-based parentage assignment provides for more direct estimates of gene flow using only genetically-successful spawners by origin, time, and location and is a more direct assessment of gene flow that includes an estimate of variation.

Marine survival (smolt-to-adult escapement “SAE”) has been observed to fluctuate by as much as 4- to 16-fold in recent years for Wallace River Hatchery Chinook. Generally, yearling SAE rates have averaged four times higher than subyearling rates; however, so has their variability, which has also fluctuated four times more than sub-yearlings for broodyears since 2000. Recent Wallace River Hatchery subyearling Chinook SAE rates (reconstructed from coded-wire tag recoveries for broodyears 2000-2011) have been low, averaging only 0.23 percent and ranged more than four-fold (min. 0.11 percent to max. 0.51 percent) during this period. Yearling SAE rates (available for broodyears 2002-2008 and 2010) were considerably higher than those observed for subyearlings, averaging 0.93 percent (~4X higher survival on average), but also exhibited more than four times the variability (as much as 15-fold, from a minimum rate of 0.14 percent to a maximum of 2.09 percent).

Reductions in adult Chinook holding survival at Wallace River Hatchery, caused by increasing surface water temperatures, have been observed to fluctuate by more than double in recent years, caused by extremely low summertime flows and abnormally high water temperatures. This has occurred primarily in the May Creek adult holding pond which is strongly influenced by variation in summertime flows.

While the co-managers have less control over marine survival, they are currently undertaking incremental water supply facilities improvements at Wallace River and Tulalip Hatcheries to significantly improve in-hatchery survival to compensate for these recent fluctuations and have tailored the proposed production levels to transition from Phase 1 to Phase 2 as facility improvements provide the capability to rear up to 750,000 yearlings.

During Phase 1, before hatchery infrastructure and water supply improvements can be made in subsequent years that are expected to afford optimal adult and yearling Chinook survival, the extant warm, untreated surface water supply available during warm summer months is assumed to continue to constrain adult female summer Chinook holding survival, which has averaged 70.3 percent from 2002-2019. Yearling production is also constrained by existing rearing facilities, summer low flows, and warm water temperatures; however, sub-yearling production can be released before summertime flows and temperatures become limiting. Therefore, the Phase 1 production levels proposed are 600,000 yearlings and up to 2.2M sub-yearlings as on-station release goals at Wallace River Hatchery. Tulalip Hatchery production under Phase 1 and Phase 2 is 4.4M.

Leading up to the Phase 2 production levels of 750,000 yearlings and 1.2M sub-yearlings at Wallace River Hatchery, increased production of yearling Chinook is phased in, which get four times the survival of the sub-yearlings on average, while sub-yearling Chinook production is reduced to increase PNI_D, reduce pHOS, and the numbers of broodstock needed to still achieve the co-manager's production goals as modeled for both phases (Table 2). This transition will be accomplished through incremental improvements in yearling and adult Chinook broodstock holding conditions and water supplies mainly at Wallace River Hatchery, but also at Tulalip Hatchery.

As production is increased under the proposed action, pHOS will increase as more Chinook salmon produced as part of the Wallace River and Tulalip Hatchery programs escape to natural spawning areas in the Skykomish and Snoqualmie Rivers as shown in Table 15 and Table 16. As shown in Table 16, the greatest contribution to pHOS will remain that from programs outside the Snohomish basin that are considered in the consultations for those programs. The Chinook salmon production increases at Wallace River and Tulalip Hatcheries are estimated to have a minor effect on pHOS in the Snoqualmie River of approximately four percent.

The pHOS estimates presented here are based on demographic data from sampling carcasses to recover tags or marks. Genetic pHOS is likely to be much lower due to lack of reproductive success of hatchery fish reaching natural spawning areas or to hatchery fish spawning in lower quality habitat than natural-origin fish. The co-managers have conducted research showing that is the case in the Snohomish basin (Crewson et al. 2017). Hatchery-origin Chinook salmon produced fewer out-migrating juveniles than natural-origin fish. Hatchery- and natural-origin fish interacted less than expected based on demographic information that reflected geographic separation due to hatchery-origin fish spawning in different locations than natural-origin fish. The lower productivity of hatchery-origin Chinook salmon was likely due to spawning in poorer habitats. In particular, the co-managers identified Chinook salmon spawning in the Wallace River as having lower reproductive success, regardless of hatchery or natural origin, than Chinook sampled from the rest of the Snohomish basin, which suggested their spawning success was more likely due to the poor quality spawning conditions in the Wallace River than their status as hatchery- or natural-origin. For this reason, NMFS does not include the hatchery-origin fish spawning in the Wallace River when calculating $pHOS_D$. $pHOS_D$ including and excluding the Wallace River is reported in Table 15 but only the $pHOS_D$ estimates excluding the Wallace River are used in the analysis consistent with the 2017 BiOp.

Although the proposed action increases $pHOS_D$, the co-managers have proposed a targeted integration strategy where NOR broodstock are primarily used to create a sub-set of the yearling production as shown in Table 4. These yearlings are expected to return to the hatchery at higher rates than sub-yearlings. Implementing this integration strategy is projected to result in PNI_D remaining at a similar rate as currently observed while production is increased in Phase 1 and then it is modeled to increase during phase two. Maintaining a PNI_D over 50 percent is expected to allow selection in the natural river environment to supersede selective forces over selection in the hatchery environment. If escapement is below the LAT, then it is unlikely that Chinook salmon will be collected at the Sunset Falls Fishway. NORs used for broodstock would be those that volunteer to the Wallace River Hatchery and May Creek traps, which would be prioritized to create the highly integrated yearling component augmented with highly integrated fish returning to the hatchery. It is expected that PNI will be between 0.25 and 0.50 when escapement is below the LAT as any NOR volunteers will be used to create the highly integrated yearling group (Haggerty 2021).

Table 21. Estimated number of natural- and hatchery-origin Chinook salmon spawners in the Skykomish population and resulting estimated $pHOS_D$ and PNI_D. Sky-Wallace $pHOS_D$ and PNI_D are the surrogate genetic metrics calculated excluding the hatchery fish that spawn in the Wallace River. The analysis was conducted with the proposed Chinook salmon production as well as the proposed production with a 10 percent overage to account for normal production fluctuations.

Production Phase	Sky NOS	Sky HOS	Sky Total	Sky $pHOS_D$	Sky-Wallace $pHOS_D$	Sky PNI_D	Sky-Wallace PNI_D	pNOB
Current Production	2,136	1,084	3,220	33.7%	23.8%	55.6%	56.0%	25.8%
Phase 1	2,131	1,737	3,868	44.9%	33.3%	56.0%	56.3%	82.7%
Phase 2 (16% holding mortality)	2,133	1,505	3,638	41.4%	30.2%	60.3%	60.6%	87.4%
Phase 2 (12% holding mortality)	2,133	1,505	3,638	41.4%	30.2%	60.5%	60.7%	86.9%
Phase 2 (8% holding mortality)	2,133	1,505	3,638	41.4%	30.2%	60.7%	61.0%	86.9%
	With 10% overage							
Phase 1	2,129	1,911	4,040	47.3%	35.4%	53.8%	54.0%	78.6%
Phase 2 (16% holding mortality)	2,132	1,656	3,788	43.7%	32.3%	58.1%	58.4%	85.0%
Phase 2 (12% holding mortality)	2,132	1,656	3,788	43.7%	32.3%	58.4%	58.7%	85.5%
Phase 2 (8% holding mortality)	2,132	1,656	3,788	43.7%	32.3%	58.7%	58.9%	85.5%

Table 22. Estimated number of natural- and hatchery-origin Chinook salmon spawners in the Snoqualmie population and resulting estimated total $pHOS_D$ and $pHOS_D$ projected from the Snohomish basin hatchery Chinook salmon production alternatives. The analysis was conducted with the proposed Chinook salmon production as well as the proposed production with a 10 percent overage to account for production fluctuations.

Production Phase	Snoqualmie NOS	Snoqualmie HOS	Snoqualmie Total	Snoqualmie $pHOS_D$	$pHOS_D$ from Snohomish hatcheries production
Current	901	341	1,242	27.5%	7.0%
Phase 1	901	384	1,285	29.9%	11.0%
Phase 2	901	383	1,284	29.8%	10.9%
With 10 percent overage					
Phase 1	901	393	1,294	30.4%	11.8%
Phase 2	901	392	1,293	30.3%	11.7%

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

Hatchery release competition and predation effects

The 2017 BiOp concluded that hatchery-origin juvenile Chinook salmon (both subyearling and yearling) and coho salmon could potentially have ecological interactions with natural-origin juvenile Chinook salmon and steelhead if there was spatial and temporal overlap in the Snohomish River basin. However, the co-managers have included measures designed to minimize competition and predation risks, such as monitoring for release timing to minimize temporal overlap with natural-origin juvenile fish, so these risks are likely negligible. All fish would continue to be released in healthy condition as seawater-ready, migrating smolts to ensure rapid emigration downstream through watershed areas where interactions with rearing listed fish may occur. The proposed changes considered here could potentially increase ecological effects as the early release group will overlap temporally with emigrating natural origin Chinook salmon and the late Chinook salmon release group could overlap temporally with 0-age steelhead. The majority of the increased Chinook salmon production will occur at Tulalip Hatchery which releases juveniles into Tulalip Bay so would not contribute to predation or competition risks to ESA-listed fish in freshwater areas within the action area.

The current release of 150k coho from Wallace River Hatchery constitutes 9.0 percent of the average number of Snohomish coho migrants (150k Wallace, 60k Eagle Creek, and 1.462M estimated wild coho emigrants). The proposed increased coho release of 300k would increase the proportion of coho from Wallace River Hatchery by 7.4 percent so Wallace River Hatchery coho would constitute 16.4 percent of the total emigrating coho. Travel rates for coho released from Wallace River Hatchery have been observed to range from 3.9 miles/day to 14.3 miles/day; averaging 10.2 miles/day. These data indicate that the majority of fish rapidly migrate downstream past the smolt trap in most years. In addition, it was estimated that on average, 41 percent of fish had migrated past the smolt trap during the ongoing volitional release period, which ranged from one to eight days depending upon the year. On average, within 7-, 14-, and 21-days post release, 88.9 percent, 91.1 percent, and 92.8 percent of the released fish moved downstream past the trap, respectively. NMFS does not expect a detectable impact to ESA listed Chinook salmon or steelhead in the Snohomish basin due to increased coho releases as the proportion of coho originating from these programs will remain low and migrate quickly downstream.

Naturally-produced progeny competition

Naturally spawning hatchery-origin salmon and steelhead are likely to be less efficient at reproduction than their natural-origin counterparts (Crewson et al. 2017; Ford et al. 2009; Williamson et al. 2010), but the progeny of such hatchery-origin spawners could potentially make up a sizable portion of the juvenile fish population for those areas where hatchery-origin fish are allowed to spawn naturally. This is actually a desired result of the integrated recovery programs such as the Wallace River Chinook and chum salmon programs considered here. Therefore, the only expected effect of this added production is a density-dependent response of decreasing growth and increased competition/predation as habitat capacity is approached, as would be expected to occur in any system. However, NMFS expects that the monitoring efforts via juvenile screw trapping and the proposed estuary, nearshore and offshore marine monitoring program would detect negative impacts before they reach problematic levels, or identify other key factors that affect growth and survival of natural- and hatchery-origin fish.

Data provided by the co-managers for coho released from the Tulalip and Wallace River Hatcheries and subsequently sampled on the spawning grounds upon their return do not indicate they have contributed substantially to natural spawning aggregations in the Snohomish basin. Previous scale pattern analyses suggested that roughly one percent of approximately 1,000 adult coho sampled from the Sunset Falls fish trap on the South Fork Skykomish River were thought to be of hatchery-origin (WDFW 2013a). Data collected from spawning ground surveys conducted from 2016 to 2019 indicate approximately five percent of hatchery coho escape to natural spawning areas in the Snohomish basin, which is less than one percent of the natural coho spawning population. Given that, it is estimated the hatchery adult coho escapement to natural spawning areas in the Snohomish basin from the proposed production increases at Wallace River Hatchery and the Everett Bay net-pen program would double from 0.33 percent to 0.67 percent (Haggerty 2020c). These estimates made using the available data indicate that escapement of adult hatchery coho is low and doubling production at Wallace and the Everett Net-Pens is unlikely to increase escapement to a level when competition between natural-origin coho and naturally-produced juvenile progeny of hatchery-origin coho spawners is of concern.

Disease

The risk of pathogen transmission to natural-origin salmon and steelhead will continue to be negligible for these hatchery programs as production is increased. Implementation of management practices specified in the co-managers' fish health policy for monitoring the health of fish in hatcheries would reduce the likelihood of disease transmission from Snohomish River basin hatchery salmon to natural populations of salmon and steelhead. When implemented, these practices would effectively contain fish disease outbreaks in the hatcheries, minimize the release of infected fish from hatcheries, and reduce the risks of disease transfer and amplification to natural populations (NMFS 2012). Protocols described in the policy and applied through the programs would help reduce risks of fish disease to propagated and natural fish populations through regular fish health monitoring and reporting, and application of management practices to reduce fish health risks. Reporting and control of specific fish pathogens will continue to be conducted in accordance with the Salmonid Disease Control Policy of the Fisheries Co-managers of Washington State (WDFW and NWIFC 1998).

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

Juvenile outmigrant trapping associated with these programs was analyzed and determined not to result in a decrease in the likelihood of survival and recovery of the listed species in NMFS (2018a) and in NMFS (2017). Other activities, such as direct observation and carcass surveys, remain the same as analyzed in the 2017 BiOp and are expected to cause avoidance behaviors that are within the range of normal predator and disturbance behaviors.

The proposed estuary and nearshore marine monitoring program would collect up to 900 juvenile Chinook salmon annually. Assuming a smolt-to-adult escapement (SAE) survival rate of 0.42 percent (calculated for broodyears 2008-2014), this would equate to approximately four adults annually. This reduction in adult escapement will not result in a detectable effect to the Snohomish Chinook salmon populations, but the information gained through the research project may be beneficial in managing the hatchery programs to moderate effects to natural populations, or to gain a better understanding on limiting factors affecting the marine survival of natural- and hatchery-origin fish.

Based on data collected from 2001 through 2019 for a similar estuary monitoring program conducted in this area (NMFS 2016b), the number of natural-origin steelhead collected annually ranged from 0 to 74 and the number of hatchery-origin steelhead collected annually ranged from 0 to 13. During this time, the average annual incidental natural-origin steelhead catch was 12 fish and the average annual incidental hatchery-origin steelhead catch was 3 fish (Robinson and Zackey 2020). We expect the number of steelhead encountered during the proposed research will be similar as the area the research is being conducted in and the collection methods are very similar to previous studies. Any steelhead encountered under the proposed increased estuary and nearshore marine monitoring would be released unharmed as soon as possible. This low projected number of steelhead encounters will not have a detectable effect on the Snohomish steelhead populations.

The co-managers will include information about the results of the estuary monitoring efforts in their annual reports and will specify the number of juvenile Chinook salmon sampled as well as the number of incidental steelhead encountered.

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

The 2017 BiOp noted that the water intake structures at Wallace River Hatchery and May Creek do not meet NMFS intake screening criteria. WDFW has been allocated funding to update the intake screens at Wallace River Hatchery and May Creek and this work could be completed as soon as 2023. As there have been no fish mortality because of the current water intake structures that are scheduled to be modified, NMFS considers the Wallace River Hatchery intake structure to pose unsubstantial risks to fish passage, as discussed within the 2017 BiOp. In addition, the current intake screens at Wallace River Hatchery and May Creek meet earlier screening criteria (NMFS 1997), which is adequately protective of listed Chinook salmon and steelhead from impingement and entrainment effects until the structures are renovated (NMFS 2008a; NMFS 2011a).

Improvements in Wallace River Hatchery operations and facilities that will be initiated in 2020 are anticipated to be completed as early as 2023. These improvements will include updating the intake screens to become compliant with the most recent screening requirements (NMFS 2011a). Operational improvements that will be initiated in 2020 include monthly adult fish transfers from the May Creek earthen adult return pond to concrete raceways supplied with the more abundant and cooler Wallace River water where it is possible to administer chemotherapeutic treatments during and after handling as warranted. Further improvements to water supply will follow with development of an existing well planned for 2020-2021 (contingent on permitting). Additional improvements scheduled for Wallace River Hatchery include installation of a water re-use and disinfection system on the Wallace River side of the hatchery that is funded and in the design development phase, to be completed as early as 2023. A capital improvement-funding request has been submitted for the development of additional horizontal and vertical wells, which includes several horizontal wells parallel to or beneath the river and other options for vertical wells, e.g., well points or a series of vertical wells adjacent to the river, that could provide larger amount of cool, pathogen-free ground water to augment the existing surface water supply for holding adult and juveniles. Phase 2 can be fully implemented when improvements to the facility allow the successful rearing of the 750K highly integrated yearlings and adult holding survival can be increased through the water quality, flow and adult holding pond improvements. Achieving the production, conservation, and fishery objectives is dependent on facility improvements that provide increased space for rearing yearling Chinook salmon and improved survival of both juvenile and adult Chinook salmon. At Tulalip Hatchery, connection of four (4) new wells was added in 2020 to the existing hatchery well water supply (five wells total) and installation of a water re-use and disinfection system is currently funded, with construction to be completed as early as 2021, which will significantly increase water availability and quality.

The total amount of surface water used for the hatchery facilities is not thought to lead to any substantial effects on listed fish as the operators would be within their permitted ground and surface water permits. The increased production is covered under the operators' current NPDES permit and pollution abatement ponds will be utilized as described in the 2017 BiOp, so the discharge from increased salmon production is not likely to have additional effects on water quality beyond what was analyzed in the 2017 BiOp that found no detectable effects to listed species as a result of water quality.

All broodstock collection methods will remain the same as analyzed in the 2017 BiOp. Because Chinook and coho salmon broodstock are predominantly volunteers to the Wallace River Hatchery rack, and the facility is located off of the mainstem Skykomish River, the 2017 BiOp concluded that collection of broodstock would not substantially affect migration or spatial distribution of natural-origin juvenile and adult Chinook salmon and steelhead.

2.6.2.6. Factor 6. Fisheries that exist because of the hatchery programs

There are no fisheries that exist because of the Proposed Action. Fisheries in the action area are subject to consultation on an annual or multi-year basis, depending on the duration of the Puget Sound fishery management plan submitted by the co-managers. As described in Section 2.4.1, Environmental Baseline, the effects of all fisheries on ESA-listed species are expected to continue at similar levels to those described in the Environmental Baseline. NMFS (2020) concluded that the fisheries will not appreciably reduce the likelihood of survival and recovery for the listed species.

2.6.3. Effects of the Action on Critical Habitat

The proposed increase in the Snohomish salmon hatchery programs will not have additional effects on critical habitat than those described in the 2017 BiOp. 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. No new facilities or construction are directly proposed as part of the proposed actions considered in this opinion.

As discussed in the 2017 BiOp, permitted water withdrawal levels for fish rearing are usually a small fraction of average annual flows in freshwater areas where listed fish may be present, and water withdrawn for hatchery use is returned near the points of withdrawal. Hatchery diversion screens protect listed juvenile Chinook salmon and steelhead from entrainment and injury and are proposed for retrofitting to meet current NMFS screen criteria (See Section 2.5.2.5).

Compliance with NPDES permits issued for the programs would continue to help ensure that water quality in downstream areas where listed fish may be present is not degraded. Effluent discharge for the hatchery operations is not expected to degrade water quality. Consistent with effluent discharge permit requirements developed by the Environmental Protection Agency and the Washington Department of Ecology for upland fish hatcheries, water used for fish production at the Wallace River and Tulalip Hatcheries would be adequately treated prior to discharge into downstream areas to ensure that federal and state water quality standards for receiving waters are met and that downstream aquatic life, including salmon and steelhead, will be no more than minimally affected.

No hatchery maintenance activities are proposed in the HGMPs that would adversely modify designated critical habitat.

For these reasons, the proposed hatchery programs are not expected to pose substantial risks through water quality impairment to downstream aquatic life, including listed salmon and steelhead. No hatchery operation and maintenance activities are expected to adversely modify designated critical habitat or habitat proposed for critical designation.

2.7. Cumulative Effects

"Cumulative effects" are those effects of future state or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 CFR 402.02 and 402.17(a)). Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

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

The Federally approved Shared Strategy for Puget Sound Recovery Plan for Puget Sound Chinook Salmon (SSPS 2007) describes, in detail, the on-going and proposed state, tribal, and local government actions that are targeted to reduce known threats to listed Puget Sound Chinook salmon in the Snohomish River watershed. A recovery plan for Puget Sound steelhead in the watershed is currently in draft form (NMFS 2018b), but many of the actions implemented for Chinook salmon recovery will also benefit steelhead. Future tribal, state, and local government actions will likely be in the form of legislation, administrative rules, policy initiatives, and land use and other types of permits. Government and private actions may include changes in land and water uses, including ownership and intensity, which could affect listed species or their habitat. Government actions are subject to political, legislative and fiscal uncertainties.

Non-Federal actions are likely to continue affecting listed species. State, tribal, and local governments have developed plans and initiatives to benefit listed species (SSPS 2007). The cumulative effects of non-Federal actions in the action area are difficult to analyze because of the political variation in the action area, and the uncertainties associated with funding and implementation of government and private actions. However, we expect the activities identified in the baseline to continue at similar magnitudes and intensities as in the recent past.

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

With these improvements, however, based on the trends discussed above, there is also the potential for adverse cumulative effects associated with some non-Federal actions to increase such as urban development (Judge 2011). To help protect environmental resources from potential future development effects, Federal, state, and tribal laws, regulations, and policies are designed to conserve air, water, and land resources. A few examples include the Federal Navigable Waters regulations of the Clean Water Act, and in Washington State, various habitat conservation plans (HCPs) have been implemented, such as the Washington Department of Natural Resources (DNR) Forest Practices HCP (Washington Department of Natural Resources (DNR) 2005).

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

2.8. Integration and Synthesis

The Integration and Synthesis section is the final step in our assessment of the risk posed to species and critical habitat as a result of implementing the proposed action. In this section, we add the effects of the action (Section 2.5) to the environmental baseline (Section 2.4) and the cumulative effects (Section 2.6), taking into account the status of the species and critical habitat (Section 2.2), to formulate the agency’s biological opinion as to whether the proposed action is likely to: (1) reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing its numbers, reproduction, or distribution; or (2) appreciably diminish the value of designated or proposed critical habitat as a whole for the conservation of the species.

2.8.1. Puget Sound Chinook Salmon ESU

Best available information indicates that the Puget Sound Chinook Salmon ESU remains threatened (NWFSC 2015). Spawner abundance is currently depressed and productivity is below levels required for the Snohomish River populations to recover to self-sustaining conditions (Section 2.2). Our environmental baseline considers the effects of dams, habitat condition, fisheries, and hatcheries on Puget Sound Chinook Salmon. Although all may have contributed to the listing, 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., hatcheries serving as a genetic reserve for natural populations).

The majority of the effects of the Proposed Action on this ESU are genetic and ecological in nature, with small, localized effects from facility operation and RM&E essential for understanding the effects of the hatchery programs on natural-origin Chinook salmon populations.

Genetic effects on the Snohomish Chinook salmon populations are limited by the use of natural-origin broodstock, and an expected PNI of over 0.5 on average is achievable as the co-managers have proposed a two-phase integration plan. However, in years of low NOR abundance generally due to poor marine survival, the co-managers will not integrate NORs. Because the Snohomish River populations are two of 22 populations in the ESU, most populations are above critical thresholds, and the Proposed Action maintains a PNI over 50% while increasing production to support Tribal Treaty harvest and SRKW prey production, the Proposed Action is unlikely to have an adverse effect at the ESU level.

Chinook salmon from the hatchery programs considered here may escape to natural spawning grounds in the Snoqualmie River. The effects of this are unknown but are not likely to be detectable. Our dispersion analysis concluded that Chinook salmon from the Snohomish River basin hatchery programs contribute about 7% of the Chinook salmon spawning naturally in the Snoqualmie River. This could increase to 11% with the increased releases sizes described in the Proposed Action. NMFS anticipates that the co-managers will continue to monitor the contribution of fish from the Snohomish hatchery programs into the Snoqualmie. In the near term, we anticipate this level of pHOS to have only a small adverse effect on the Snoqualmie population diversity because we recognize that demographic (carcass-based) pHOS is likely an overestimate of genetic effects; peak spawning is temporally and spatially segregated between the two populations to a significant degree, and it is likely the two populations exchanged some number of migrants historically.

Ecological effects on the Puget Sound Chinook salmon ESU associated with hatchery program releases are likely to be small as the majority of fish from these hatchery programs are released directly into Tulalip Bay while others are released directly into marine areas as a part of net-pen programs. The majority of fish released from Wallace River Hatchery are released before natural-origin fish begin their migration. Any resulting decrease in adult abundance is likely to be small and at a level that is likely to have little effect on the ESU. The ESU is composed of 21 other populations in addition to the

Skykomish, and some of those populations are situated in basins that have more productive habitat than the Snohomish River. In addition, most Chinook salmon populations are above the critical threshold and are on their way to the rebuilding threshold.

Added to the Species' Status, Environmental Baseline, and effects of the Proposed Action are the effects of future state, private, or tribal activities, not involving Federal activities, within the Action Area. The recovery plan for this ESU describes the on-going and proposed state, tribal, and local government actions that are targeted to reduce known threats to ESA-listed Chinook salmon. Such actions include improving habitat conditions, and hatchery and harvest practices to protect natural-origin Chinook salmon, and NMFS expects this trend to continue, potentially leading to increases in abundance, productivity, spatial structure and diversity.

The Snohomish River basin has been impacted by loss of riparian forest cover and wetlands, barriers to fish passage, and the proliferation of exempt groundwater wells. Development in the area, which is right outside of Seattle, WA, is only likely to increase as the human population continues to grow. Despite these realities, the Chinook salmon population is still likely to achieve a PNI under the Proposed Action which will maintain genetic variation of the population while habitat improvement programs progress and more is learned about the effects of hatchery programs from the proposed RM&E. Because the proposed action is likely to maintain genetic diversity of the population, the Proposed Action will not appreciably reduce the likelihood of survival and recovery of the Puget Sound Chinook Salmon ESU.

2.8.2. Puget Sound Steelhead DPS

Best available information indicates that the Puget Sound Steelhead DPS remains threatened (NWFSC 2015). Spawner abundance is currently depressed, and population diversity, spatial structure, and productivity are also below desired levels required for the Snohomish River basin populations to recover to a self-sustaining condition (Section 2.2). Our Environmental Baseline considers the effects of hydropower, habitat, fisheries, and hatcheries. Although all may have contributed to the listing of the DPS, all factors have also seen improvements in the way they are managed and 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., hatcheries serving as a genetic reserve for natural populations).

None of the hatchery programs considered here target steelhead. The majority of the effects of the Proposed Action on this DPS are ecological in nature, with small, localized effects from facility operation and effects from RM&E essential for understanding the effects of the hatchery programs on natural-origin steelhead populations. Ecological effects on natural-origin juvenile steelhead associated with releases from the hatchery program are expected to be limited as the majority of fish from the programs considered here are released directly into Tulalip Bay marine areas, or at a time steelhead are not emigrating. With these localized effects expected to occur at such low levels, we do not expect them to cause detectable impacts to viability parameters of the DPS.

Added to the Species' Status, Environmental Baseline, and effects of the Proposed Action, are the effects of future state, private, or tribal activities, not involving Federal activities, within the Action

Area. The recovery plan for this DPS describes the on-going and proposed state, tribal, and local government actions that are targeted to reduce known threats to ESA-listed steelhead. Such actions include improving habitat conditions, and hatchery and harvest practices to protect listed steelhead DPSs, and NMFS expects this trend to continue, potentially leading to increases in abundance, productivity, spatial structure and diversity.

Habitat conditions for steelhead are the same as for Chinook salmon above; the anthropogenic and climate change impacts to the Snohomish River basin have reduced and degraded spawning and rearing habitat for anadromous species including Puget Sound steelhead. Development in the area, which is right outside of Seattle, Washington, is only likely to increase as the human population continues to grow. The steelhead populations in the Snohomish basin are five of 32 in the DPS, and any potential decreases in abundance and productivity due to the effects of the Proposed Action are insignificant when scaled up to the DPS level. Thus, our analysis leads NMFS to conclude, after considering all factors, that the Proposed Action will not appreciably reduce the likelihood of survival and recovery of the Puget Sound Steelhead DPS.

2.9. 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, the effects of other activities caused by the proposed action, and cumulative effects, it is NMFS' biological opinion that the proposed action is not likely to jeopardize the continued existence of Puget Sound Chinook salmon and Puget Sound steelhead or destroy or adversely modify their designated critical habitat.

2.10. Incidental Take Statement

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

Due to changes in the proposed action from the 2017 Opinion, NMFS is issuing a new Statement described in its entirety in this section.

2.10.1. Amount or Extent of Take

NMFS analyzed six factors applicable to the proposed hatchery salmon actions. Four factors analyzed are likely 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; Wallace River Hatchery yearling Chinook and coho salmon predation effects; and Wallace River Hatchery water intake screening effects on Chinook salmon survival and migration. Two factors are likely to result in take of listed Puget Sound steelhead: Wallace River Hatchery facility water intake screening effects on steelhead survival and migration and incidental collection of steelhead during research and monitoring.

Factor 1. Take through Broodstock Collection

Annual collection of broodstock to sustain the Wallace River Hatchery program will lead to the removal of listed natural-origin Skykomish Chinook salmon from the Sunset Falls Fishway trap, from traps located in the Wallace River, and through collections of broodstock downstream of the Wallace River Hatchery rack. Up to 400 natural-origin adult Chinook salmon may be taken through their removal for holding and spawning at the hatchery each year. In addition, up to 1,912 natural-origin Skykomish Chinook salmon may be captured, handled and released incidentally during annual broodstock collection actions at Wallace River Hatchery, in the Wallace River, and at the Sunset Falls Fishway (Table 1a in WDFW 2013b). For the 1,912 fish encountered at Wallace River Hatchery and downstream areas that are not retained as broodstock, incidental take effects may include migration delay, injury, and unintentional mortality.

NMFS expects that the total annual number of natural-origin Skykomish Chinook salmon captured, handled and held for spawning for the Wallace River Hatchery program will not exceed 400 adult fish, of which 100 fish may incidentally die before spawning. Further, NMFS expects that the number of natural-origin Skykomish Chinook salmon captured, handled, and released during annual Wallace River Hatchery, and in-Wallace River, Chinook and coho salmon broodstock collection activities (excluding Sunset Falls Fishway) will not exceed 1,912 fish. Of the 1,912 natural-origin fish captured, handled, and released, 307 fish may be taken each year through incidental mortality (Table 1a in WDFW 2013b) - 457 fish less 50 fish that die as a result of the Sunset Falls Fishway operation (NMFS 2009) and less 100 fish that expire during holding for spawning.

Factor 2. Take by Genetic Effects

As described in Section 2.5.2.2, implementation of the Wallace River Hatchery (WDFW 2013b) and Tulalip Hatchery (Tulalip Tribes 2012) Chinook salmon programs have the potential to result in some degree of genetic impact to the Skykomish and Snoqualmie Chinook salmon populations. It is not possible to measure genetic effects on Snohomish River basin Chinook salmon solely assignable to hatchery actions in a manner that would allow for the precise quantification of genetic take, necessitating use of a take surrogate. NMFS will rely on the demographic-based PNI metric described in section 2.5 as a surrogate for incidental take of salmonids as a result of genetic effects, as well as the LAT. For a surrogate indicator of take of threatened salmon from the Skykomish Chinook population, NMFS estimates that PNI will exceed 0.5 each year the natural-origin Chinook salmon escapement is forecasted to exceed the LAT. If escapement is below the LAT, then it is expected that PNI will be between 0.25 and 0.50. This highly integrated group is expected to increase PNI, which is expected to moderate the genetic effects of increased hatchery influence on the Skykomish spawning grounds resulting from increased hatchery production. This metric therefore has a rational relationship to assessing the level of take caused by genetic effects. In the process of calculating PNI, co-managers will also provide estimates of both pHOS and pNOB. These metrics can be reliably measured and monitored through a combination of carcass surveys, CWT analysis, otolith analysis, and genetic monitoring.

Factor 3. Take by Predation Effects

NMFS has determined that juvenile hatchery fish from the Wallace River Hatchery yearling Chinook and coho salmon programs could potentially prey on juvenile Chinook salmon from the Skykomish and Snoqualmie natural populations although this has not been observed in monitoring at two smolt traps and estuary monitoring conducted by co-managers beginning in the early 2000's. It is not possible to quantify the take associated with predation in the action area because it is not possible to meaningfully measure the number of interactions between hatchery-origin yearling salmon and juvenile Chinook salmon from several populations. Therefore, NMFS will rely on a surrogate take indicator showing the proportion of the estimated total annual Wallace River Hatchery and Eagle Creek Hatchery-origin yearling Chinook and coho salmon in the lower Skykomish River that have emigrated seaward, past the juvenile outmigrant trapping site on the lower Skykomish River watershed for the period after the hatchery fish are released.

As a surrogate for predation take, NMFS expects that annual juvenile outmigrant trap-based analysis to show that 90 percent of the Wallace River Hatchery-origin yearling Chinook and coho salmon and Eagle Creek coho salmon smolt populations released each year will have exited freshwater areas downstream of the hatchery release sites on or after the 21st day after the last release of the yearling smolts. The estimated number of yearling smolts passing the trapping sites can be reliably calculated by statistical week, commencing the fourth week post-hatchery release and continuing until no hatchery-origin yearling Chinook and coho salmon are captured, as identified through either expanded estimates or CPUE.

This standard has a rational connection to the amount of take expected from ecological effects, since the co-occurrence of hatchery-origin and natural-origin fish is a necessary precondition for predation, and the assumption that the greater the proportion of yearling Chinook and coho salmon hatchery smolts of total annual releases that remain in freshwater post-release, the greater likelihood that predation will occur. The number of yearling Chinook and coho salmon smolts in the downstream salmon and steelhead rearing and migration areas will be monitored by standing co-manager juvenile out-migrant screw trap monitoring activities.

Factor 4: Take Associated with Research and Monitoring Activities

To assess the effects of hatchery releases on estuary use of juvenile Chinook salmon, up to 900 juvenile Chinook salmon may be collected annually as described in Section 1.3.3. NMFS does not expect the collection of this number of juvenile Chinook salmon to have a detectable effect on the Puget Sound

Chinook salmon ESU. A summary of the results of estuary collections will be included in annual reports.

Juvenile steelhead may be incidentally collected during estuary monitoring activities. Based on similar research conducted in the Snohomish estuary, NMFS and the co-managers agree that it is not likely that more than 25 juvenile steelhead will be incidentally captured and handled annually. Incidentally captured steelhead will be released alive and unharmed. The incidental collection and subsequent handling of what will likely be a small number of steelhead will not result in a detectable effect to the Puget Sound steelhead ESU. The number of incidentally collected steelhead will be included in annual reports.

Factor 5: Take by Facility Effects

The existing Wallace River Hatchery water intake structure takes ESA-listed Chinook salmon and/or listed steelhead through migration delay or impingement of fish on screens. Because take by water intake structures occurs in the water and effects of delay or impingement may not be reflected until the fish have left the area of the structure, it is not possible to quantify the level of take associated with operation of the current water intake structures. Therefore, NMFS will rely on a surrogate take indicator in the form of the amount of habitat affected by the intake structure. Currently, the intake structure affects a very small proportion of the 2,718 miles (4,374 km) of river and stream habitat available to salmon and steelhead in the Snohomish River basin (Section 2.3 of the 2017 BiOp). The Wallace River Hatchery surface water intake screens present risks of entrainment for juvenile fish in no more than a total of four square meters of migration and rearing area adjacent to the intake, where intake water velocities may be high enough to cause fish to be drawn from the Wallace River into the intake screens. Therefore, the surrogate metric for take is the extent of habitat impacted by the intake, which is expected to be no more than four square meters.

The surrogate indicator of incidental take is rationally connected to the take associated with operation of the Wallace River Hatchery water intake structure, because take occurring by blocked access to habitat or by entrainment or impingement will only occur in the areas identified. This take can be reliably measured by continuing to observe effects associated with the water intakes by checking the intake screens daily for entrained fish.

2.10.2. Effect of the Take

In the biological opinion, NMFS determined that the amount or extent of anticipated take, coupled with other effects of the proposed action, is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat.

2.10.3. Reasonable and Prudent Measures

“Reasonable and prudent measures” are nondiscretionary measures that are necessary or appropriate to minimize the impact of the amount or extent of incidental take (50 CFR 402.02).

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

RPM 1. The action agencies shall assure that the applicants follow all conditions specified in each authorization issued as well as guidelines specified in this opinion to limit and reduce take and the effect of take of Puget Sound Chinook salmon and steelhead.
RPM 2. The action agencies shall assure that screening for the Wallace River Hatchery is renovated so that all screening at the facility complies with NMFS (2011a) "Anadromous Salmonid Passage Facility Design" criteria with work beginning as soon as funding is available.
RPM 3. The action agencies shall assure that the applicants provide reports to SFD annually for all hatchery programs and associated RM&E.
RPM 4. The action agencies shall assure that the applicants document the performance and effects of the hatchery salmon programs, including compliance with the Terms and Conditions set forth in this opinion, through completion and submittal of annual reports.

2.10.4. Terms and Conditions

The terms and conditions described below are non-discretionary, and the NMFS and BIA must assure that they or any applicant must comply with them in order to implement the RPMs (50 CFR 402.14). The NMFS and BIA or any applicant has a continuing duty to monitor the impacts of incidental take and must report the progress of the action and its impact on the species as specified in this ITS (50 CFR 402.14). If the entity to whom a term and condition is directed does not comply with the following terms and conditions, protective coverage for the proposed action would likely lapse.

1a. Conduct annual surveys to determine the migration timing, abundance, distribution, and origin (hatchery and natural-origin) of Chinook salmon spawning naturally and escaping to hatchery releases sites in the Snohomish, Skykomish, and Snoqualmie river watersheds. The co-managers shall submit any revisions of protocols described in the proposed HGMPs for annual spawning ground surveys and biological sampling for NMFS concurrence on or before June 1 of each year.
1b. Collect demographic, mark/tag, and/or genetic data, and conduct analyses necessary to indicate the total annual adult contribution, by origin, of Snohomish River basin Chinook salmon to fisheries, hatcheries, and escapements.
1c. Annually report, estimates of adult escapement to natural spawning areas and basin hatcheries, adult fish contributions to terminal area fisheries by origin (hatchery and natural), estimates of total recruit per spawner levels for the Skykomish and Snoqualmie Chinook salmon populations, potential causative factors (e.g., ocean productivity and freshwater habitat conditions) for hatchery-origin Chinook salmon escapement levels to natural spawning areas (pHOS) relative to natural-origin Chinook salmon escapement levels, and, if available, genetic based levels of gene flow between naturally spawning hatchery-origin fish and natural-origin fish in the Skykomish and Snoqualmie rivers.
1d. The total number of natural-origin Chinook salmon held each year for spawning at the Wallace River Hatchery shall not exceed 400 fish. Annual reports will include the number of natural-origin Chinook incorporated into the Wallace River Hatchery broodstock and PNI. If natural-origin

Chinook salmon are not incorporated, the annual report will include the information used as part of the decision process to not include natural-origin Chinook salmon as broodstock. If adult Chinook salmon escapement is below the LAT, the annual report will include information describing what factors may have contributed to low escapement.

1e. Report when and how many fall Chinook salmon collected post October 1 at Wallace River Hatchery are used for hatchery broodstock at Tulalip Hatchery.

1f. Endeavor to annually decrease the proportion of hatchery-origin Chinook salmon that make up the total number of surplus fish not used as broodstock at Wallace River Hatchery that are released upstream of the Wallace River weir to spawn naturally.

2a. As a means to evaluate predation risks to natural-origin Chinook salmon juveniles, annually monitor, through the ongoing Tulalip tribal juvenile salmonid outmigrant trapping program, the statistical week incidence of hatchery-origin Chinook salmon and coho salmon yearling smolts relative to the total number of Chinook salmon and coho salmon smolts released, respectively, in watershed areas downstream of Wallace River Hatchery and Eagle Creek Hatchery for at least one month after release of the yearlings from the facility.

2b. Collect data regarding the relative proportions, emigration timings, and individual fish sizes, for hatchery-origin yearling Chinook and coho salmon, and natural-origin juvenile Chinook salmon, encountered through trapping in the lower Skykomish River.

2c. Submit any revisions of individual fish release size and timing protocols described in the Wallace River Hatchery HGMPs for yearling Chinook and coho salmon for NMFS concurrence on or before January 1 of each year.

2d. Annually report results of monitoring and data collection activities described in 2a and 2b as well as a summary of the results of the estuary monitoring research and reporting of fish that were incidentally collected during estuary monitoring.

2e. Up to 900 juvenile Chinook salmon may be collected annually as part of estuary monitoring research activities. Up to 25 juvenile steelhead may be incidentally collected during estuary monitoring research with the intent to be released unharmed.

3a. Comply with the NMFS Anadromous Salmonid Passage Facility Design criteria (NMFS 2011a) for water intake structures and screening used by the Wallace River Hatchery programs with work beginning as soon as funding becomes available and design and permitting processes are completed. Annual reports shall include an update of construction activities improving screen conditions until the screening meets current standards.

3b. Monitor and annually report all incidences of juvenile natural-origin Chinook salmon and steelhead entrainment and mortality associated with screening at action area hatchery facilities and include these incidences in annual reports.

3c. Ensure that new water intake structures and associated screening at Wallace River Hatchery do not present risks of entrainment for juvenile fish in more than a total of four square meters of migration and rearing area adjacent to the intake structures.

4a. Immediately release unharmed fish at the point of capture any natural-origin steelhead and bull trout incidentally encountered in the course of salmon broodstock collection operations. Hatchery-origin steelhead, identifiable by a clipped adipose fin, that are collected during salmon broodstock collection operations, shall be removed at the point of capture and not returned to waters accessible to ESA-listed steelhead to reduce the threat of genetic and ecological effects to the native Snohomish River basin steelhead population.

4b. Annually monitor and report the number, location, and deposition of any steelhead and bull trout encountered during salmon broodstock collection operations.

5. Implement the hatchery programs as described in the HGMPs to promote achievement of fish production goals while minimizing impacts on listed Puget Sound Chinook salmon and steelhead. Manage the programs by limiting production to no more than 110 percent of levels described in the HGMPs, and by releasing hatchery salmon only from the locations described in the HGMPs. NMFS's SFD must be notified in advance of any change in hatchery program operation and implementation that potentially would result in increased take of ESA-listed species.

6. Provide one comprehensive annual report to NMFS SFD on or before November 1st of each year that includes the RM&E for the previous year described in Term and Conditions 1c, 3b, 4b, and 5. The numbers of hatchery-origin salmon released, release dates and locations, and tag/mark information shall be included in the annual report. All reports, as well as all other notifications required in the permit, shall be submitted electronically to the SFD point of contact for this program:

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2.11. Conservation Recommendations

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

1. The co-managers, in cooperation with the NMFS and other entities, should investigate the relative reproductive success, and relative survival, of hatchery- and natural-origin Chinook salmon in the Snohomish River basin to further scientific understanding of the genetic diversity and fitness effects of artificial propagation of the species, particularly, effects resulting from hatchery subyearling Chinook salmon production. Following this research through generations would allow detection of whether observed fitness differences are heritable and assess genetically-effective pHOS and PNI ($PHOS_G$, PNI_G). The relative contribution of these and other hatchery effects, in context with harvest and habitat effects, on all four viability parameters is being included in a watershed H-Integration Total Viability Analysis (TVA) under development by the co-managers.

2.12. Re-initiation of Consultation

As 50 CFR 402.16 states, reinitiation of consultation is required and shall be requested by the Federal agency or by the Service where discretionary Federal agency involvement or control over the action has been retained or is authorized by law and if: (1) The amount or extent of incidental taking specified in the ITS is exceeded, (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion, (3) the identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in the biological opinion, or (4) a new species is listed or critical habitat designated that may be affected by the action.

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

Section 305(b) of the MSA directs Federal agencies to consult with NMFS on all actions or proposed actions that may adversely affect essential fish habitat (EFH). Under the Magnuson Stevens Act (MSA), this consultation is intended to promote the conservation of EFH as necessary to support sustainable fisheries and the managed species' contribution to a healthy ecosystem. For the purposes of the MSA , EFH means "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity", and includes the physical, biological, and chemical properties that are used by fish (50 CFR 600.10). Adverse effect means any impact that reduces quality or quantity of EFH, and may include direct or indirect physical, chemical, or biological alteration of the waters or substrate and loss of (or injury to) benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality or quantity of EFH. Adverse effects on EFH may result from actions occurring within EFH or outside of it and may include site-specific or EFH-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810). Section 305(b) of the MSA also requires NMFS to recommend measures that can be taken by the action agency to conserve EFH. Such recommendations may include measures to avoid, minimize, mitigate, or otherwise offset the adverse effects of the action on EFH [CFR 600.905(b)]

This analysis is based, in part, on the EFH assessment provided by the NMFS and descriptions of EFH for Pacific Coast salmon (PFMC 2014a; PFMC 2014b) contained in the fishery management plans (FMP) 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 implementation of seven hatchery salmon programs in the Snohomish River basin, as described in detail in Section 1.3. The action area of the Proposed Action includes habitat described as EFH for Chinook salmon, pink salmon and coho salmon. Because EFH has not been described for steelhead, the analysis is restricted to the effects of the Proposed Action on EFH for the three salmon species for which EFH has been designated.

The areas affected by the Proposed Action include the Snohomish River basin from RM 0.0 to the upstream extent of anadromous fish access in the Skykomish River and Snoqualmie river watersheds including habitat accessed when fish are passed over Sunset Falls; Wallace River from its confluence with the Skykomish River at RM 35.7 to the upstream extent of anadromous fish access; Battle Creek, a tributary to Tulalip Bay, from its mouth to RM 0.1; the South Fork Skykomish River from Sunset Falls at RM 51.5 to the upstream extent of anadromous fish access; and Everett Bay, in the vicinity of Mukilteo, Washington.

Freshwater EFH for Pacific salmon, includes all those streams, lakes, ponds, wetlands, and other water bodies currently, or historically accessible to salmon in Washington, Oregon, Idaho, and California, except areas upstream of certain impassable manmade barriers, and long-standing, naturally-impassable barriers (i.e., natural waterfalls in existence for several hundred years) (PFMC 2014a). As described by PFMC (2014a), within these areas, freshwater EFH for Pacific salmon consists of four major components: (1) spawning and incubation; (2) juvenile rearing; (3) juvenile migration corridors; and (4) adult migration corridors and adult holding habitat.

The Snohomish River, Skykomish River, and Snoqualmie River and their tributaries accessible to anadromous salmon have been designated EFH for Chinook, coho, and pink salmon. Assessment of the potential adverse effects on these salmon species' EFH from the Proposed Action is based, in part, on these descriptions. The aspects of EFH that might be affected by the Proposed Action include: effects of hatchery operations on adult and juvenile fish migration corridors in the Snohomish River basin; ecological interactions and genetic effects in Chinook, coho, and pink salmon spawning areas in the watershed; and ecological effects in rearing areas for the species in the Basin, including its estuary and adjacent nearshore marine areas.

3.2. Adverse Effects on Essential Fish Habitat

The Proposed Action generally does not have substantial effects on the major components of EFH. Adult salmon holding and spawning habitat, and juvenile salmon rearing locations, are not expected to be affected by the operation of the hatchery programs, as no modifications to these areas would occur. Upgraded screening at Wallace River Hatchery to meet current NMFS hatchery facility screening criteria is proposed to occur by fall 2020, and retrofitting of the screens is included as a condition through NMFS's ESA consultation. Potential effects on EFH by the Proposed Action are only likely to occur predominately in Snohomish River basin waters downstream of Wallace River Hatchery where Chinook, coho, and chum salmon migrate and spawn naturally.

The effects to EFH itself is largely due to effects on fish that could result in reducing marine-derived nutrients available in the habitat through lower productivity. Implementation of the Snohomish River basin hatchery programs is expected to increase abundance and spatial distribution of hatchery Chinook, coho, and chum salmon produced through the programs, in the progeny of naturally-spawning hatchery fish, and in the natural populations relative to their baseline diversity and productivity status. Pink and sockeye salmon and steelhead are not propagated as part of these salmon hatchery programs, and there would therefore be no hatchery-related genetic effects to these species associated with the Proposed Action. The PFMC (2014a) 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 (Section 2.5.2). Additional detail on possible genetic effects of salmon hatchery programs can be found in NMFS (2012) and Ford et al. (2011). In implementing the Snohomish River basin hatchery salmon programs, the co-managers will apply best management practice risk reduction measures described as part of the proposed actions. These measures, pertaining to broodstock collection, mating, fish rearing, and fish release practices, should adequately reduce the risk that the Wallace River Hatchery Chinook, coho and chum salmon, and the Tulalip Hatchery Chinook, coho and chum salmon programs will have an adverse effect on the genetic diversity and fitness of Chinook, coho or chum salmon populations in the Snohomish River basin. The co-managers will also monitor and report annual run timing, location, age and sex composition, and origin of escaping Chinook and coho salmon to gauge changes in population traits that may be associated with the hatchery actions. Genetic samples will be collected from natural-origin and hatchery-origin Chinook salmon to monitor spatial structure of genetic diversity of the Skykomish and Snoqualmie Chinook populations, and genetic equilibrium of the integrated hatchery and natural-origin Skykomish Chinook aggregations, predicated on available funding for laboratory analysis of the samples collected The co-managers will also analyze genetic samples to determine levels of gene flow between naturally spawning hatchery-origin Chinook salmon and the natural-origin Chinook salmon populations predicated on available funding for laboratory analysis. In addition to enhancing the overall abundance of Skykomish Chinook salmon and Skykomish River coho salmon, the hatchery programs for the species may serve as a genetic reserve for the extant populations in the basin as buffers against catastrophic losses of the naturally spawning components, and as an important rebuilding tool for the integrated recovery of Skykomish chum salmon. In addition, adult salmon produced through the hatchery programs that escape to natural spawning areas may benefit spatial structure of the populations by augmenting natural spawning abundances in under-seeded and unutilized areas. These potential benefits would help offset risks to Snohomish River basin Chinook, coho and chum salmon diversity and productivity that may result from natural spawning by hatchery-origin fish at high proportions of total abundances. For these reasons, adverse effects on salmon EFH resulting from genetic effects would be inconsequential.

Very few coho salmon and fall chum salmon adults originating from the Tulalip Hatchery program are expected to escape Tulalip Bay fisheries to natural spawning areas comprising EFH. Further, any naturally spawning hatchery coho and fall chum salmon would not overlap temporally and spatially to a substantial degree with natural-origin Chinook, coho, or pink salmon in natural spawning areas, so there would be no effects on spawning, or redds created by, those species. The new native chum program is operated as integrated program and HORs are intended to spawn in natural spawning areas to increase population abundance. The co-managers will monitor and report hatchery-origin salmon escapements to gauge changes to EFH that may result from the hatchery actions.

The release of yearling Chinook and coho salmon through programs at Wallace River Hatchery (including coho salmon releases from Eagle Creek Hatchery) may lead to effects on EFH through predation on juvenile Chinook, coho, and pink salmon. Juvenile salmon produced through the Tulalip Tribes' salmon hatchery programs would be released as smolts or fry into Tulalip Bay and therefore would be no effects on freshwater salmon EFH from the tribal Chinook, coho, and fall chum salmon programs. Coho salmon yearlings from the Everett Bay Net-pen program would be released directly into seawater, and there would be no effects on freshwater salmon EFH. The risk of hatchery-origin smolt predation on natural-origin juvenile fish in freshwater is dependent upon three factors: 1) the hatchery fish and their potential natural-origin prey must overlap temporally; 2) the hatchery fish and their prey must overlap spatially; and, 3) the prey should be less than 1/3 the length of the predatory fish.

Regarding hatchery facility operation effects on salmon EFH, the Wallace River Hatchery water intake screens on Wallace River and May Creek are in compliance with state and federal guidelines (NMFS 1995; NMFS 1996), but the screens do not meet current NMFS Anadromous Salmonid Passage Facility Design Criteria (NMFS 2011a) designed to protect natural-origin salmon from injury and mortality. WDFW has indicated the intent in their HGMPs to modify screening at Wallace River Hatchery to comply with NMFS screening requirements to protect natural-origin fish from entrainment and impingement that may lead to injury and mortality. Intake screens on both tributaries are scheduled by WDFW for rebuild by as early as 2023 to bring the screens into compliance with those criteria and to reduce risks to salmon EFH. Proposed retrofitting of the Wallace River Hatchery screens to be in compliance with current NMFS criteria should adequately reduce risks to listed Chinook salmon and steelhead in the Wallace River watershed. Screening at the Tulalip Tribes' hatchery facilities is not a risk factor to EFH, as there are no natural-origin salmon fish populations in the small tributaries to Tulalip Bay where the facilities are located. The Everett Bay Net-Pen program would operate using mesh sizes on the net-pen containing hatchery-origin coho salmon smolts (WDFW and Everett Steelhead and Salmon Club (ESSC) 2013) that do not pose any measurable risks of entrainment and mortality to salmon, and would have no effects on salmon EFH. Upon upgrading the intake screens, WDFW will comply with NMFS Anadromous Salmonid Passage Facility Design criteria (NMFS 2011a) as early as 2023 based on availability of funding. They will monitor and annually report all incidences of juvenile natural-origin Chinook salmon and steelhead entrainment and mortality associated with screening at Wallace River Hatchery. For these reasons, screens at the Wallace River Hatchery facility will pose a negligible risk to EFH for salmon in the Snohomish River basin (Section 2.5.2.5).

3.3. Essential Fish Habitat Conservation Recommendations

For each of the potential adverse effects by the Proposed Action on EFH for Chinook, coho, and pink salmon, NMFS believes that the Proposed Action, as described in the HGMPs (Tulalip Tribes 2012; Tulalip Tribes 2013a; Tulalip Tribes 2013b; WDFW 2013a; WDFW 2013b; WDFW 2019b; WDFW and Everett Steelhead and Salmon Club (ESSC) 2013) and the ITS (Section 2.9), includes the best approaches to avoid or minimize those adverse effects. The Reasonable and Prudent Measures and Terms and Conditions included in the ITS constitute NMFS recommendations to address potential EFH effects. NMFS and BIA shall ensure that the ITS, including Reasonable and Prudent Measures and implementing Terms and Conditions, are carried out.

To address the potential effects on EFH of hatchery fish on natural fish in natural spawning and rearing areas, the PFMC (2014a) provided an overarching recommendation that hatchery programs:

"[c]omply with current policies for release of hatchery fish to minimize impacts on native fish populations and their ecosystems and to minimize the percentage of nonlocal hatchery fish spawning in streams containing native stocks of salmonids."

The biological opinion explicitly discusses the potential risks of hatchery fish on fish from natural populations and their ecosystems, and describes operation and monitoring appropriate to minimize these risks on Chinook, coho, and chum salmon in the Snohomish River basin.

3.4. Statutory Response Requirement

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

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

3.5. Supplemental Consultation

The FWS and BOR must reinitiate EFH consultation with NMFS if the Proposed Action is substantially revised in a way that may adversely affect EFH, or if new information becomes available that affects the basis for NMFS' EFH conservation recommendations [50 CFR 600.920(l)].

4. DATA QUALITY ACT DOCUMENTATION AND PRE-DISSEMINATION REVIEW

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

4.1. Utility

Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable, and beneficial to the intended users. The intended users of this opinion are the Tulalip Tribes and WDFW (operators); NMFS (regulatory agency), and BIA (indirect funding entity). Other interested users could include the scientific community, resource managers, and stakeholders. Individual copies of this opinion were provided to the NMFS, BIA, Tulalip Tribes, and WDFW. The document will be available within two weeks at the NOAA Library Institutional Repository [https://repository.library.noaa.gov/welcome]. The format and naming adheres to conventional standards for style.

4.2. Integrity

This consultation was completed on a computer system managed by NMFS in accordance with relevant information technology security policies and standards set out in Appendix III, 'Security of Automated Information Resources,' Office of Management and Budget Circular A-130; the Computer Security Act; and the Government Information Security Reform Act.

4.3. Objectivity

Information Product Category: Natural Resource Plan

Standards: This consultation and supporting documents are clear, concise, complete, and unbiased, and were developed using commonly accepted scientific research methods. They adhere to published standards including the NMFS ESA Consultation Handbook, ESA Regulations, 50 CFR 402.01 *et seq*., and the MSA implementing regulations regarding EFH, 50 CFR 600.920(j).

Best Available Information: This consultation and supporting documents use the best available information, as described in the references section. The analyses in this biological opinion/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 Northwest Region ESA quality control and assurance processes.

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6. APPENDIX A: EFFECTS OF HATCHERY PROGRAMS ON SALMON AND STEELHEAD POPULATIONS: REFERENCE DOCUMENT FOR NMFS ESA HATCHERY CONSULTATIONS (REVISED JULY 29, 2020)[6]

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

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

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

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

In choosing the literature we cite in this Appendix, our overriding concern is our mandate to use "best available science". Generally, this means recent peer-reviewed journal

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

articles and books. However, as appropriate we cite older peer-reviewed literature that is still relevant, as well as "gray" literature. Although peer-review is typically considered the "gold standard" for scientific information, occasionally there are well-known and popular papers in the peer-reviewed literature we do not cite because we question the methodology, results, or conclusions. In citing sources, we also consider availability, and try to avoid sources that are difficult to access. For this reason, we generally avoid citing master's theses and doctoral dissertations, unless they provide unique information.

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

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

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

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

6.2.1. Genetic effects (Revised July 29, 2020)

6.2.1.1. Overview

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

We recognize that there is considerable debate regarding aspects of genetic risk. The extent and duration of genetic change and fitness loss and the short- and long-term implications and consequences for different species (i.e., for species with multiple life-history types and species subjected to different hatchery practices and protocols) remain unclear and should be the subject of further scientific investigation. As a result, we believe 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 2011d). We expect the scientific uncertainty surrounding genetic risks to be reduced considerably in the next decade due to the rapidly increasing power of genomic analysis (Waples et al. 2020).

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

- Selection- changes in genetic composition over time due to some genotypes being more successful at survival or reproduction (i.e, more fit) than others
- Migration- individuals, and thus their genes, moving from one population to another
- Genetic drift- random loss of genetic material due to finite population size
- Mutation- generation of new genetic diversity through changes in DNA

Mutations are changes in DNA sequences that are generally so rare[7] that they can be ignored for relatively short-term evaluation of genetic change, but the other three processes are considerations in evaluating the effects of hatchery programs on the productivity and genetic diversity of natural salmon and steelhead populations. Although there is considerable biological interdependence among them, we consider three major areas of genetic effects of hatchery programs in our analyses (Figure 12):

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

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

In the sections below we discuss these three major areas of risk, but preface this with an explanation of some key terms relevant to genetic risk, and in some cases terms relevant to ecological risk as well.

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

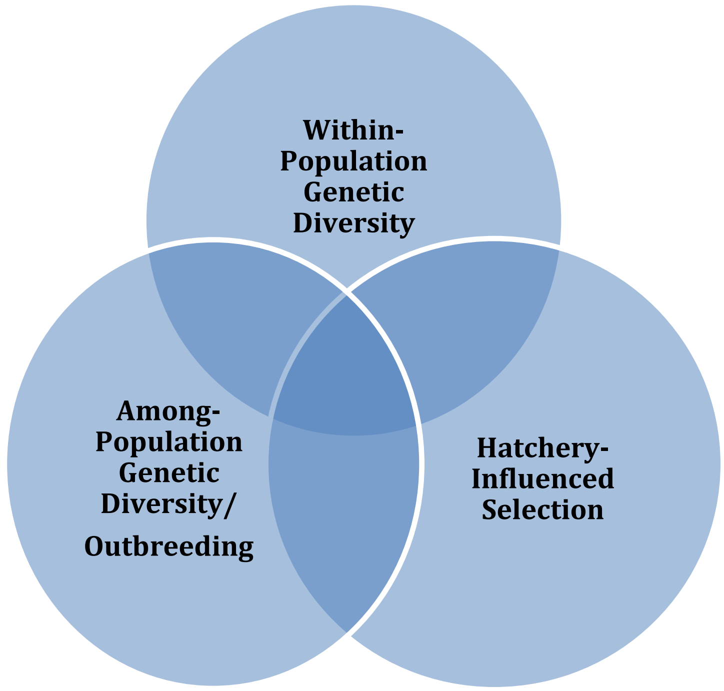

Figure 11. Major categories of hatchery program genetic effects analyzed by NMFS.

Key Terms

The terms "wild fish" and "hatchery fish" are commonly used by the public, management biologists, and regulatory biologists, but their meaning can vary depending on context. For genetic risk assessment, more precise terminology is needed:

- **Hatchery-origin (HO)**- refers to fish that have been reared and released by a hatchery program, regardless of the origin of their parents. A series of acronyms has been developed for subclasses of HO fish:
  - **Hatchery-origin recruits (HOR)** – HO fish returning to freshwater as adults or jacks. Usage varies, but typically the term refers to post-harvest fish that will either spawn in nature, used for hatchery broodstock, or surplused.
  - **Hatchery-origin spawners (HOS)**- hatchery-origin fish spawning in nature.
  - **Hatchery-origin broodstock (HOB)**- hatchery-origin fish that are spawned in the hatchery (i.e., are used as broodstock).
- **Natural-origin (NO)**- refers to fish that have resulted from spawning in nature, regardless of the origin of their parents. A series of acronyms has been developed for subclasses of NO fish:

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

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

- **Natural-origin broodstock (NOB)**- natural-origin fish that are spawned in the hatchery (i.e., are used as broodstock).

These terms have led to development of three metrics that are very important to genetic risk assessment. They are commonly attributed to the Hatchery Scientific Review Group (HSRG), but were developed in 2004 technical discussions between the HSRG and scientists from the Washington Department of Fish and Wildlife (WDFW) and the Northwest Indian Fisheries Commission (HSRG 2009a). All three are typically computed as means based on multiple spawning seasons:

- **pHOS -** proportion of fish on the spawning grounds consisting of HO fish. Mathematically, pHOS = HOS/(HOS + NOS. Assuming random mating, equal reproductive success of HO and NO spawners, and no selection, pHOS is the expected genetic contribution of HO spawners to the naturally spawning population, i.e., the expected level of gene flow from HO fish into the naturally spawning population.

  Genetic risk guidelines discussed in Section 1.2.1.4 have been developed based on refinements of pHOS:

  - **$pHOS_{census}$ -** pHOS based on census information (e.g., redd counts, spawner counts). pHOS without a subscript usually means $pHOS_{census}$

  - **$pHOS_{eff}$** - $pHOS_{census}$ discounted by the spawning success of HO fish relative to that of NO fish. For example, if HO fish are assumed to be 80 percent as reproductively capable as NO fish, then $pHOS_{eff} \approx 0.8 * pHOS_{census}$[8]

Because of expected differences in spatial distribution and spawning success between HO and NO fish, we consider pHOS an estimate of maximum potential gene flow. As a surrogate metric for gene flow, $pHOS_{census}$ computed over an entire basin becomes increasingly less satisfactory as biological complexity is considered (e.g., spawner distributions, sex ratios, varying fecundity). In response, approaches for finer scaled computation of pHOS have been developed (Falcy 2019; HSRG 2017), in addition to the previously mentioned adjustment for relative reproductive success.

- **pNOB -** proportion of fish in the hatchery broodstock consisting of NO fish. Mathematically, pNOB = NOB/(HOB + NOB).

[8] We present a more precise equation in Section 1.2.1.4.

- **Proportionate natural influence (PNI) -** in a population affected by hatchery programs, the relative selective influence of the natural environment. In populations affected by integrated hatchery programs, PNI is represented mathematically as PNI ≈ pNOB/(pNOB + pHOS). PNI is a confusing concept that we explain in greater detail in Section 1.2.1.4.

6.2.1.1.1.1. pHOS and mating-type frequency

Figure 13 illustrates the expected proportion of mating types in a mixed population of NO and HO fish (denoted as N and H, respectively, in the figure) as a function of $pHOS_{census}$, assuming that NO and HO adults mate randomly[9] (Figure 14). For example, at a $pHOS_{census}$ level of 10 percent, 81 percent of the matings would be expected to be NxN, 18 percent NxH, and 1 percent HxH.

You can also interpret the curves in the diagram as probability of naturally produced progeny of specified mating types, assuming random mating and equal reproductive success of all mating types. Under this interpretation, for example, progeny produced by a population with a pHOS level of 10 percent will have an 81 percent chance of having two NO parents. This logic has specific application to Canada's Wild Salmon Policy (WSP) (DFO 2005), in which wild fish are defined as naturally produced fish whose parents were naturally produced. Withler et al. (2018) used mating type probabilities to refine and extend HSRG gene flow guidelines for compatibility with the WSP.

[9] We made these computations using the simple mathematical binomial squared expansion $(a+b)^2=a^2 + 2ab + b^2$.

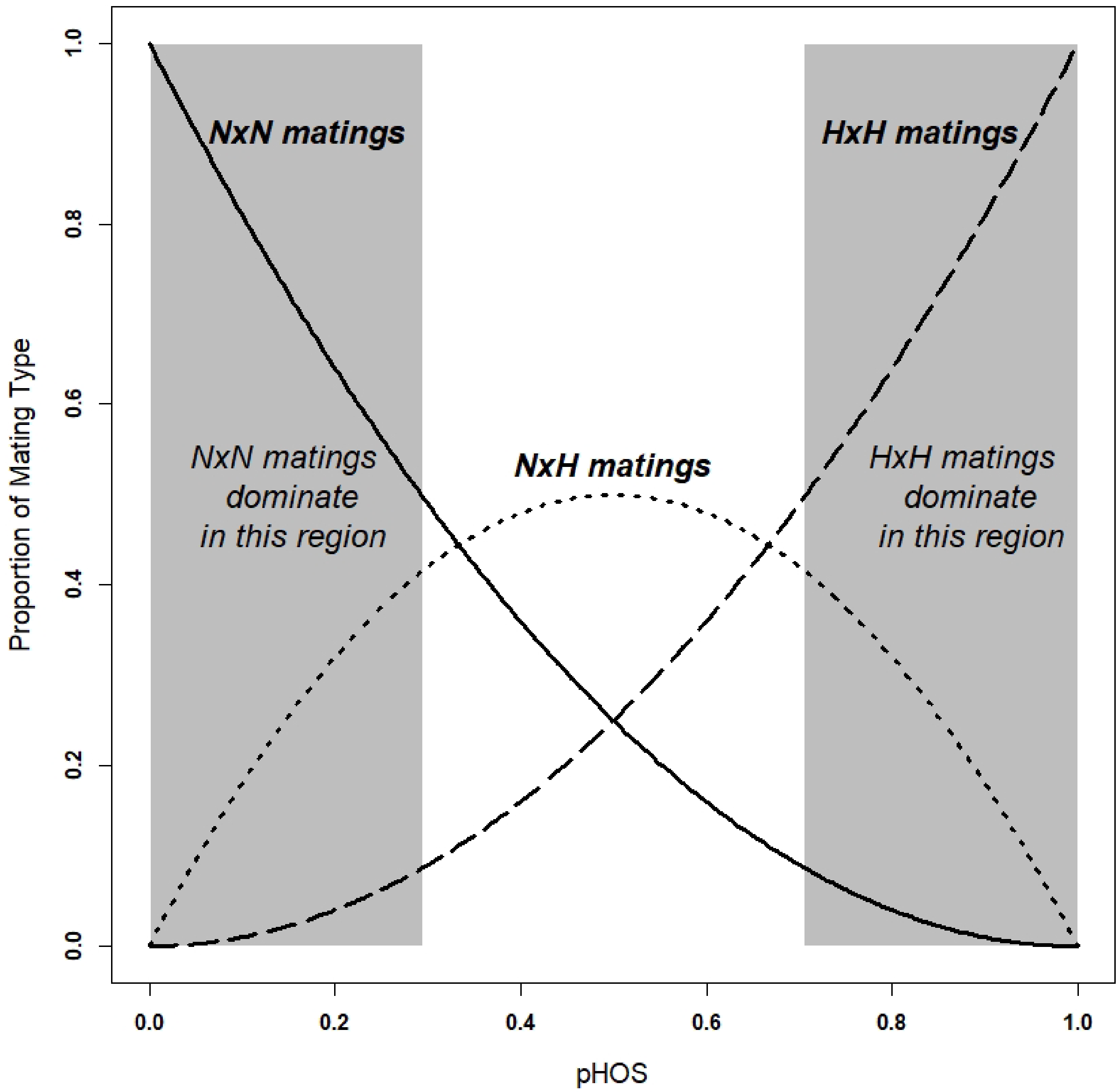

Figure 12. Relative proportions of mating types as a function of proportion of hatchery-origin fish on the spawning grounds (pHOS), assuming random mating. Line codes: solid = NxN, dashed = NxH, dotted = HxH. Shaded rectangles on left and right denote pHOS ranges at which NxN and HxH matings are most probable, respectively.

6.2.1.2. Within-population diversity effects

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

6.2.1.2.1. Genetic drift

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

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

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

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

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

Hatchery programs, simply by virtue of being able to create more progeny than natural spawners are able to, can increase N_b in a fish population. In very small populations, this

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

increase can be a benefit, making selection more effective and reducing other small-population risks (e.g., Lacy 1987; Whitlock 2000; Willi et al. 2006). Conservation hatchery programs can thus serve to protect genetic diversity; several programs, such as the Snake River sockeye salmon program, are important genetic reserves. However, hatchery programs can also directly depress N_b by three principal pathways:

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

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

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

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

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

Inbreeding depression, another N_e-related phenomenon, is a reduction in fitness and survival caused by the mating of closely related individuals (e.g., siblings, half-siblings, cousins). Related individuals are genetically similar and produce offspring characterized by low genetic variation, low heterozygosity, lower survival, and increased expression of recessive deleterious mutations (Allendorf et al. 2013; Frankham et al. 2010; Hedrick and Garcia-Dorado 2016; Rollinson et al. 2014). Lowered fitness due to inbreeding depression exacerbates genetic risk relating to small population size and low genetic variation which further shifts a small population toward extinction (Nonaka et al. 2019). The protective hatchery environment masks the effects of inbreeding which becomes apparent when fish are released into the natural environment and experience decreased survival (Thrower and Hard 2009). Inbreeding concerns in salmonids related to hatcheries have been reviewed by Wang et al. (2002) and Naish et al. (2008).

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

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

6.2.1.2.2. Biased/nonrepresentational sampling

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

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

Another source of biased sampling is non-inclusion of precocious males in broodstock. Precociousness, or early male maturation, is an alternative reproductive tactic employed by Atlantic salmon (Bagliniere and Maisse 1985; Myers et al. 1986), Chinook salmon (Bernier et al. 1993; Larsen et al. 2004), coho salmon (Iwamoto et al. 1964; Silverstein and Hershberger 1992), steelhead (McMillan et al. 2012; Schmidt and House 1979) , sockeye salmon (Ricker 1959), as well as several salmonid species in Asia and Europe (Dellefors and Faremo 1988; Kato 1991; Morita et al. 2009; Munakata et al. 2001).

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

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

6.2.1.3. Among-population diversity/ Outbreeding effects

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

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

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

Gene flow from other populations can increase genetic diversity (e.g., Ayllon et al. 2006), which can be a benefit in small populations, but it can also alter established allele frequencies (and co-adapted gene complexes) and reduce the population’s level of adaptation, a phenomenon called outbreeding depression (Edmands 2007; McClelland and Naish 2007). In general, the greater the geographic separation between the source or origin of hatchery fish and the recipient natural population, the greater the genetic difference between the two populations (ICTRT 2007), and the greater potential for outbreeding depression. For this reason, NMFS advises hatchery action agencies to develop locally derived hatchery broodstock.

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

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

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

- Adult salmon may wander on their return migration, entering and then leaving tributary streams before spawning (Pastor 2004). These "dip-in" fish may be detected and counted as strays, but may eventually spawn in other areas, resulting in an overestimate of the number of strays that potentially interbreed with the natural population (Keefer et al. 2008). On the other hand, "dip-ins" can also be captured by hatchery traps and become part of the broodstock.

- Strays may not contribute genetically in proportion to their abundance. Several studies demonstrate little genetic impact from straying despite a considerable presence of strays in the spawning population (Blankenship et al. 2007; e.g., Saisa et al. 2003). The causes of poor reproductive success of strays are likely similar to those responsible for reduced productivity of HO fish in general, e.g., differences in run and spawn timing, spawning in less productive habitats, and reduced survival of their progeny (Leider et al. 1990; Reisenbichler and McIntyre 1977; Williamson et al. 2010).

6.2.1.4. Hatchery-influenced selection effects

Hatchery-influenced selection (often called domestication[12]), the third major area of genetic effects of hatchery programs that NMFS analyses, occurs when selection pressures imposed by hatchery spawning and rearing differ greatly from those imposed by the natural environment and causes genetic change that is passed on to natural populations through interbreeding with HO fish. These differing selection pressures can be a result of differences in environments or a consequence of protocols and practices used by a hatchery program.

Hatchery-influenced selection can range from relaxation of selection that would normally occur in nature, to selection for different characteristics in the hatchery and natural environments, to intentional selection for desired characteristics (Waples 1999), but in this section, for the most part, we consider hatchery-influenced selection effects that are general and unintentional. Concerns about these effects, often noted as performance

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

[12] We prefer the term "hatchery-influenced selection" or "adaptation to captivity" (Fisch et al. 2015) to "domestication" because in discussions of genetic risk in salmon "domestication" is often taken as equivalence to species that have been under human management for thousands of years; e.g., perhaps 30,000 yrs for dogs (Larson and Fuller 2014), and show evidence of large-scale genetic change (e.g., Freedman et al. 2016). By this standard, the only domesticated fish species is the carp (*Cyprinus carpio*) (Larson and Fuller 2014). "Adaptation to captivity", a term commonly used in conservation biology (e.g., Allendorf et al. 2013; Frankham 2008), and becoming more common in the fish literature (Christie et al. 2011; Fisch et al. 2015) is more precise for species that have been subjected to semi-captive rearing for a few decades. We feel "hatchery-influenced selection" is even more precise, and less subject to confusion.

differences between HO and NO fish have been recorded in the scientific literature for more than 60 years (Vincent 1960, and references therein).

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

- The difference in selection pressures presented by the hatchery and natural environments. Hatchery environments differ from natural environments in many ways (e.g., Thorpe 2004). Some obvious ones are food, density, flows, environmental complexity, and protection from predation.

- How long the fish are reared in the hatchery environment. This varies by species, program type, and by program objective. Steelhead, coho and "stream-type" Chinook salmon are usually released as yearlings, while "ocean-type" Chinook, pink, and chum salmon are usually released at younger ages.

- The rate of gene flow between HO and NO fish, which is usually expressed as pHOS for segregated programs and PNI for integrated programs.

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

6.2.1.4.1. Relative Reproductive Success Research

Although hundreds of papers in the scientific literature document behavioral, morphological and physiological differences between NO and HO fish, the most frequently cited research has focused on RRS of HO fish compared to NO fish determined through pedigree analysis. The influence of this type of research derives from the fact that it addresses fitness, the ability of the fish to produce progeny that will then return to sustain the population. The RRS study method is simple: genotyped NO and HO fish are released upstream to spawn, and their progeny (juveniles, adults, or both) are sampled genetically and matched with the genotyped parents. In some cases, multiple-generation pedigrees are possible.

RRS studies can be easy to misinterpret (Christie et al. 2014a) for at least three reasons:

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

- RRS studies often have little experimental power because of limited sample sizes and enormous variation among individual fish in reproductive success (most fish leave no offspring and a few leave many). This can lead to lack of statistical significance for HO:NO comparisons even if a true difference does exist. Kalinowski and Taper (2005) provide a method for developing confidence intervals around RRS estimates that can shed light on statistical power.

- An observed difference in RRS may not be genetic. For example, Williamson et al. (2010) found that much of the observed difference in reproductive success between HO and NO fish was due to spawning location; the HO fish tended to spawn closer to the hatchery. Genetic differences in reproductive success require a multiple generation design, and only a handful of these studies are available.

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

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

In addition to pink salmon, RRS results are now available for:

- Coho salmon(Theriault et al. 2011)
- Chum salmon (Berejikian et al. 2009)
- "Ocean-type" Chinook salmon (Anderson et al. 2012; Evans et al. 2019; Sard et al. 2015)
- "Stream-type" Chinook salmon (Ford et al. 2012; Ford et al. 2015; Ford et al. 2009; Hess et al. 2012; Janowitz-Koch et al. 2018; Williamson et al. 2010)
- Steelhead (Araki et al. 2007; Araki et al. 2009; Berntson et al. 2011; Christie et al. 2011)

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

As mentioned above, few studies have been designed to detect unambiguously a genetic component in RRS. Two such studies have been conducted with steelhead and both detected a statistically significant genetic component in steelhead (Araki et al. 2007; Christie et al. 2011; Ford et al. 2016), but the two conducted with "stream-type" Chinook salmon have not (Ford et al. 2012; Janowitz-Koch et al. 2018).

This suggests that perhaps the impacts of hatchery-influenced selection on fitness differs between Chinook salmon and steelhead.[14] The possibility that steelhead may be more affected by hatchery-influenced selection than Chinook salmon by no means suggest that effects on Chinook are trivial, however. A small decrement in fitness per generation can lead to large fitness loss.

6.2.1.4.2. Hatchery Scientific Review Group (HSRG) Guidelines

Key concepts concerning the relationship of gene flow to hatchery-influenced selection were developed and promulgated throughout the Pacific Northwest by the Hatchery Scientific Review Group (HSRG). Because these concepts have been so influential, we devote the next few paragraphs to them.

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

The HSRG guidelines (HSRG 2009b) vary according to type of program and conservation importance of the population. The HSRG used conservation importance classifications that were developed by the Willamette/Lower Columbia Technical Recovery Team (McElhany et al. 2003).[15] (Table 18). In considering the guidelines, we equate "primary" with a recovery goal of "viable" or "highly viable", and "contributing" with a recovery goal of "maintain". We disregard the guidelines for "stabilizing", because we feel they are inadequate for conservation guidance.

Table 23. HSRG gene flow guidelines (HSRG 2009b).

	Program classification	
Population conservation importance	**Integrated**	**Segregated**
Primary	**PNI $\geq$ 0.67 and pHOS $\leq$ 0.30**	**pHOS $\leq$ 0.05**

[14] This would not be surprising. Although steelhead are thought of as being quite similar to the "other" species of salmon, genetic evidence suggests the two groups diverged well over 10 million years ago (Crête-Lafrenière et al. 2012).

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

	Program classification	
Contributing	PNI ≥ 0.50 and pHOS ≤ 0.30	pHOS ≤ 0.10
Stabilizing	Existing conditions	Existing conditions

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

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

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

NMFS has not adopted the HSRG gene flow guidelines per se. However, at present the HSRG guidelines, along with the 5% stray guideline from Grant (1997) are the only acknowledged scientifically based quantitative guidelines for gene flow available. NMFS has considerable experience with the HSRG guidelines. They are based on a model (Ford 2002) developed by a NMFS geneticist, they have been evaluated by a NMFS-lead scientific team (RIST 2009), and NMFS scientists have extended the Ford model for more flexible application of the guidelines to complex situations (Busack 2015) (Section 1.2.1.4.3).

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

6.2.1.4.2.1. PNI and segregated hatchery programs

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

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

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

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

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

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

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

6.2.1.4.2.2. The effective pHOS concept

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

$$pHOS_{eff} = (RRS * HOS_{census}) / (NOS + RRS * HOS_{census}),$$

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

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

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

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

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

6.2.1.4.2.3. Gene flow guidelines in phases of recovery

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

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

The HSRG provided guidance on development of quantitative "triggers" for determining when a population had moved (up or down) from one phase to another. As explained in HSRG (2015), in the preservation and re-colonization phase, no PNI levels were specified for integrated programs (Table 19). The emphasis in these phases was to "Retain genetic diversity and identity of the existing population". In the local adaptation phase, when PNI standards were to be applied, the emphasis shifted to "Increase fitness, reproductive success and life history diversity through local adaptation (e.g., by reducing hatchery influence by maximizing *PNI*)". The HSRG provided additional guidance in HSRG (2017), which encouraged managers to use pNOB to "…the extent possible…" during the preservation and recolonization phases.

Table 24. HSRG gene flow guidelines/standards for conservation and harvest programs, based on recovery phase of impacted population (Table 2 from HSRG 2015).

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

We agree that conservation of populations at perilously low abundance may require prioritization of demographic over genetic concerns, but is concerned that high pHOS/low PNI regimes imposed on small recovering populations may prevent them from advancing to higher recovery phases[16]. A WDFW scientific panel reviewing HSRG principles and guidelines reached the same conclusion (Anderson et al. 2020).

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

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

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

Extending Ford's recursion equations (equations 5 and 6) to three populations allowed us to calculate PNI for a system of this type. We successfully applied this approach to link two spring Chinook salmon hatchery programs: Winthrop NFH (segregated) and Methow FH (integrated). By using some level of Methow returnees as broodstock for the Winthrop program, PNI for the natural population could be increased significantly[17](Busack 2015). We have since used the multi-population PNI model in numerous hatchery program consultations in Puget Sound and the Columbia basin, and have extended to it to include as many as ten hatchery programs and natural production areas.

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

[17] Such programs can lower the effective size of the system, but the model of Tufto (Section 1.2.1.3) can easily be applied to estimate this impact.

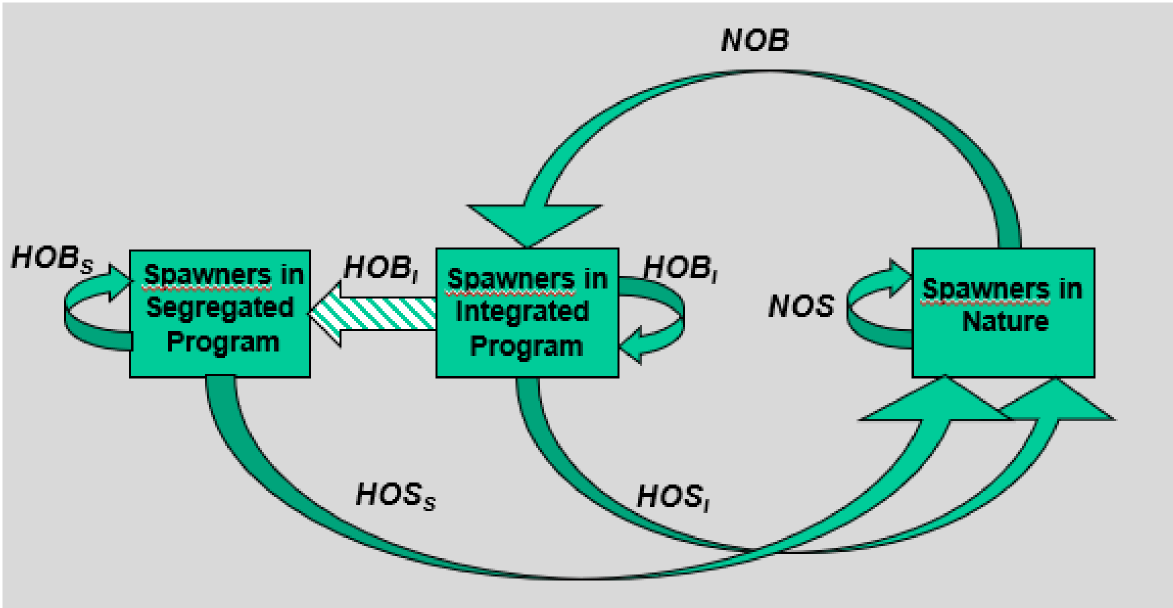

Figure 13. Example of genetically linked hatchery programs. The natural population is influenced by hatchery-origin spawners from an integrated (HOSI) and a segregated program (HOSS). The integrated program uses a mix of natural-origin (NOB) and its own returnees (HOBI) as broodstock, but the segregated uses returnees from the integrated program (HOBI above striped arrow) as all or part of its broodstock, genetically linking the two programs. The system illustrated here is functionally equivalent to the HSRG's (HSRG 2014) "stepping stone" concept.

6.2.1.4.4. California HSRG

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

- Felt that truly isolated programs in which no HO returnees interact genetically with natural populations were impossible in California, and was "generally unsupportive" of the concept of segregated programs. However, if programs were to be managed as isolated, they recommend a pHOS of less than 5 percent.

- Rejected development of overall pHOS guidelines for integrated programs because the optimal pHOS will depend upon multiple factors, such as "the amount of spawning by NO fish in areas integrated with the hatchery, the value of pNOB, the importance of the integrated population to the larger stock, the fitness differences between HO and NO fish, and societal values, such as angling opportunity."

- Recommended that program-specific plans be developed with corresponding population-specific targets and thresholds for pHOS, pNOB, and PNI that reflect these factors. However, they did state that PNI should exceed 50 percent in most cases, although in supplementation or reintroduction programs the acceptable pHOS could be much higher than 5 percent, even approaching 100 percent at times.

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

6.2.2. Ecological effects

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

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

The added spawner density resulting from hatchery-origin fish spawning in the wild can have negative consequences, such as increased competition, and potential for redd superimposition. Although males compete for access to females, female spawners compete for spawning sites. Essington et al. (2000) found that aggression of both sexes increases with spawner density, and is most intense with conspecifics. However, females tended to act aggressively towards heterospecifics as well. In particular, when there is spatial overlap between natural-and hatchery-origin spawners, the potential exists for hatchery-derived fish to superimpose or destroy the eggs and embryos of ESA-listed species. Redd superimposition has been shown to be a cause of egg loss in pink salmon and other species (e.g., Fukushima et al. 1998).

6.2.3. Adult Collection Facilities

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

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

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

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

6.3.1. Competition

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

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

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

A few exceptions to this general stream residence-aggression pattern have been observed (e.g., Hasegawa et al. 2004; Lahti et al. 2001; Young 2003; Young 2004), but all the species and migratory forms evaluated in these studies spend one year or more in stream habitat prior to outmigrating. Other than the Taylor (1991) and Hasegawa et al. (2014) papers noted above, we are not aware of any other studies that have looked specifically at interspecific interactions between early-outmigrating species (e.g., sockeye, chum, and pink salmon) and those that rear longer in streams.

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

A proportion of the smolts released from a hatchery may not migrate to the ocean but rather reside for a time near the release point. These non-migratory smolts (residuals) may compete for food and space with natural-origin juvenile salmonids of similar age (Bachman 1984; Tatara and Berejikian 2012). Although this behavior has been studied and observed, most frequently in the case of hatchery steelhead, residualism has been reported as a potential issue for hatchery coho and Chinook salmon as well (Parkinson et al. 2017). Adverse impacts of residual hatchery Chinook and coho salmon on natural-origin salmonids can occur, especially given that the number of smolts per release is generally higher; however, the issue of residualism for these species has not been as widely investigated compared to steelhead. Therefore, for all species, monitoring of natural stream areas near hatchery release points may be necessary to determine the potential effects of hatchery smolt residualism on natural-origin juvenile salmonids.

The risk of adverse competitive interactions between hatchery- and natural-origin fish can be minimized by:

- Releasing hatchery smolts that are physiologically ready to migrate. Hatchery fish released as smolts emigrate seaward soon after liberation, minimizing the potential for competition with juvenile natural-origin fish in freshwater (California HSRG 2012; Steward and Bjornn 1990)
- Rearing hatchery fish to a size sufficient to ensure that smoltification occurs
- Releasing hatchery smolts in lower river areas, below areas used for stream-rearing by natural-origin juveniles
- Monitoring the incidence of non-migratory smolts (residuals) after release and adjusting rearing strategies, release location, and release timing if substantial competition with natural-origin juveniles is likely

Critical to analyzing competition risk is information on the quality and quantity of spawning and rearing habitat in the action area,[18] including the distribution of spawning and rearing habitat by quality and best estimates for spawning and rearing habitat capacity. Additional important information includes the abundance, distribution, and timing for naturally spawning hatchery fish and natural-origin fish; the timing of emergence; the distribution and estimated abundance for progeny from both hatchery and natural-origin natural spawners; the abundance, size, distribution, and timing for juvenile hatchery fish in the action area; and the size of hatchery fish relative to co-occurring natural-origin fish.

6.3.2. Predation

Another potential ecological effect of hatchery releases is predation. Salmon and steelhead are piscivorous and can prey on other salmon and steelhead. Predation, either direct (consumption by hatchery fish) or indirect (increases in predation by other predator species due to enhanced attraction), can result from hatchery fish released into the wild. Considered here is predation by hatchery-origin fish, the progeny of naturally spawning

[18] "Action area," in ESA section 7 analysis documents, means all areas to be affected directly or indirectly by the action in which the effects of the action can be meaningfully detected and evaluated.

hatchery fish, and avian and other predators attracted to the area by an abundance of hatchery fish.

Hatchery fish originating from egg boxes and fish planted as non-migrant fry or fingerlings can prey upon fish from the local natural population during juvenile rearing. Hatchery fish released at a later stage, so they are more likely to migrate quickly to the ocean, can prey on fry and fingerlings that are encountered during the downstream migration. Some of these hatchery fish do not emigrate and instead take up residence in the stream where they can prey on stream-rearing juveniles over a more prolonged period, as discussed above. The progeny of naturally spawning hatchery fish also can prey on fish from a natural population and pose a threat.

Predation may be greatest when large numbers of hatchery smolts encounter newly emerged fry or fingerlings, or when hatchery fish are large relative to natural-origin fish (Rensel et al. 1984). Due to their location in the stream, size, and time of emergence, newly emerged salmonid fry are likely to be the most vulnerable to predation. Their vulnerability is 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 2004; Pearsons and Fritts 1999), but other studies have concluded that salmonid predators prey on fish up to 1/3 their length (Beauchamp 1990; Cannamela 1992; CBFWA 1996; Daly et al. 2009; 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).

Size is an important determinant of how piscivorous hatchery-origin fish are. Keeley and Grant (2001) reviewed 93 reports detailing the relationship between size and piscivory in 17 species of stream-dwelling salmonids. *O. mykiss* and Pacific salmon were well represented in the reviewed reports. Although there is some variation between species, stream-dwelling salmonids become piscivorous at about 100 mm FL, and then piscivory rate increases with increasing size. For example:

- For 140 mm fish, 15% would be expected to have fish in their diet but would not be primarily piscivorous; 2% would be expected to be primarily piscivorous (> 60% fish in diet).
- For 200 mm fish, those figures go to 32% (fish in diet) and 11% (primarily piscivorous).

The implication for hatchery-origin fish is pretty clear: larger hatchery-origin fish present a greater predation risk because more of them eat fish, and more of them eat primarily fish.

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

- Ensuring that a high proportion of the hatchery fish have physiologically achieved full smolt status. Juvenile salmon tend to migrate seaward rapidly when fully smolted, limiting the duration of interaction between hatchery- and natural-origin fish present within, and downstream of, release areas.
- Releasing hatchery smolts in lower river areas near river mouths and below upstream areas used for stream-rearing young-of-the-year naturally produced salmon fry, thereby reducing the likelihood for interaction between the hatchery and naturally produced fish.
- Operating hatchery programs to minimize the potential for residualism.

6.3.3. Disease

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. Noninfectious 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. For our purposes, exotic pathogens are those that have little to 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. 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
- Intentional 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; ODFW 2003; USFWS 2004; WWTIT and WDFW 2006). 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.

Noninfectious 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 National

Pollutant Discharge Elimination System (NPDES) permit administered by the Environmental Protection Agency. Other chemicals are discharged in accordance with manufacturer instructions. The NPDES permit also requires 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. One group of non-infectious diseases that are expected to occur rarely in current hatchery operations are those caused by nutritional deficiencies because of the vast literature available on successful rearing of salmon and trout in aquaculture.

6.3.4. Ecological Modeling

While competition, predation, and disease are important effects to consider, they are events which can rarely, if ever, be observed and directly calculated. However, these behaviors have been established to the point where NMFS can model these potential effects to the species based on known factors that lead to competition or predation occurring. In our Biological Opinions, we use the Predation, Competition, Decrement (PCD) Risk model version 3.2 based on Pearsons and Busack (2012). PCD Risk is an individual-based model that simulates the potential number of ESA-listed natural-origin juveniles lost to competition, predation, and disease from the release of hatchery-origin juveniles in the freshwater environment.

The PCD Risk model has undergone considerable modification since 2012 to increase supportability and reliability. Notably, the current version no longer operates in a Windows environment and no longer has a probabilistic mode. We also further refined the model by allowing for multiple hatchery release groups of the same species to be included in a single run.

There have also been a few recent modifications to the logic of the model. The first was the elimination of competition equivalents and replacement of the disease function with a delayed mortality parameter. The rationale behind this change was to make the model more realistic; competition rarely directly results in death in the model because it takes many competitive interactions to suffer enough weight loss to kill a fish. Weight loss is how adverse competitive interactions are captured in the model. However, fish that are competed with and suffer some degree of weight loss are likely more vulnerable to mortality from other factors such as disease. Now, at the end of each run, the competitive impacts for each fish are assessed, and the fish has a probability of delayed mortality based on the competitive impacts. This function will be subject to refinement based on research. For now, the probability of delayed mortality is equal to the proportion of a fish's weight loss. For example, if a fish has lost 10% of its body weight due to competition and a 50% weight loss kills a fish, then it has a 20% probability of delayed death, (0.2 = 0.1/0.5).

The second logic change was to the habitat segregation parameter to make it size-independent or size-dependent based on hatchery species. Some species, such as coho salmon, are more aggressive competitors than other species, such as chum and sockeye salmon. To represent this difference in behavior more accurately in the model, for less aggressive species such as chum and sockeye salmon, hatchery fish segregation is random, whereas for more aggressive species, segregation occurs based on size, with the largest fish eliminated from the model preferentially.

6.3.5. Acclimation

One factor that can affect hatchery fish distribution and the potential to spatially overlap with natural-origin spawners, and thus the potential for genetic and ecological impacts, is the acclimation (the process of allowing fish to adjust to the environment in which they will be released) of hatchery juveniles before release. Acclimation of hatchery juveniles before release increases the probability that hatchery adults will home back to the release location, reducing their potential to stray into natural spawning areas.

Acclimating fish for a time also allows them to recover from the stress caused by the transportation of the fish to the release location and by handling. Dittman and Quinn (2008) provide an extensive literature review and introduction to homing of Pacific salmon. They note that, as early as the 19th century, marking studies had shown that salmonids would home to the stream, or even the specific reach, where they originated. The ability to home to their home or "natal" stream is thought to be due to odors to which the juvenile salmonids were exposed while living in the stream (olfactory imprinting) and migrating from it years earlier (Dittman and Quinn 2008; Keefer and Caudill 2014). Fisheries managers use this innate ability of salmon and steelhead to home to specific streams by using acclimation ponds to support the reintroduction of species into newly accessible habitat or into areas where they have been extirpated (Dunnigan 1999; Quinn 1997; YKFP 2008).

Dittman and Quinn (2008) reference numerous experiments that indicated that a critical period for olfactory imprinting is during the parr-smolt transformation, which is the period when the salmonids go through changes in physiology, morphology, and behavior in preparation for transitioning from fresh water to the ocean (Beckman et al. 2000; Hoar 1976). Salmon species with more complex life histories (e.g., sockeye salmon) may imprint at multiple times from emergence to early migration (Dittman et al. 2010). Imprinting to a particular location, be it the hatchery, or an acclimation pond, through the acclimation and release of hatchery salmon and steelhead is employed by fisheries managers with the goal that the hatchery fish released from these locations will return to that particular site and not stray into other areas (Bentzen et al. 2001; Fulton and Pearson 1981; Hard and Heard 1999; Kostow 2009; Quinn 1997; Westley et al. 2013). However, this strategy may result in varying levels of success in regards to the proportion of the returning fish that stray outside of their natal stream. (e.g., (Clarke et al. 2011; Kenaston et al. 2001).

Increasing the likelihood that hatchery salmon and steelhead home to a particular location is one measure that can be taken to reduce the proportion of hatchery fish in the naturally spawning population. When the hatchery fish home to a particular location, those fish can be removed (e.g., through fisheries, use of a weir) or they can be isolated from primary spawning areas. Factors that can affect the success of acclimation as a tool to improve homing include:

- The timing of acclimation, such that a majority of the hatchery juveniles are going through the parr-smolt transformation during acclimation
- A water source unique enough to attract returning adults
- Whether or not the hatchery fish can access the stream reach where they were released
- Whether or not the water quantity and quality is such that returning hatchery fish will hold in that area before removal and/or their harvest in fisheries.

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

NMFS also analyzes proposed RM&E for its effects on listed species and on designated critical habitat. 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 uncertainty. RM&E actions can cause harmful changes in behavior and reduced survival; such actions include, but are not limited to:

- Observation during surveying
- Collecting and handling (purposeful or inadvertent)
- Sampling (e.g., the removal of scales and tissues)
- Tagging and fin-clipping, and observing the fish (in-water or from the bank)

NMFS also considers the overall effectiveness of the RM&E program. There are five factors that 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 concerning effects 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 it makes any recommendations to the action agency(s) NMFS considers the benefit or usefulness of new or additional information, whether the desired information is available from another source, the effects on ESA-listed species, and cost.

6.4.1. Observing/Harassing

For some activities, listed fish would be observed in-water (e.g., by snorkel surveys, wading surveys, or observation from the banks). Direct observation is the least disruptive method for determining a species' presence/absence and estimating their relative numbers. Its effects are also generally the shortest-lived and least harmful of the research activities discussed in this section because a cautious observer can effectively obtain data while only slightly disrupting fishes' behavior.

Fish frightened by the turbulence and sound created by observers are likely to seek temporary refuge in deeper water, or behind/under rocks or vegetation. In extreme cases, some individuals may leave a particular pool or habitat type and then return when observers leave the area. These avoidance behaviors are expected to be in the range of normal predator and disturbance behaviors.

6.4.2. Capturing/handling

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

NMFS has developed general guidelines to reduce impacts when collecting listed adult and juvenile salmonids (NMFS 2000; NMFS 2008) that have been incorporated as terms and conditions into section 7 opinions and section 10 permits for research and enhancement. Additional monitoring principles for supplementation programs have been developed by the (Galbreath et al. 2008).

6.4.3. Fin clipping and tagging

Many studies have examined the effects of fin clips on fish growth, survival, and behavior. The results of these studies are somewhat varied, but fin clips do not generally alter fish growth (Brynildson and Brynildson 1967; Gjerde and Refstie 1988). Mortality among fin-clipped fish is variable, but can be as high as 80 percent (Nicola and Cordone 1973). In some cases, though, no significant difference in mortality was found between clipped and un-clipped fish (Gjerde and Refstie 1988; Vincent-Lang 1993). The mortality rate typically depends on which fin is clipped. Recovery rates are generally higher for adipose- and pelvic-fin-clipped fish than for those that have clipped pectoral, dorsal, or anal fins (Nicola and Cordone 1973), probably because the adipose and pelvic fins are not as important as other fins for movement or balance (McNeil and Crossman 1979).

However, some work has shown that fish without an adipose fin may have a more difficult time swimming through turbulent water (Buckland-Nicks et al. 2011; Reimchen and Temple 2003).

In addition to fin clipping, PIT tags and CWTs are additional ways available to differentially mark fish. PIT tags are inserted into the body cavity of the fish just in front of the pelvic girdle. The tagging procedure requires that the fish be captured and extensively handled. Thus, tagging needs to take place where there is cold water of high quality, a carefully controlled environment for administering anesthesia, sanitary conditions, quality control checking, and a recovery tank.

Most studies have concluded that PIT tags generally have very little effect on growth, mortality, or behavior. Early studies of PIT tags showed no long-term effect on growth or survival (Prentice et al. 1987; Prentice and Park 1984; Rondorf and Miller 1994). In a study between the tailraces of Lower Granite and McNary Dams (225 km), Hockersmith et al. (2000) concluded that the performance of yearling Chinook salmon was not adversely affected by orally or surgically implanted sham radio tags or PIT tags. However, (Knudsen et al. 2009) found that, over several brood years, PIT tag induced smolt-adult mortality in Yakima River spring Chinook salmon averaged 10.3 percent and was at times as high as 33.3 percent.

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

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

6.4.4. Masking

Hatchery actions also must be assessed for risk caused by masking effects, defined as when hatchery fish included in the Proposed Action are not distinguishable from other fish. Masking undermines and confuses RM&E, and status and trends monitoring. Both adult and juvenile hatchery fish can have masking effects. When presented with a proposed hatchery action, NMFS analyzes the nature and level of uncertainties caused by masking, and whether and to what extent listed salmon and steelhead are at increased risk as a result of misidentification in status evaluations. The analysis also takes into account the role of the affected salmon and steelhead population(s) in recovery and whether unidentifiable hatchery fish compromise important RM&E.

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

The construction/installation, operation, and maintenance of hatchery facilities can alter fish behavior and can injure or kill eggs, juveniles, and adults. These actions can also degrade habitat function and reduce or block access to spawning and rearing habitats altogether. Here, NMFS analyzes changes to: riparian habitat, channel morphology, habitat complexity, in-stream substrates, and water quantity and quality attributable to operation, maintenance, and construction activities. NMFS also confirms whether water diversions and fish passage facilities are constructed and operated consistent with NMFS criteria.

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

There are two aspects of fisheries that are potentially relevant to NMFS' analysis:

1) Fisheries that would not exist but for the program that is the subject of the Proposed Action, and listed species are inadvertently and incidentally taken in those fisheries.
2) Fisheries that are used as a tool to prevent the hatchery fish associated with the HGMP, including hatchery fish included in an ESA-listed salmon ESU or steelhead DPS, from spawning naturally.

"Many hatchery programs are capable of producing more fish than are immediately useful in the conservation and recovery of an ESU and can play an important role in fulfilling trust and treaty obligations with regard to harvest of some Pacific salmon and steelhead populations. For ESUs listed as threatened, NMFS will, where appropriate, exercise its authority under section 4(d) of the ESA to allow the harvest of listed hatchery fish that are surplus to the conservation and recovery needs of the ESU, in accordance with approved harvest plans" (NMFS 2005). In any event, fisheries must be carefully evaluated and monitored based on the take, including catch and release effects, of ESA-listed species.

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