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

National Marine Fisheries Service (NMFS) Re-initiation Evaluation of Three Hatchery and Genetic Management Plans for Dungeness River Basin Salmon under Limit 6 of the Endangered Species Act Section 4(d) Rule

NMFS Consultation Number: WCRO-2022-00977

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

Affected Species and NMFS' Determinations:

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

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

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

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1 INTRODUCTION

On June 10, 2016, the National Marine Fisheries Service (NMFS) made a determination that the Dungeness River Basin Chinook salmon, coho salmon, and pink salmon hatchery programs satisfy the requirements under Limit 6 of the Endangered Species Act (ESA) Section 4(d) Rule. To reach the determination, NMFS completed a biological opinion (NMFS 2016g; 2016 BiOp) that evaluated the effects of its determination that the Dungeness River Basin Chinook salmon, coho salmon, and pink salmon hatchery programs would meet the standard for an exemption under Limit 6 of the Endangered Species Act section 4(d) regulations (50 CFR 223.203(b)(6)) on May 31, 2016 (Table 1). NMFS then completed a new determination on September 24, 2019, under Limit 6 of the 4(d) Rule for these Dungeness River Basin hatchery programs as a result of an increase in the size of the coho salmon hatchery program previously determined to meet Limit 6 (NMFS 2019a; 2019 BiOp).

NMFS is now proposing to make a new determination under Limit 6 of the 4(d) Rule for these Dungeness River Basin hatchery programs as a result of a proposal by the co-managers Washington Department of Fish and Wildlife (WDFW) and the Jamestown S'Klallam Tribe to increase the size of the current Chinook salmon hatchery program in the basin. In this reinitiated biological opinion, the NMFS evaluates whether the newly submitted HGMP for the Dungeness River Chinook salmon program meets the requirements of Section 4(d) Limit 6. The 2016 BiOp (NWR-2013-9701) and the 2019 BiOp (WCRO-2018-01254), which analyze NOAA Fisheries' prior determination regarding the HGMPs, are superseded by this biological opinion, although this opinion incorporates by reference elements of both the 2016 and 2019 BiOps that still remain valid.

Table 1. Hatchery programs associated with the Proposed Action, including program operator and primary funding agency. PST = Pacific Salmon Treaty, BIA = Bureau of Indian Affairs, WSFR = Wildlife and Sport Fish Restoration-Dingle Johnson.

Hatchery and Genetics Management Plan (HGMP)	Program Operator	Funding Agency*
Dungeness River Hatchery Spring Chinook salmon	WDFW	PST, BIA, WSFR
Dungeness River Hatchery coho salmon	WDFW	WDFW, WSFR
Dungeness River Hatchery pink (fall-run) salmon	WDFW	BIA

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 Lacey, Washington, office.

1.2 Consultation History

On June 10, 2016, NMFS made a determination that the Dungeness River Basin Chinook salmon, coho salmon, and pink salmon hatchery programs satisfy the requirements under Limit 6 of the Endangered Species Act (ESA) Section 4(d) Rule. To reach the determination, NMFS completed a biological opinion that evaluated the effects of its determination that the Dungeness River Basin Chinook salmon, coho salmon, and pink salmon hatchery programs would meet the standard for an exemption under Limit 6 of the Endangered Species Act section 4(d) regulations (50 CFR 223.203(b)(6)) on May 31, 2016 (NMFS 2016g). Since the 2016 BiOp was issued, the applicants have submitted a revised HGMP (WDFW 2019) to propose an increased production for the Dungeness River coho program on August 14, 2019. That 2019 BiOp was signed on September 24, 2019 (NMFS 2019a). The Jamestown S'Klallam Tribe and WDFW, as co-managers, have since submitted a revised HGMP (WDFW 2022) to propose to increase production of Dungeness River Chinook salmon.

1.3 Proposed Federal Action

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

Under MSA, Federal action means any action authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken by a Federal Agency (50 CFR 600.910).

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 Jamestown S'Klallam Tribe and WDFW's hatchery salmon programs in the Dungeness River basin; (2) the BIA's ongoing disbursement of funds for operation and maintenance of the Dungeness salmon hatchery programs listed in Table 1; and (3) the USFWS's ongoing disbursement of funds for operation and maintenance of the WDFW Dungeness spring Chinook and coho salmon hatchery programs as 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 distinct purpose and that may have independent spawning, rearing, marking and release strategies (NMFS 2008b). The operation and management of every hatchery program is unique in time, and specific to an identifiable stock and its native habitat (Flagg et al. 2004). All of the programs are currently operating. These three programs help meet tribal fishery harvest allocations that are guaranteed through treaties, as affirmed in *United States* v. *Washington* (1974) and to help meet Pacific Salmon Treaty harvest sharing agreement with Canada. In addition, the proposed Chinook salmon production increase is intended to benefit Southern Resident Killer Whale (SRKW) diet.

The pink salmon programs described in the proposed action for the 2016 BiOp remain the same for this Opinion. The coho program, under the new proposed action analyzed in the 2019 BiOp, included increased production of yearlings to 800,000 fish (from 500,000) released at the Dungeness Hatchery; all other aspects of the coho program (e.g., broodstock collection methods, water usage, release sites) remained the same as those described in the 2016 BiOp. These programs will not be considered further in this opinion, except as part of the baseline of actions affecting listed species.

The Chinook salmon program, under the new proposed action analyzed in this opinion, includes a proposed increased production to 600,000 sub-yearlings, a captive brood program, updated weir placement, and modifications of release locations within the Dungeness Basin. The increased production is proposed to increase adult returns to the Dungeness Basin in an effort to preserve genetic variability and increase spatial diversity of spawners throughout the basin. The escapement goal of the program is 1200 naturally spawning Chinook salmon, which is the most current Recovery Planning Abundance Target for spawners in the Dungeness Basin (NMFS 2019e; 2020; Ford 2022).

We considered, under the ESA, whether or not the proposed action would cause any other activities and determined that it would not cause directed fisheries in the action area. There are no fisheries that exist because of the Proposed Action. 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 2021c). 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 Dungeness 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 2022 Puget Sound harvest plan assembled by the co-managers that found that the harvest plan for 2022 fisheries did not jeopardize ESA-listed species (NMFS 2022). 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 2022 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 Dungeness River Hatchery spring Chinook and coho salmon programs. Because the funding of the programs under consideration does not result in any actions or effects not already under consideration as part of NMFS' review of the programs themselves, this Opinion will not separately discuss the funding action other than to note its inclusion in the consultation. USFWS has no other active role in the proposed action.

The objective of this opinion is to determine the likely effects on ESA-listed salmon and steelhead and their designated critical habitat resulting from these Federal actions. The effects of funding the programs are subsumed within the operation of these hatchery programs. Therefore, this opinion will determine if the actions proposed by the operators comply with the provisions of sections 7 and 4(d) of the ESA. The duration of the Proposed Action is unlimited for the 4(d) determination. More information on the management of each program follows in the description below.

1.3.1 Describing the Proposed Action

1.3.1.1 Proposed hatchery broodstock collection, mating, and rearing protocols

Up to 130 natural- and hatchery-origin Chinook salmon will be collected as volunteers to the Dungeness River Hatchery ladder and trap, at the mainstream weir and trap located in the lower Dungeness River below river mile (RM) 5, and as opportunistic gillnetting and gaffing in the lower Dungeness River. Dungeness River Hatchery will operate its fish ladder and trap from mid-May through February to collect Chinook salmon as broodstock. Collection of Chinook salmon broodstock in the lower river and the mainstem weir occurs as needed from May through September. If water levels are very low to the point co-managers anticipate environmental conditions will impede successful spawning, adult Chinook salmon collected in excess of broodstock needs may be moved up into the watershed up to RM 15.3 in order to increase the probability of successful spawning. The progeny of any captive brood adults will be differentially marked so they can be identified and will not be collected for broodstock. Progeny of captive brood adults and any other adult Chinook salmon not needed as broodstock will be returned to the river or moved upriver if warranted by environmental conditions.

The co-managers’ annual escapement goal is 1200 Chinook salmon spawning naturally in the Dungeness Basin with at least 50% of spawners being NORs. To achieve this goal, up to 640 juvenile Chinook salmon will be retained at the Dungeness hatchery annually for a captive broodstock component. After tagging, juveniles destined for the captive brood component will be moved to Hurd Creek Hatchery. The adults maintained as captive brood will be held and spawned at Hurd Creek Hatchery. To maintain genetic variation in the captive brood component, up to 20 fertilized eggs will be retained from approximately 40 – 50 river spawned families depending on available space. These fish would then be reared on-station at Hurd Creek Hatchery annually as captive broodstock. Each brood year will be ponded separately. Jacks will be included as broodstock. Excess jacks will be removed and surplused when encountered.

Juveniles would be held annually for the captive broodstock program and the offspring of successfully spawned captive brood fish would be released for eight years. During the eight-year period the captive brood program is active, adults held as captive brood may be outplanted to spawn naturally in the upriver areas of the Dungeness River basin up to RM 15.3 or the rearing channel next to the Dungeness hatchery if they are not needed as broodstock. The rearing channel is equipped with a counter so any juveniles produced by adults planted in the channel can be enumerated as they out-migrate from the channel. This will allow for opportunities to ascertain the productivity of captive-reared adults. After this eight year period, adults currently held as captive brood will be planted in up-river spawning areas up to RM 15.3 or the rearing channel next to Dungeness Hatchery.

All available mature Chinook salmon collected from returns to the river are used for spawning. Adults held as broodstock are chosen at random for spawning, without consideration for age or size. The program goal is to conduct mating at a 1:1 sex ratio. For the captive broodstock, fertilized eggs will be pooled after 1:1 spawning.

The co-managers would reserve the ability to re-initiate the captive brood component if adult spawning escapement over multiple return years declines below the rebuilding threshold of 925 (NMFS 2020). In the future, it is possible some of the Dungeness Chinook salmon juveniles produced from the captive broodstock will be used for other recovery programs, such as the proposed Mid-Hood Canal program, which would be analyzed in a separate Biological Opinion addressing the effects of that program.

1.3.1.2 Proposed release protocols

In May through the end of June, 600,000 sub-yearling Chinook salmon will be released annually at 50 fish per pound with an estimated 400,000 of these juveniles originating from the captive broodstock program. Up to 100,000 of the juveniles may be released as yearlings instead of sub-yearlings at the co-managers discretion in March through April. The co-managers may opt to hold a portion or the entirety of the sub-yearling production for a late August through October release. Chinook salmon may be released infrequently at other times at the direction of a fish health specialist to address fish health concerns or during emergency situations such as floods or low water events. While the proposed release level is 600,000 sub-yearlings, our analysis was performed at 660,000 sub-yearlings to account for the 10% increase in the production level allowed as a buffer against variability in within-hatchery survival; an overage of 10% is anticipated to be an infrequent occurrence with a five-year running average of the total number of Chinook salmon released not to exceed 630,000 fish with no one year's release exceeding 660,000 juvenile Chinook salmon.

Once the juveniles produced as part of the captive brood component have been released for eight years and juveniles are no longer held on station to mature as captive broodstock the release number will decline back to current levels. The co-managers expect eight captive brood years will be required to meet the escapement goal (Table 2). The first release of juveniles created as part of the captive brood will be in 2022 and 2029 is the final year juveniles created as part of the captive broods will be released. Once the progeny of all fish held as captive broodstock have been released, the proposed release level will be 200,000 juvenile Chinook salmon with up to 100,000 being released as yearlings at the co-managers discretion. As a buffer against variability in in-hatchery survival, a 10% increase in the production level may occur infrequently with a five-year running average of the total number of juvenile Chinook salmon released not to exceed 210,000 fish and no one year's release exceeding 220,000 juvenile Chinook salmon.

Table 2. Estimated adult returns by release site for sub-yearling releases associated with the Dungeness Chinook salmon hatchery program.

Release Site	SAR%	700K	600K	500K	400K
Dungeness	0.23	402	345	287	230
Hurd Creek	0.46	805	690	575	460

Upper Dungeness	0.37	648	555	463	370
Gray Wolf	0.30	525	450	375	300
High Bound		2380	2040	1700	1360
Low Bound		2100	1800	1500	1200

Although the co-managers goal is to release 600,000 sub-yearlings, the productivity of the captive brood program is likely to be variable across years. The current egg-take goal for the Dungeness River spring Chinook program is 230,000 with the egg-take goal for the captive brood component of the program being up to 460,000. The maximum production from the captive brood component is estimated to be 840,000 eggs. The co-managers will release all juveniles produced through the captive brood component. However, when egg takes indicate the release goal is likely to be achieved, ripe adults produced as part of the captive brood will be released into a rearing channel adjacent to the hatchery. If the number of juveniles released from the captive brood component exceeds the target for three consecutive years, the co-managers will adjust the number of fish held for captive brood downward. If excess captive reared adults are released into the Dungeness River for any reason, they will be released below RM 15.3.

All Chinook salmon will be marked with a CWT and the adipose fin of juveniles produced from in-river broodstock collections will remain intact. Progeny of captive brood adults will also receive a vent clip, adipose fin clip, or some other co-manager agreed to mark to distinguish them from the offspring of adults collected in the river. As discussed above, Chinook salmon produced by the captive brood component will have a different tag code to allow monitoring of the production from different program components. Co-managers may release 10% of juveniles produced through either component of the program with an adipose fin clip to determine rates of encounter in mixed-stock marine fisheries.

Fish may be released volitionally from the Dungeness River Hatchery, Hurd Creek Hatchery, Gray Wolf Acclimation Pond, and Upper Dungeness Acclimation Pond. Chinook salmon may also be trucked to the lower Dungeness River for release to avoid predation during release. The co-managers will take an adaptive management approach to release locations and may select alternative release locations from RM 0.9 to RM 15.8 in the Dungeness watershed to maximize survival. However, no more than 100,000 hatchery juvenile Chinook salmon will be released above RM 15.3. Data will be collected to allow analysis of release locations that promote survival and reduce exposure to predators. Dungeness spring Chinook salmon have experienced high levels of predation during marine emigration, so co-managers may release Chinook salmon at different locations each year to deter predators. The co-managers will include an explanation of the results of previous release sites and the choice for selecting current release sites in the report submitted to NMFS annually.

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" (WWTIT and WDFW 2006).

1.3.1.3 Proposed Chinook salmon adult management

The Dungeness Chinook salmon program does not have a target for integration of NORs. NORs generally make up 20-30% of the broodstock and is consistent with the composition of Chinook salmon carcasses encountered during spawning ground surveys. As the abundance of Chinook salmon spawning naturally increases the number of NORs in the Dungeness River, the co-managers expect the proportion of NORs collected for broodstock to increase as well.

Carcasses of inoculated Chinook salmon are disposed of in a landfill. Other Chinook salmon carcasses may be returned to the river for nutrient enhancement or disposed of in a landfill.

1.3.1.4 Proposed research, monitoring, and evaluation

The co-managers will conduct annual spawning ground surveys throughout the Dungeness Watershed to identify natural-origin and CWT hatchery-origin Chinook salmon and to provide estimates of natural spawner escapement. A smolt trap is used to monitor outmigration. The co-managers will conduct genetic monitoring to evaluate the conservation genetic benefits of the Dungeness Chinook hatchery program in maintaining genetic diversity until habitat improves to the point of supporting a viable population of naturally spawning Chinook salmon. Co-managers will collect tissues from Chinook salmon collected for broodstock, carcasses of fish that spawned in the river, adults handled and released to spawn naturally, juveniles produced as part of the hatchery program, and naturally produced juveniles to understand patterns of spatial genetic diversity within the Dungeness watershed. Co-managers will collaborate with WDFW Molecular Ecology Laboratory staff to conduct annual genetic analysis as outlined in the co-managers genetic monitoring proposal (WDFW 2022). At this time, funding for genetic analysis of Chinook salmon held as captive brood is available through the most recent PST funding cycle.

Returning Chinook salmon will be thoroughly monitored during and after the captive brood program to identify factors relating to the success of the program. Records of factors that have led to increased juvenile survival and adult returns as well as those that have led to more substantial losses will provide valuable information as to how to best operate captive broodstock programs. During operation of the previous captive brood program, for example, the use of river water during rearing and the presence of the pathogen Cryptobia were found to reduce survival. This information has led to the current captive brood program being reared solely on pathogen free ground water at Hurd Creek Hatchery to increase survival. Chinook salmon produced as part of the captive brood program will be differentially CWT marked to monitor return rates of captive brood vs non-captive brood juveniles. Differential CWTs will also be informative during spawning ground surveys to determine if Chinook salmon produced as part of the captive brood program return to spawning grounds at the same rate as NORs and spawn at the same time and place as NORs.

The co-managers will investigate vent clipping progeny of the captive brood program so they can be visually differentiated from progeny of the adults collected for broodstock. Captive brood progeny will only be vent clipped if it is found to not substantially reduce survival. The co-managers will collect data to determine if vent clipping reduces survival and if the vent clip heals to become indistinguishable over time. If successful, vent clipping would be valuable in many hatchery programs as an externally visible mark. Vent clipped Chinook salmon would not be used as broodstock to avoid domestication, they would be released upstream to spawn in the wild. This would ensure fish spawned in the hatchery were only one generation removed from in-river fish. If vent clipping is not successful co-managers will determine an alternative exterior mark to apply to progeny of captive brood including adipose clips.

To monitor genetic variation and manage matings, tissue samples will be collected from every captive brood fish spawned. Co-managers may examine the possibility of a Parental Based Tagging (PBT) study to better understand population dynamics in the Dungeness River Basin. Chinook fin clip samples may be collected from all broodstock at Hurd Creek and captive brood, from spawning ground carcasses that are in good condition, and out-migrating smolts. Genetics analysis may also include an analysis of run-timing markers, Y chromosome markers, genes associated with age at maturity, and pedigree analysis to better understand reproductive success.

The co-managers propose to evaluate different release strategies and release locations within the Dungeness watershed to maximize survival of emigrating juveniles and productivity of spawning adults. This will include an evaluation of bulltrout and other predators on hatchery and wild Chinook salmon. Annual surveys to locate adult carcasses will be conducted throughout the Dungeness watershed. Fin clips and CWTs will be collected from any carcasses found to assess efficiency of different release strategies and to determine the origin of spawners.

Research into the effectiveness of the Vibrio vaccine in reducing pathogens will be conducted in collaboration with fish health experts over a four-year time period. The vaccinated and unvaccinated groups of Chinook salmon have differing CWT tag codes so adult return rates can be monitored to measure the success of the vaccine. If it is successful all Chinook may be vaccinated at the recommendation of fish health experts.

Table 3. Research, monitoring, and evaluation associated with the three Dungeness hatchery programs and any existing ESA coverage.

Activity	Associated Program	ESA Coverage
Monitor adult collection, numbers, origins, sex, adipose fin clip or other external mark and CWT status and record fork length, and collect scales, otoliths, tissues for genetic analysis and record other demographic data from 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; 4(d) WDFW permit 24284
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
Genetic monitoring of Chinook salmon at the hatchery and throughout the watershed	Dungeness Chinook salmon	This Opinion
Sample terminal area fisheries, spawning grounds, and hatcheries for CWTs, otoliths, scales, tissues for DNA analysis, demographic and morphometric data	All	This Opinion
Sonar surveys to estimate steelhead throughout the river	All	4(d) WDFW Permit 24276
Within hatchery monitoring of fish health and survival	All	This Opinion

1.3.1.5 Proposed Facility Operations

The mainstem weir is operated in the Dungeness River periodically to collect Chinook salmon from May (if feasible given flow levels) through the end of September. The mainstream weir consists of panels, which may be removed to allow fish to freely access areas above the weir. Sections of the weir have larger 2.5-inch openings between panels, which allow non-target fish species including pink salmon and bull trout to swim through the panels and freely access upstream locations even when the weir is operational. The weir panels are first put in the River when flows reach 300 cfs, which generally does not occur until July. The weir panels are set in place Sunday afternoons and removed Friday afternoons allowing fish a two-day period each week to freely move into the upper watershed. The weir panels may be removed for longer time periods during this operational period if broodstock are not being collected. The weir is checked twice daily when in place and non-target species as well as Chinook salmon not needed for broodstock are passed upstream. The weir is only used to collect broodstock for the Chinook salmon program and the panels are removed for the year once the broodstock target has been met. Chinook salmon collected as broodstock are representative of the run-at-large adult returns. In 2021, most of the egg take came from adult Chinook salmon that were collected via net collections with only 20 adult Chinook salmon collected at the weir. Generally, half of the adult Chinook salmon used for broodstock are collected at the weir. Adult Chinook salmon collected at the weir that are not needed for broodstock may be trucked upstream below RM 15.3 when water conditions are low to facilitate escapement under adverse conditions. The co-managers will explore an optimal location for the weir below RM 5 to find a location to efficiently collect broodstock without adverse effects on non-target species.

Since the 2016 BiOp was completed, a fish ladder has been constructed at the Canyon Creek diversion dam, which is used to withdraw water for use in the Dungeness Hatchery. The Canyon Creek intake now meets NMFS most current screening standards (NMFS 2013b). Water is withdrawn from Canyon Creek only when withdrawal of water from the main source in the Dungeness River becomes infeasible due to icing and high flows during the winter months when flows are at their highest. Water flow is too low in Canyon Creek to use the intake during the summer and fall months when flows in Canyon Creek are at their lowest.

The Dungeness River Hatchery facility uses surface water exclusively, withdrawn through one water intake on the Dungeness River and one on Canyon Creek, an adjacent tributary. Hurd Creek Hatchery facility uses a combination of groundwater withdrawn from five wells, and surface water withdrawn from Hurd Creek for fish rearing and as an emergency back-up source. No additional water will need to be withdrawn to maintain the captive brood component at Hurd Creek Hatchery. The Gray Wolf Acclimation Pond is supplied with surface water that is gravity fed from the Gray Wolf River. The Upper Dungeness Acclimation Ponds are supplied with pumped surface water from the Dungeness River. Water withdrawals up to maximum levels would only occur during the spring months, when fish sizes and rearing water needs at the hatcheries are highest and flows in surface waters are at seasonal maximums. All water used at the facilities is non-consumptive and discharged 0.9 miles downstream of the Dungeness Hatchery intake, 0.5 miles downstream of the Canyon Creek intake, and adjacent to the Hurd Creek Hatchery.

The main water intake on the Dungeness River mainstem where most water is currently withdrawn for fish production at Dungeness River Hatchery is in compliance with current NMFS fish passage guidelines (NMFS 2011a) to protect juvenile fishes. The surface water emergency backup intake screens for Hurd Creek Hatchery are in compliance with earlier federal guidelines (NMFS 1995; 1996), but do not meet more recent criteria (NMFS 2011a; WDFW 2013a). Co-managers have plans to upgrade these screens to meet the most current federal guidelines and work will begin as soon as requested funding is allocated and the necessary permits have been granted with work anticipated to be completed by fall 2024.

Table 4. Water source, water withdrawal amount, NPDES and water rights permits, and screening information for facilities associated with the three hatchery programs presented in the Dungeness River HGMPs.

Facility	Water Source	Withdrawal (cfs)	Instream Structures	Water Rights Permit*	NPDES	Screening
Hurd Creek Hatchery	Ground Water	6.4 cfs	Intake	G2-24026	Not Required	Meets NMFS 1995 Standards
	Hurd Creek	1.4 cfs				
Dungeness Hatchery	Dungeness River	25 cfs	Intake	S2-06221	WAG 13-1037	Meets NMFS 2011 Standards
		15 cfs	Intake	S2-21709		
	Canyon Creek	8.5 cfs	Intake	S2-00568		Meets NMFS 2011 Standards
Gray Wolf Acclimation Pond	Gray Wolf River	1.0 cfs	None; Gravity fed		Not Required	Not Applicable
Upper Dungeness Acclimation Pond	Dungeness River	1.0 cfs	None; Gravity fed		Not Required	Not Applicable

All Dungeness River Hatchery programs operate under National Pollutant Discharge Elimination System (NPDES) permit number WAG 13-1037. Under its NPDES permit, Dungeness River Hatchery operates an off-line settling pond and artificial wetland to remove effluent before the water is released back into the Dungeness River (WDFW 2013a). Although under the 20,000 pounds per year fish production criteria set by WDOE as the limit for concern regarding hatchery effluent discharge effects, at Hurd Creek Hatchery, WDFW has constructed a two-bay pollution abatement pond to treat water prior to its release into Hurd Creek. The fish rearing ponds on the Gray Wolf River and the Upper Dungeness River also have low annual fish production levels, below those for which a NPDES permit is required.

2 ENDANGERED SPECIES ACT: BIOLOGICAL OPINION AND INCIDENTAL TAKE STATEMENT

The ESA establishes a national program for conserving threatened and endangered species of fish, wildlife, plants, and the habitat upon which they depend. As required by section 7(a)(2) of the ESA, each Federal agency must ensure that its actions are not likely to jeopardize the continued existence of endangered or threatened species, or 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 rangewide status of the species and critical habitat expected to be adversely affected by the proposed action.
- Evaluate the environmental baseline of the species and critical habitat.
- Evaluate the effects of the proposed action on species and their 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 that would be adversely affected by the proposed action. The status is determined by the level of extinction risk that the listed species face, based on parameters considered in documents such as recovery plans, status reviews, and listing decisions. This informs the description of the species' likelihood of both survival and recovery. The species status section also helps to inform the description of the species' "reproduction, numbers, or distribution" as described in 50 CFR 402.02. The opinion also examines the condition of critical habitat throughout the designated area, evaluates the conservation value of the various watersheds and coastal and marine environments that make up the designated area, and discusses the function of the PBFs that are essential for the conservation of the species.

Table 5. 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 Life History and Status of the 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. 2006). The ESU encompasses all runs of Chinook salmon from rivers and streams flowing into Puget Sound, including the Strait of Juan de Fuca from the Elwha River eastward, and rivers and streams flowing into Hood Canal, South Sound, North Sound, and the Strait of Georgia in Washington. We use the term ''Puget Sound'' to refer to this collective area of the ESU. As of 2016, there are 24 artificial propagation programs producing Chinook salmon that are included as part of the listed ESU (71 FR 20802, April 14, 2014). Indices of spatial distribution and diversity have not been developed at the population level, though diversity at the ESU level is declining (NWFSC 2015; Ford 2022).

Table 6 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. Total abundance in the ESU over the entire time series shows that trends for individual populations are mixed. Generally, many populations experienced increases in total abundance during the years 2000-2008, and more recently in 2015-2017, but general declines during 2009-2014, and a downturn again in the two most recent years, 2017-2018. The downturn in the most recent years was likely associated with the period of anomalously warm sea surface temperatures in the northeast Pacific Ocean that developed in 2013 and continued to persist through much of 2015; this phenomenon was termed “the Blob.” Chinook salmon returning in 2017 and 2018 would have reached maturation in the ocean during these years, experiencing lower marine survival as a result of the hostile ocean conditions. Abundance across the Puget Sound ESU has generally increased since the last status review, with only 2 of the 22 populations (Cascade and North Fork Stillaguamish) showing a negative % change in the 5-year geometric mean natural-origin spawner abundances since the prior status review. Several populations (North Fork and South Fork Nooksack, Sammamish, Green, White, Puyallup, Nisqually, Skokomish, Dungeness and Elwha) are dominated by hatchery returns. Fifteen of the remaining 20 populations with positive % change in the 5-year geometric mean natural-origin spawner abundances since the prior status review have relatively low natural spawning abundances of < 1000 fish, so some of these increases represent small changes in total abundance (Ford 2022).

The Recovery Plan describes the ESU's population structure, identifies populations essential to recovery of the ESU, establishes recovery goals for most of the populations, and recommends habitat, hatchery, and harvest actions designed to contribute to the recovery of the ESU (NMFS 2006; SSPS 2007). It adopts ESU and population level viability criteria recommended by the Puget Sound Technical Recovery Team (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 2010). NMFS understands that there are non-scientific factors, (e.g., the importance of a salmon or steelhead population to tribal culture and economics) that are important considerations in salmon and steelhead recovery. Tier 1 populations are of primary importance for preservation, restoration, and ESU recovery. Tier 2 populations play a secondary role in recovery of the ESU and Tier 3 populations play a tertiary role. When NMFS analyzes proposed actions, it evaluates impacts at the individual population scale for their effects on the viability of the ESU. Accordingly, impacts on Tier 1 populations would be more likely to affect the viability of the ESU as a whole than similar impacts on Tier 2 or 3 populations.

Trends in long-term growth rate of natural-origin escapement are generally higher than growth rate of natural-origin recruitment (i.e., abundance prior to fishing) indicating some stabilizing influence on escapement, possibly from past reductions in fishing-related mortality (Table 7). Since 1990, 13 populations show long-term growth rates that are at or above replacement for natural-origin escapement including populations in four of five regions. Currently, only five populations, in two regions, show long-term neutral to positive growth rates in natural-origin recruitment (Table 7). Additionally, most populations are consistently well below the productivity goals identified in the recovery plan (Table 6). Although long-term trends (1990 forward) vary for individual populations across the ESU, currently 20 populations exhibit a stable or increasing long-term trend in total natural escapement (Table 7). Thirteen of 22 populations show a growth rate in the 18-year geometric mean natural-origin spawner escapement that is greater than or equal to 1.00 (Table 7). Even given some of the incremental increases in natural-origin spawner abundances in the most recent five-year period, the long-term trends in both abundance and productivity, in most Puget Sound populations, are well below the levels necessary for recovery (Table 7).

Table 6. Long-term[13] estimates of escapement and productivity (recruits/spawner) for Puget Sound Chinook populations. Natural origin escapement information is provided where available. Populations at or below their critical escapement threshold are bolded. Populations exceeding their rebuilding natural-origin escapement threshold are underlined.

Region	Population	1999 to 2018 Run Year Geometric mean Escapement (Spawners)		NMFS Escapement Thresholds		Recovery Planning Abundance Target in Spawners (productivity)[2]	Average % hatchery fish in escapement 1999-2018 (min-max)[5]
		Natural [1]	Natural-Origin (Productivity[2])	Critical[3]	Rebuilding[4]		
Georgia Basin	Nooksack MU	1,798	236	400	500		
	NF Nooksack	1, 532	**180** (0.3)	*200*[6]	-	3,800 (3.4)	86 (63-97)
	SF Nooksack	266	**56** (1.9)	*200*[6]	-	2,000 (3.6)	51 (19-82)
Whidbey/Main Basin	Skagit Summer/Fall MU						
	Upper Skagit River	9,349	8,314 (2.7)	738	5,740	5,380 (3.8)	11 (2-36)
	Lower Sauk River	560	531 (3.1)	*200*[6]	371	1,400 (3.0)	5 (0-33)
	Lower Skagit River	2,090	1,845 (2.8)	281	2,131	3,900 (3.0)	9 (0-23)
	Skagit Spring MU						
	Upper Sauk River	633	624 (2.2)	130	470	750 (3.0)	1 (0-5)
	Suiattle River	379	372 (2.0)	170	223	160 (2.8)	2 (0-7)
	Upper Cascade River	289	260 (1.5)	130	148	290 (3.0)	7 (0-25)
	Stillaguamish MU						
	NF Stillaguamish R.	1,029	472 (0.9)	300	550	4,000 (3.4)	51 (25-80)
	SF Stillaguamish R.	122	**58** (1.2)	*200*[6]	300	3,600 (3.3)	48 (9-79)
	Snohomish MU						
	Skykomish River	3,193	2,212 (1.5)	400	1,491	8,700 (3.4)	28 (0-62)
	Snoqualmie River	1,449	1,182 (1.3)	400	816	5,500 (3.6)	18 (0-35)

Region	Population	1999 to 2018 Run Year Geometric mean Escapement (Spawners)		NMFS Escapement Thresholds		Recovery Planning Abundance Target in Spawners (productivity)[2]	Average % hatchery fish in escapement 1999-2018 (min-max)[5]
		Natural [1]	Natural-Origin (Productivity[2])	Critical[3]	Rebuilding[4]		
Central/South Sound	Cedar River	924	659 (2.7)	*200*[6]	*282*[7]	2,000 (3.1)	28 (10-50)
	Sammamish River	1,073	**161** (0.5)	*200*[6]	*1,250*[6]	1,000 (3.0)	80 (36-96)
	Duwamish-Green R.	4,014	1,525 (1.4)	400	1,700	-	59 (27-79)
	White River[9]	1,859	625 (0.8)	*200*[6]	488[7]	-	59 (14-90)
	Puyallup River[10]	1,646	784 (1.2)	*200*[6]	797[7]	5,300 (2.3)	54 (19-83)
	Nisqually River	1,670	621 (1.5)	*200*[6]	1,200[8]	3,400 (3.0)	56 (17-87)
Hood Canal	Skokomish River	1,398	**282** (0.8)	452	1,160	-	71 (7-96)
	Mid-Hood Canal Rivers[11]	**187**		*200*[6]	*1,250*[6]	1,300 (3.0)	36[11] (2-87)
Strait of Juan de Fuca	Dungeness River	411	**98**(1.0)	*200*[6]	925[8]	1,200 (3.0)	72 (39-96)
	Elwha River[12]	1,231	**171**(1.02)	*200*[6]	*1,250*[6]	6,900 (4.6)	74 (31-98)

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

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

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

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

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

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

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

[8] Based on alternative habitat assessment.

[9] Captive broodstock program for early run Chinook salmon ended in 2000; estimates of natural spawning escapement include an unknown fraction of naturally spawning hatchery-origin fish from late- and early run hatchery programs in the White and Puyallup River basins.

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

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

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

[13] Differences in results reported in Tables 5 and 6 from those in the most recent status review (Tables 3 and 4, above) are related to the data source, method, and time period analyzed (e.g., 5-year vs 20-year estimates).

Table 7. Long-term trends[1] in abundance and productivity for Puget Sound Chinook populations. Long-term, reliable data series for natural-origin contribution to escapement are limited in many areas.

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

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

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

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

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

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[1] Differences in results reported in Tables 5 and 6 from those in the most recent status review (Tables 3 and 4, above) are related to the data source, method, and time period analyzed (e.g., 5-year vs 20-year estimates).

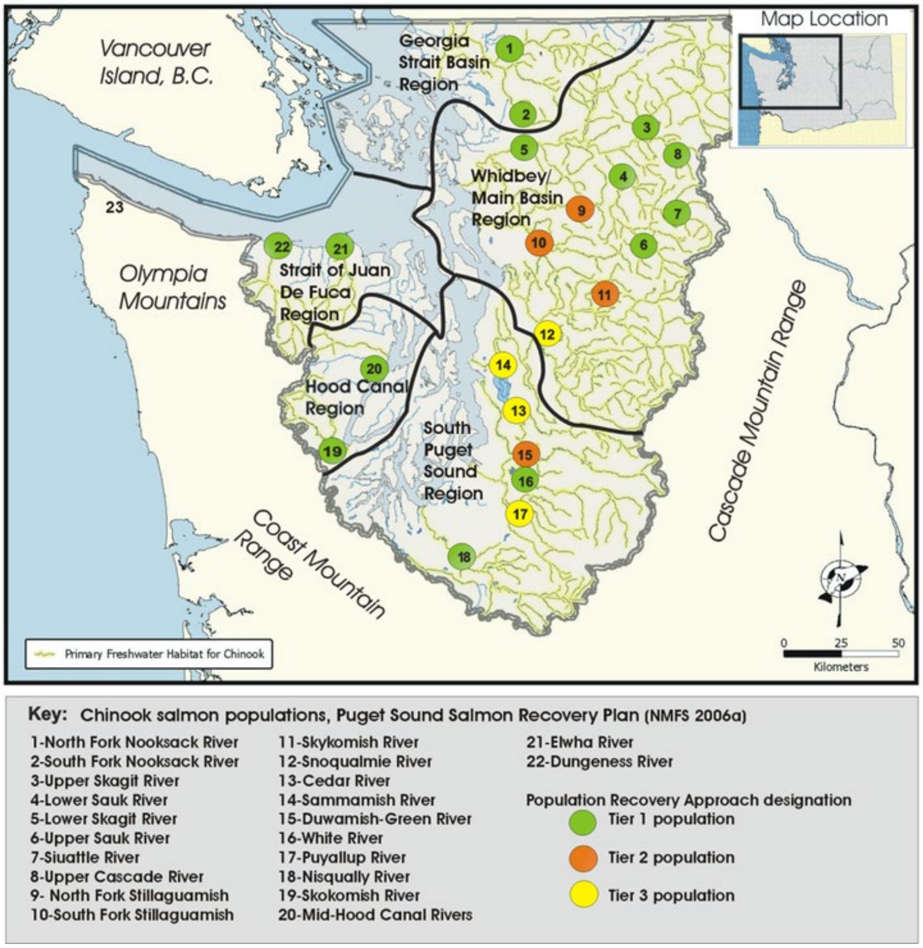

Figure 1. Populations delineated by NMFS for the Puget Sound Chinook salmon ESU and their assigned Population Recovery Approach tier status (SSPS 2007; NMFS 2010). Note: Dosewallips, Duckabush and Hamma Hamma River Chinook salmon are aggregated as the "Mid Hood Canal" population.

The limiting factors described in SSPS (2007) and NMFS (2006) 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).

Strait of Juan de Fuca BGR

The Strait of Juan de Fuca BGR contains two Chinook salmon populations: Dungeness and Elwha. Both populations would need to be viable for recovery of the ESU (NMFS 2006). The Dungeness and Elwha are early and late-timed populations, respectively, although both basins historically exhibited components across the run-timing spectrum (Ruckelshaus et al. 2006). Evidence suggests that much of the life-history diversity represented by early-type populations or population components that existed historically in the Puget Sound Chinook ESU has been lost (Ruckelshaus et al. 2006) so protection of the remaining early-type populations like the Dungeness is particularly important to recovery of the ESU. Genetic and ocean distribution data indicate the Elwha population is intermediate between Puget Sound and Washington coastal populations and considered to be a transitional population between the Puget Sound and Washington Coastal Chinook salmon ESUs (Myers et al. 1998). Based on the most recent available information, escapement in both populations in the BGR are above their critical thresholds but below rebuilding thresholds with high proportions of the escapement being composed of hatchery-origin Chinook salmon (Table 6). Both populations show a declining growth rate (Table 7). Both populations have on-going conservation hatchery programs to increase the number of natural spawners and reduce short-term extinction risk. These supportive hatchery programs are considered essential components to the recovery strategies for both populations (SSPS 2005; Ward et al. 2008; NMFS 2012b). The Elwha River watershed is undergoing a substantial restoration effort associated with removal of the two dams, which restored salmon access to 70 miles of spawning and rearing habitat (Ward et al. 2008). In summary, populations within the Strait of Juan de Fuca BGR exhibit life history components unique within the ESU and present significant challenges to ESU recovery given their critical status.

Dungeness Population

The extant Dungeness Chinook salmon population is considered a spring/summer-run timed (or “early”) population, based on spawn timing. The population spawns in the watershed from mid-August to mid-October (WDFW 1994b; 1994a). Chinook salmon spawn in the mainstem Dungeness River up to RM 18.7, where natural falls block further access. Spawning distribution in recent years has been weighted toward the lower half of the accessible river reach, with approximately 75 percent of redds located downstream of RM 10.8. Chinook salmon also spawn in the Gray Wolf River (confluence with Dungeness at RM 15.8) up to RM 5.1 (WDFW 1994b; 1994a). From 1998-2020 the average proportion of Chinook redds in the Dungeness River were

0.731 in the lower basin (RM 0.5- RM 10.8), 0.214 in the upper basin (RM 10.8- RM 18.7), and 0.073 in the Gray Wolf River (RM 0.0-6.1) (Table 8). In 2020, 279 Chinook salmon redds were counted in the Dungeness River equating to 698 adults and 14 redds were counted in the Gray Wolf River equating to 35 adults for a total estimated return to the river of 733 adults with another 100 adults collected for hatchery broodstock (WDFW 2020).

Table 8. Chinook salmon redd survey index sections in the Dungeness and Gray Wolf rivers including the minimum, maximum, and average redd counts, proportion of redds per reach, and average redds per mile from 1998-2020.

Stream and section	Reach	SURVEY REACHES (miles)				Minimum	Maximum	Average		Average
	Number	Lower RM	Upper RM	Total length (mi)	2021	Redd count	Redd count	Redd count	Proportion	redds/mi
Mouth to Woodcock Bridge	1	0.5	3.3	2.80	23	2	127	33.2	0.167	11.85
Woodcock Bridge to Hwy 101	2	3.3	6.4	3.10	74	1	128	43.8	0.229	14.12
Hwy 101 to Taylor Cut-Off - May	3	6.4	9.2	2.80	69	5	88	37.7	0.198	13.45
Taylor Cut-Off - May to Canyon Ck.	4	9.2	10.8	1.60	38	4	75	28.0	0.145	17.53
Total				**10.30**	**204**			**142.7**	**0.739**	**13.85**
Canyon Creek to Clink Bridge	5	10.8	13.8	3.00	4	0	79	18.7	0.092	6.25
Clink Bridge to Forks Campground	6	13.8	15.8	2.00	10	0	59	11.6	0.059	5.78
Forks Campground to East Crossing	7	15.8	17.5	1.70	3	0	42	9.3	0.046	5.50
East Crossing to Gold Creek	8	17.5	18.7	1.20	0	0	13	2.1	0.010	1.78
Total				**7.90**	**17**	**3**	**193**	**41.8**	**0.208**	**5.29**
Mouth to RM 1.0 Bridge	9	0.0	1.0	1.00	2	0	26	5.5	0.027	5.52
RM 1.0 Bridge to Above 2 Mile Camp	10	1.0	2.5	1.50	0	0	38	4.6	0.022	3.04
Above 2 Mile Camp to Cliff Camp	11	2.5	4.0	1.50	NS	0	5	0.4	0.002	0.27
Cliff Camp to Slab Camp -Suppl. Surveys	12	4.0	5.1	1.10	NS	0	3	0.2	0.001	0.21
Slab Camp and upstream 1 mile -Suppl. Surveys	13	5.1	6.1	1.00	NS	0	0	0.0	0.000	0.00
Total				**6.10**	**2**			**10.7**	**0.053**	**1.75**
Dungeness Basin Grand Total				**24.30**	**223**					

Dungeness Chinook salmon predominantly exhibit an ocean-type life history trajectory (Myers et al. 1998), with juveniles emigrating seaward from mid-February through the end of July (Topping et al. 2008a; Topping et al. 2008b). A small portion of the population (< 5 %) may rear in the river for a year and emigrate seaward as yearlings (Marlowe et al. 2001; SSPS 2005). Adults mature primarily at age four with NOR tending to return at an older age than HOR. Based on the CWT results and scale samples analyzed, the preliminary NOR/HOR composition for return year (RY) 2020 was 323 (38.8%) NOR and 509 (61.2%) HOR. The ages of the NOR Chinook for RY 2020 consisted of 0.0% age 2, 15.8% age-3, 75.2% age-4, and 9.0% age-5 while the HOR Chinook for RY 2020 consisted of 0.0% age 2, 24.0% age-3, 71.3% age-4, and 4.7% age-5 (WDFW 2020).

The current abundance of Dungeness Chinook salmon is substantially reduced from historical levels (SSPS 2005). Between 1999 and 2018, the estimated average total annual naturally spawning Chinook salmon escapement was 411, compared to the recovery goal at high productivity of 1,200 natural spawners (Table 6) (Ford 2022). Hatchery-origin Chinook salmon associated with the Dungeness conservation hatchery program make up a sizeable fraction of the annual naturally spawning adult abundance, averaging 72% for the basin (Table 6). Total naturally spawning fish escapements have fluctuated with changes in the conservation hatchery program with the highest escapements reflecting years when adult progeny from the hatchery program returned to spawn (Figure 2). Total annual naturally spawning Chinook salmon escapement for the most recent 5 years has averaged 779 ranging from 523 to 930, and with 73.5 percent and 26.5 percent on average being hatchery-origin and natural-origin, respectively (Table 9) (WDFW 2020).

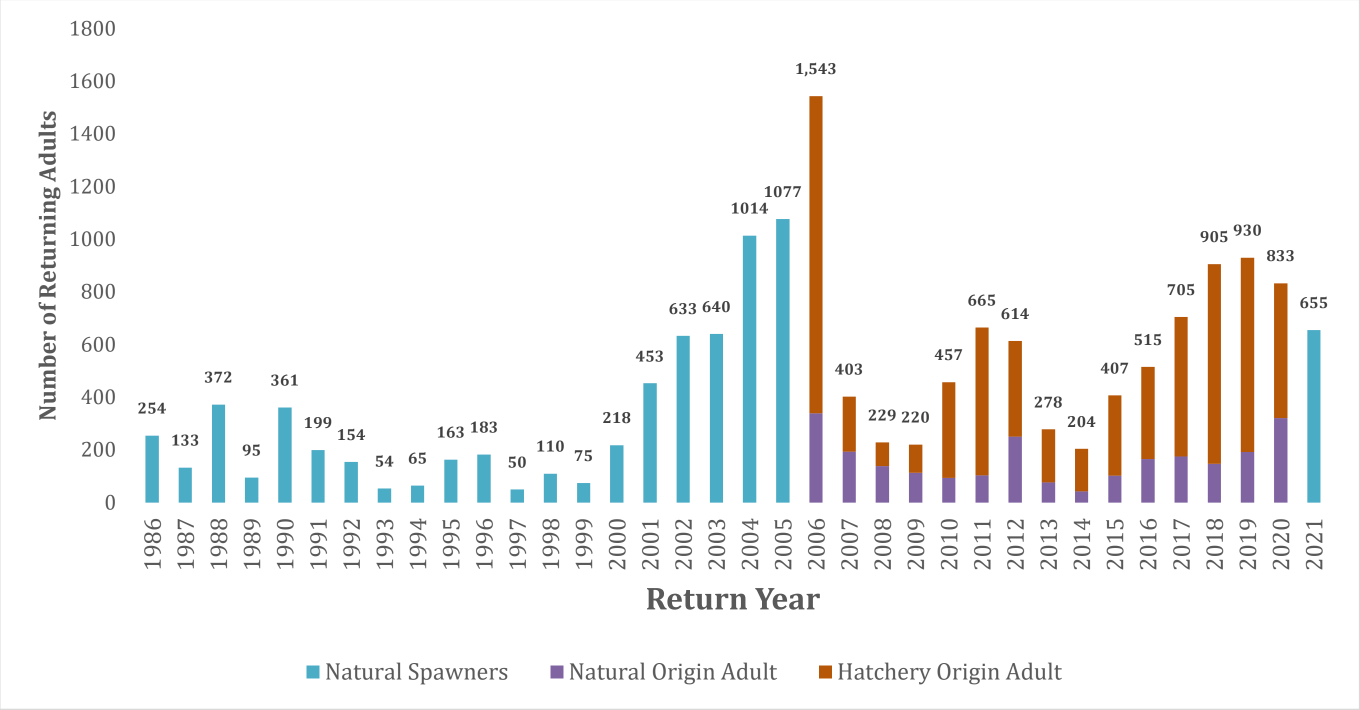

Figure 2. Number of adult Chinook salmon returning to the Dungeness River basin from 1986 to 2020 (WDFW 2020). The adults are broken out into hatchery- and natural-origin in years where this data is available.

Table 9. Total number of natural- and hatchery-origin returning adult Chinook salmon collected in the mainstem Dungeness River from return year 2006 – 2020.

Return year	Natural spawners 1/ NOR	Natural spawners 1/ HOR	Natural spawners 1/ NOR+HOR	Broodstock collection 2/ NOR	Broodstock collection 2/ HOR	Broodstock collection 2/ NOR+HOR	Natural Spawners + Broodstock NOR	Percentage NOR Spawners + Broodstock	Natural Spawners + Broodstock HOR	Percentage HOR Spawners + Broodstock	Total returns NOR+HOR
2006	**293**	**1,112**	**1,405**	**46**	**92**	**138**	339	21.97%	1,204	78.03%	**1,543**
2007	**146**	**159**	**305**	**47**	**51**	**98**	193	47.89%	210	52.11%	**403**
2008	**86**	**54**	**140**	**53**	**36**	**89**	139	60.70%	90	39.30%	**229**
2009	**71**	**57**	**128**	**42**	**50**	**92**	113	51.36%	107	48.64%	**220**
2010	**76**	**269**	**345**	**18**	**94**	**112**	94	20.57%	363	79.43%	**457**
2011	**83**	**452**	**535**	**21**	**109**	**130**	104	15.64%	561	84.36%	**665**
2012	**212**	**296**	**508**	**38**	**68**	**106**	250	40.72%	364	59.28%	**614**
2013	**46**	**122**	**168**	**31**	**79**	**110**	77	27.70%	201	72.30%	**278**
2014	**21**	**87**	**108**	**22**	**74**	**96**	43	21.08%	161	78.92%	**204**
2015	**65**	**200**	**265**	**37**	**105**	**142**	102	25.06%	305	74.94%	**407**
2016	**135**	**273**	**408**	**30**	**77**	**107**	165	32.04%	350	67.96%	**515 4/**
2017	**149**	**456**	**605**	**26**	**74**	**100**	175	24.82%	530	75.18%	**705**
2018	**127**	**661**	**788**	**20**	**97**	**117**	147	16.24%	758	83.76%	**905**
2019	**173**	**665**	**838**	**19**	**73**	**92**	192	20.65%	738	79.35%	**930**
2020	**294**	**439**	**733**	**27**	**70 + 3unk**	**100**	321	38.54%	512	61.46%	**833**
Mean	**131.8**	**353.5**	**485.3**	**31.8**	**76.8**	**108.6**	163.6	31.00%	430.3	69.00%	**599.5**

1/ Natural spawners: Chinook that spawned naturally in the river. Natural spawner estimate based on redd surveys.

2/ Broodstock collection: Chinook that were collected in the river or returned to the hatchery and used for broodstock. Total includes pre-spawn mortalities.

3/ NORs and HORs determined by CWT detection, otolith marks, scales, or visible marks (adipose clips) from broodstock and river carcasses sampled.

4/ Excludes 8 jacks

The most recent NMFS status review for the ESU found that productivity trends for the Dungeness Chinook salmon population, as measured by recruit per spawner and spawner to spawner rates, are low and decreasing with natural spawner-to-spawner productivity falling below replacement levels in all years since the mid-1980s (Ford 2022). Estimates for juvenile Chinook salmon outmigrant production for brood year 2004-2019 ranged from a high of 164,814 out-migrating fish in 2013 to a low of 3,870 outmigrants in 2015 (Table 10). Estimated egg to migrant survival has ranged from 0.99 percent to 15.32 percent and averaged 4.96 percent for return years 2004 through 2019 (WDFW 2020).

Table 10. Natural and hatchery sub-yearling Chinook and natural coho, pink, chum, and steelhead smolt production in Dungeness River for trap years 2005-2020.

TRAP DATE		Sub-yearling Chinook [1]		Natural Smolt Production			
Beginning	Ending	Natural	Hatchery	Coho 1+[3]	Pink 0+[2]	Chum 0+[2]	Steelhead 1+[3]
3/8/2005	8/5/2005	81,865		57,095	0		9,192
2/2/2006	8/17/2006	136,724		43,888	696,642	194,721	6,125
2/21/2007	8/19/2007	110,021	65,016	22,134	0	381,781	11,445
2/13/2008	8/12/2008	11,612	74,038	21,293	472,334	98,483	10,344
2/19/2009	8/12/2009	20,443	11,374	30,780	43,161	630,358	10,101
2/8/2010	7/28/2010	10,604	36,547	38,210	197,963	41,326	17,486
2/9/2011	8/31/2011	10,250	63,608	26,280	33,209	202,658	19,600
2/14/2012	8/28/2012	71,810	72,868	31,794	3,687,547	38,968	5,521
2/6/2013	8/8/2013	164,815	74,038	52,336	11,043	338,568	7,812
1/16/2014	8/13/2014	26,513	86,954	35,839	29,547,068	92,275	13,167
2/4/2015	7/28/2015	3,870	101,696	6,040	0	155,645	5,972
2/3/2016	7/25/2016	5,556	73,279	20,493	89,802	23,927	4,354
2/2/2017	8/10/2017	27,881	33,780	12,991	0	214,914	11,897
2/6/2018	8/14/2018	45,595	56,904	58,173	237,410	27,051	10,387
1/31/2019	8/10/2019	76,474	26,626	48,462	0	63,934	10,618
1/30/2020	8/11/2020	136,130	37,203	34,434	1,331,613	54,697	12,281
Average	**183 trap days**	**58,760**	**58,138**	**33,765**	**2,271,737**	**170,620**	**10,394**

1. Natural origin Chinook production estimates are extrapolated to and starting date of 1/15 and an ending date of 8/31
2. Production estimates for Chinook, chum and Pink are generated using maiden captured fish that are marked after capture and released above the trap. Individual efficiency tests are pooled using a G-test to inform efficiency strata that are applied to the estimated maiden catch for each efficiency strata.
3. Production estimates for Coho and steelhead are generated by utilizing a two-trap design, Coho and steelhead captured in a weir trap on Matriotti Creek located upstream of the screw trap are marked, released, and recaptured downstream in the screw trap. (Source: Pete Topping, WDFW).

Spatial structure for the Dungeness Chinook population has also been affected over time relative to historical levels. A full river spanning permanent weir at RM 10.8 operating in association with the Dungeness River Hatchery program from the 1930s to the 1980s precluded unrestricted upstream access by Chinook salmon and spawning in the upper Dungeness River watershed for 50 years, although some Chinook salmon were known to have regularly escaped upstream during that period (Haring 1999; SSPS 2005). Chinook salmon continue to have access to their historical geographic range of habitat, and now spawn throughout the entire watershed. Low adult return levels in recent years have led to underutilization of accessible areas, especially in the Gray Wolf River (SSPS 2005). Dikes, levees, and other actions to control the lower reaches of the river and tributaries have adversely affected population spatial structure, particularly through adverse impacts on side-channel habitat and increased scour of redds (Haring 1999). These actions have degraded available spawning and migration areas for adult fish, and refugia for rearing juvenile salmon. Finally, water withdrawals associated with human development have substantially reduced flows needed during the adult salmon upstream migration and spawning periods, forcing adults to construct spawning redds in channel areas that are extremely susceptible to sediment scour and aggradation.

Genetic diversity of the Dungeness Chinook salmon population has been substantially impacted by anthropogenic activities over the last century leading to the loss of habitat complexity in the watershed. A captive broodstock program that was terminated in 2004 may have also affected genetic diversity of the Dungeness River Chinook salmon population. In founding the original hatchery program, the risk of within-population genetic diversity loss was reduced by selecting the indigenous Chinook salmon population for use as captive broodstock. The duration of the captive broodstock program was limited to a six-year period (1992 through 1997 broods) to reduce the risk of genetic diversity loss that may occur due to captive breeding.

Recent assessments indicate that only one Chinook salmon stock with no discontinuity in spawning distribution through time or space exists in the basin (Marlowe et al. 2001; Ruckelshaus et al. 2006). As discussed previously, the disproportionate loss of early-run life history diversity represents a particularly significant loss of the evolutionary legacy of the historical Puget Sound ESU. The substantially reduced abundance of the Dungeness spring/summer-run population relative to historical levels represents a risk to remaining ESU diversity.

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 2005a).

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 D 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.

The Dungeness watershed and associated nearshore area received high conservation value ratings. Critical habitat is designated for Puget Sound Chinook in the Dungeness River watershed action area. Critical habitat also encompasses the estuarine areas and adjacent riparian zones in Dungeness Bay. Within the watershed, critical habitat extends from the outlet of the Dungeness River upstream to the limits of Chinook salmon access in the Dungeness River mainstem, Gray Wolf River, Matriotti Creek, and an unnamed tributary (located at latitude 48.1514, longitude – 123.1216), 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 Dungeness Basin including irrigation, channel modifications/diking, forage fish/species harvest, forestry, urbanization, sand/gravel mining, and road building/maintenance (NMFS 2005a).

2.2.1.3 Life History and Status of the Puget Sound Steelhead DPS

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. 2007; Hard et al. 2015). 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 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 3. 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 11).

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 predominantly 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 11. 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)

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[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.

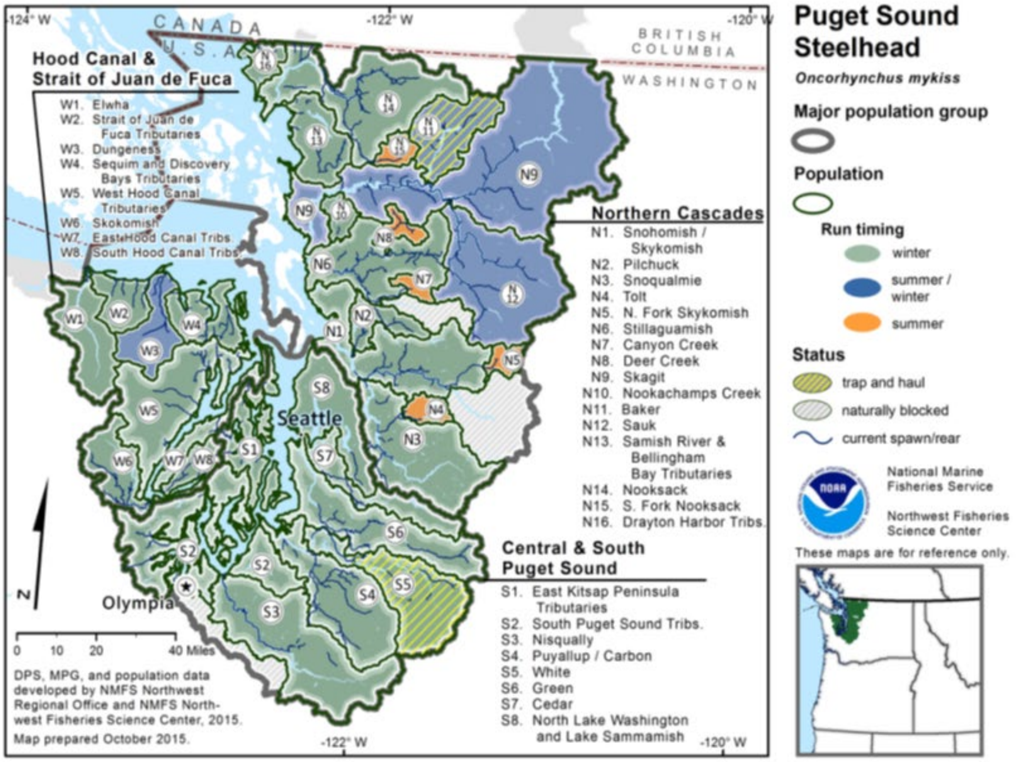

Figure 3. The Puget Sound Steelhead DPS showing MPGs and DIPs. The steelhead MPGs include the Northern Cascades, Central & Sound Puget Sound, and the Hood Canal & Strait of Juan de Fuca. The Dungeness steelhead population is indicated by W3.

Hood Canal and Strait of Juan de Fuca MPG

The Hood Canal and Strait of Juan de Fuca MPG has 8 DIP's including eight summer or summer/winter, and eight winter DIPs (Table 11). In general, populations in this MPG have experienced an increase in abundance during the 2015-2019 period. The five-year geomean for the Elwha River DIP increase to 1,241 winter run steelhead, an 82% increase over the 2010- 2014 period. Productivity estimates for recent brood years have also been strongly positive (Ford 2022). In addition, summer run steelhead have been observed in the upper Elwha River, with recent counts in the low hundreds of returning adults. Rather than a recolonization, these fish appear to be re-anadromized *O. mykiss* from summer-run steelhead originally isolated behind the Elwha and Glines Canyon dams. Although summer run may also persist as residents or at very low abundances elsewhere in the MPG, the Elwha River population is the only extant summer run identified, and although precise data on this "population" is lacking, it represents a considerable contribution to the DPS. The Skokomish River winter-run steelhead DIP exhibited a five-year geomean abundance of 958, an 80%

increase over the previous five-year period, and represents the second largest DIP in this MPG (Table 12). Further, both the long-term trend, 10% (Table 13), and recent productivity are both strongly positive. The Dungeness River Summer and Winter DIP abundance was estimated at 408; however, this represented a 21% decrease over the previous period (Table 12), longer term trends could not be calculated, but the current abundance level is an improvement over estimates from the 1990s. The remaining populations consist of assemblages of small tributaries with abundances of less than 250 individuals. The three Hood Canal winter run populations (Eastside Hood Canal, South Hood Canal, and Westside Hood Canal) all experienced increases in abundance from 9 to 55% (Table 9), but remain at relatively low population abundances. The Strait of Juan de Fuca Independent Tributaries winter run DIP abundance fell below 100 for its five-year geomean, a 37% decrease over the previous period. Finally, no information was available for the Sequim and Discovery Bay Tributaries winter run DIP. Based on previous monitoring in Snow Creek, a small tributary in this DIP, overall abundance is unlikely more than 100 individuals. Overall, this MPG exhibited an increase in abundance related to the expansion of steelhead spawning in the Elwha River and general improvements among populations in Hood Canal. Total abundance, however, was still low to moderate (Ford 2022).

Table 12. Five-year geometric mean of raw natural spawner counts for Puget Sound steelhead. This is the raw total spawner count times the fraction natural estimate, if available. In parentheses, the 5-year geometric mean of raw total spawner counts is shown*.

Population	MPG	1990-1994	1995-1999	2000-2004	2005-2009	2010-2014	2015-2019	% Change
Samish R./Bellingham Bay Tribs. W	NC	316 (316)	717 (717)	852 (852)	535 (535)	748 (748)	1305 (1305)	74 (74)
Nooksack R. W	NC	-	-	-	-	1745 (1745)	1906 (1906)	9 (9)
Skagit R. S and W	NC	7202 (7202)	7656 (7656)	5419 (5419)	4677 (4677)	6391 (6391)	7181 (7181)	12 (12)
Stillaguamish R. W	NC	1078 (1078)	1166 (1166)	550 (550)	327 (327)	386 (386)	487 (487)	26 (26)
Snohomish/Skykomish R. W	NC	3629 (3629)	3687 (3687)	1718 (1718)	2942 (2942)	975 (975)	690 (690)	-29 (-29)
Pilchuck R. W	NC	1225 (1225)	1465 (1465)	604 (604)	597 (597)	626 (626)	638 (638)	2 (2)
Snoqualmie R. W	NC	1831 (1831)	2056 (2056)	1020 (1020)	1250 (1250)	706 (706)	500 (500)	-29 (-29)
Tolt R. S	NC	112 (112)	212 (212)	119 (119)	70 (70)	108 (108)	40 (40)	-63 (-63)
N. Lake WA Tribs. W	SCC	60 (60)	4 (4)	-	-	-	-	-
Cedar R. W	SCC	241 (241)	295 (295)	37 (37)	12 (12)	4 (4)	6 (6)	50 (50)
Green R. W	SCC	2062 (2062)	2585 (2585)	1885 (1885)	1045 (1045)	662 (662)	1282 (1282)	94 (94)

Population	MPG	1990-1994	1995-1999	2000-2004	2005-2009	2010-2014	2015-2019	% Change
White R. W	SCC	169 (169)	183 (183)	147 (147)	57 (57)	79 (79)	182 (182)	130 (130)
Puyallup R. W	SCC	199 (199)	196 (196)	93 (93)	72 (72)	85 (85)	201 (201)	136 (136)
Nisqually R. W	SCC	1200 (1200)	754 (754)	409 (409)	446 (446)	477 (477)	1368 (1368)	187 (187)
S. Hood Canal W	HCSJF	97 (97)	148 (148)	176 (176)	145 (145)	69 (69)	91 (91)	32 (32)
Eastside Hood Canal Tribs W	HCSJF	27 (27)	21 (21)	25 (25)	37 (37)	60 (60)	93 (93)	55 (55)
Skokomish R. W	HCSJF	385 (385)	359 (359)	205 (205)	320 (320)	533 (533)	958 (958)	80 (80)
Westside Hood Canal Tribs W	HCSJF		97 (97)	208 (208)	167 (167)	138 (138)	150 (150)	9 (9)
Dungeness R. S and W	HCSJF	356 (356)				517 (517)	408 (408)	-21 (-21)
Strait of Juan de Fuca Independents W	HCSJF	89 (89)	191 (191)	212 (212)	118 (118)	151 (151)	95 (95)	-37 (-37)
Elwha R. W	HCSJF					680 (680)	1241 (1241)	82 (82)

* A value only in parentheses means that a total spawner count was available but none or only one estimate of natural spawners was available. The geometric mean was computed as the product of counts raised to the power 1 over the number of counts available (2 to 5). A minimum of 2 values was used to compute the geometric mean. Percent change between the most recent two 5-year periods is shown on the far right. MPG, major population group; NC, Northern Cascades, SCC South and Central Cascades, HCSJF, Hood Canal and Strait of Juan de Fuca, W, winter run; S, summer run.

Table 13. Recent (2015-2019) 5-year geometric mean of raw wild spawner counts for Puget Sound steelhead populations and population groups compared with Puget Sound Steelhead Recovery Plan high and low productivity recovery targets (NMFS 2019g). (SR) – Summer run. An "*" indicates that the abundance is only a partial population estimate. Abundance is compared to the high productivity individual DIP targets. Colors indicate the relative proportion of the recovery target currently obtained: red (<10%), orange (10%>x<50%), yellow (50%>x<100%), green (>100%).

Major Population Group	Demographically Independent Population	Recent Abundance 2015-2019	Recovery Target	
			High Productivity	Low Productivity
Northern Cascades	Drayton Harbor Tributaries	NA	1,100	3,700
	Nooksack River	1,906	6,500	21,700
	South Fork Nooksack River (SR)	NA	400	1,300
	Samish River & Independent Tributaries	1,305*	1,800	6,100

Major Population Group	Demographically Independent Population	Recent Abundance 2015-2019	Recovery Target	
			High Productivity	Low Productivity
	Skagit River	7,181*	15,000	
	Sauk River	[1]		
	Nookachamps River	[1]		
	Baker River	NA		
	Stillaguamish River	487*	7,000	23,400
	Canyon Creek (SR)	NA	100	400
	Deer Creek (SR)	NA	700	2,300
	Snohomish/Skykomish River	690	6,100	20,600
	Pilchuck River	638	2,500	8,200
	Snoqualmie River	500	3,400	11,400
	Tolt River (SR)	40*	300	1,200
	North Fork Skykomish River (SR)	NA	200	500
Central and South Sound	Cedar River	<10*	1,200	4,000
	North Lake Washington Tributaries	NA	4,800	16,000
	Green River	1,282	5,600	18,700
	Puyallup Carbon River	136* 735*	4,500	15,100
	White River	451	3,600	12,000

Major Population Group	Demographically Independent Population	Recent Abundance 2015-2019	Recovery Target	
			High Productivity	Low Productivity
	Nisqually River	1,368	6,100	20,500
	East Kitsap Tributaries	NA	2,600	8,700
	South Sound Tributaries	NA	6,300	21,200
Strait of Juan de Fuca	East Hood Canal Tributaries	93*	1,800	6,200
	South Hood Canal Tributaries	91	2,100	7,100
	Skokomish River	958	2,200	7,300
	West Hood Canal Tributaries	150*	2,500	8,400
	Sequim and Discovery Bay Tributaries	NA	500	1,700
	Dungeness River	408	1,200	4,100
	Strait of Juan de Fuca Independent Tributaries	95*	1,000	3,300
	Elwha River	1,241	2,619	

Data Source: (Ford 2022)

Dungeness River Basin Populations

The PSSTRT delineated one extant steelhead population that is native to the Dungeness River watershed and part of the listed Puget Sound steelhead DPS: Dungeness River Winter-Run (Myers et al. 2015). A summer-run component of the steelhead return to the Dungeness River is thought to have existed historically in the upper accessible reaches of the mainstem Dungeness River and Gray Wolf River (Haring 1999), but it is uncertain whether this run still persists in the watershed although WDFW lists the summer-run race in the Dungeness River as extant (Scott and Gill 2008). Further monitoring is needed to establish whether native summer-run fish are still present and if they are part of a combined summer/winter natural population or represent an independent population (Myers et al. 2015). Steelhead recovery viability criteria recommend that at least one winter-run and one summer-run population of the six populations in the Hood Canal and Strait of Juan de Fuca MPG need to be restored to a low extinction risk status for recovery and delisting of the DPS (Hard et al. 2015). Hatchery-origin steelhead released from Dungeness River Hatchery are not included as part of the listed DPS (NMFS 2016a).

The majority of the Dungeness River winter-run steelhead population includes fish spawning in the mainstem Dungeness and Gray Wolf rivers (Myers et al. 2015). The extent of spawning is confined to areas downstream of naturally impassable barriers. Dungeness winter steelhead spawning distribution extends from the Dungeness River mainstem at RM 18.7, downstream to the upper extent of tidewater (Haring 1999). Winter steelhead distribution is assumed to also include the Bell, Gierin, Cassalery, Cooper, Meadowbrook, Matriotti, Beebe, Lotsgazell, Woodcock, Mud, Bear, Hurd, Canyon, and Gold Creek subbasins.

Adult winter-run steelhead enter the river on their spawning migration from November to early June. Spawning occurs from March through June, with peak spawning in May (Myers et al. 2015). Although age at spawning data are lacking for the Dungeness population, most natural-origin winter-run steelhead in Puget Sound return to spawn as four year-old fish, with five year-olds comprising a significant proportion of total returns (Myers et al. 2015). WDFW juvenile out-migrant trapping data from the 2005 through 2007 migration years indicate that natural-origin Dungeness River basin steelhead juveniles emigrate seaward as smolts between February and early July, with peak migration during the first two weeks of May (Topping et al. 2008a; Topping et al. 2008b). Steelhead smolt individual sizes observed in the WDFW trapping study ranged from 85-mm to 290-mm fork length (fl), and averaged 170 mm (fl).

An estimate of the intrinsic potential based on spawner capacity indicates that the Dungeness River watershed could support the production of 2,465 natural-origin steelhead, or 24,650 smolts (Myers et al. 2015). Smolt production from 2005 through 2020 has ranged from 4,354 (2016) to 19,600 (2011), averaging 10,394 (Figure 4) (WDFW 2020). The most recent year's (2020) smolt production of 12,281 is approximately 50 percent of the intrinsic potential estimated by Myers et al. (2015). The critical threshold for winter-run steelhead natural spawners identified by the co-managers' is 125 fish and the viable threshold, reflecting a level of population abundance associated with a very high probability of persistence, or conversely, a very low risk of extinction, for a period of 100 years, is between 500 and 750 natural-origin spawners (PSIT and WDFW 2010b). Recent abundance of adult steelhead spawning in the Dungeness River over the most recent five-year period (2015-2019) averaged 408 adult steelhead annually. In contrast, the recovery target is 1,200 spawners at high productivity and 4,100 spawners at low productivity (Table 13).

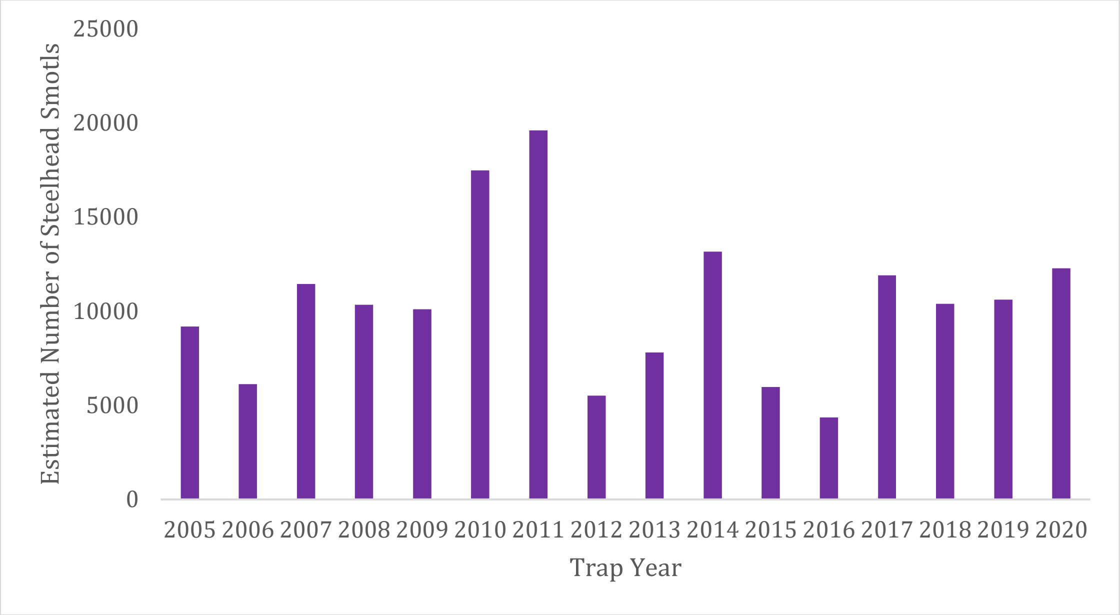

Figure 4. Annual estimated natural-origin steelhead smolt production in the Dungeness River basin (WDFW 2020).

Spatial structure of the winter-run steelhead natural population has been reduced by habitat loss and degradation in the Dungeness River watershed. Dikes, levees and other actions to control the lower reaches of the river and tributaries have reduced natural population spatial structure, particularly through adverse impacts on side channel habitat and increased scour of redds (Haring 1999). These actions have degraded available spawning and migration areas for adult fish, and refugia for rearing juvenile steelhead. Water withdrawals for irrigation and residential use have substantially reduced flows needed during the adult steelhead upstream migration and spawning periods, forcing adults to construct spawning redds in channel areas that are extremely susceptible to sediment scour and aggradation. Due to their late-winter and spring adult migration timing, spatial structure for the extant winter-run steelhead population was not thought to have been affected by seasonal operation of the Dungeness River Hatchery weir from the 1930s through the 1980s. Summer-run steelhead, if they still existed (Myers et al. 2015), may have been adversely affected by the weir when it was in operation over that period through migration delay and blockage.

Available data indicate that steelhead diversity in the Dungeness River watershed has declined relative to historical levels. It is likely that the historically extant summer-run component of the steelhead return has declined to very low levels or has become extirpated (Myers et al. 2015). As with Chinook salmon in the watershed, degradation and loss of habitat in the watershed, and past harvest practices, have reduced the diversity of the species in general relative to historical levels. Releases of non-native EWS from Dungeness River Hatchery have likely reduced genetic diversity of the native winter-run population in watershed areas where spawn timings for natural and hatchery-origin fish have over-lapped. However, there are no genetic data indicating that introgression associated with planting of the non-native stock has occurred (NMFS 2016d).

2.2.1.4 Status of Critical Habitat for Puget Sound Steelhead

Critical habitat for Puget Sound steelhead was designated on February 24, 2016 (81 FR 9252). Designated critical habitat for the Puget Sound steelhead DPS includes 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. The designation does not identify specific areas in the nearshore zone in Puget Sound because steelhead move rapidly out of freshwater and into offshore marine areas, unlike Puget Sound Chinook and Hood Canal summer chum, for which nearshore critical habitat areas were designated. Critical habitat also does not include offshore marine areas. There are 18 subbasins (HUC4 basins) containing 66 occupied watersheds (HUC5 basins) within the range of this DPS. Nine watersheds received a low conservation value rating, 16 received a medium rating, and 41 received a high rating to the DPS (78 FR 2726, January 14, 2013). Of the nine subbasins within the action area (Dungeness River, upper North Fork Nooksack, Middle Fork Nooksack, South Fork Nooksack, Lower North Fork Nooksack, Nooksack River, North Fork Stillaguamish, South Fork Stillaguamish, and Lower Stillaguamish River), seven received high and two medium (upper N.F. and M.F. Nooksack River) conservation value ratings (78 FR 2726, January 14, 2013).

NMFS determines the range-wide status of critical habitat by examining the condition of its physical and biological features (also called “primary constituent elements,” or PCEs, in some designations) that were identified when the critical habitat was designated (81 FR 9252, February 24, 2016). These features are essential to the conservation of the listed species because they support one or more of the species’ life stages (e.g., sites with conditions that support spawning, rearing, migration and foraging). PCEs for Puget Sound steelhead, including the Dungeness population, 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 supporting juvenile development; and (iii) Natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.
(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.

The critical habitat for Puget Sound steelhead includes the Dungeness River within the action area and extends from the mouth of the Dungeness River upstream to the limits of steelhead access in the mainstem Dungeness River, Matriotti Creek, Bear Creek, Canyon Creek, Gold Creek, and the Gray Wolf River, 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 Dungeness Basin including irrigation impoundments/withdrawals, channel modifications/diking, sand/gravel mining, forestry, urbanization, and road building/maintenance (78 FR 2726, January 14, 2013; NMFS 2012a). The Puget Sound CHART found that habitat utilization by steelhead in a number of Puget Sound areas has been substantially affected by large dams and other manmade barriers in a number of drainages (NMFS 2013a). Affected areas include the Nooksack, Skagit, White, Nisqually, Skokomish, and Elwha River basins. In addition to limiting habitat accessibility, dams have affected steelhead habitat quality through changes in river hydrology, altered temperature profile, reduced downstream gravel recruitment, and the reduced recruitment of large woody debris. In addition, many upper tributaries in the Puget Sound region have been affected by poor forestry practices, while many of the lower reaches of rivers and their tributaries have been altered by agriculture and urban development. Urbanization has caused direct loss of riparian vegetation and soils, significantly altered hydrologic and erosional rates and processes (e.g., by creating impermeable surfaces such as roads, buildings, parking lots, sidewalks etc.), and polluted waterways with stormwater and point-source discharges. The loss of wetland and riparian habitat has dramatically changed the hydrology of many streams all to the detriment of steelhead habitat, with increases in flood frequency and peak flow during storm events and decreases in groundwater driven summer flows. River braiding and sinuosity have been reduced through the construction of dikes, hardening of banks with riprap, and channelization of the mainstem rivers. These actions have led to constriction of river flows, particularly during high flow events, increasing the likelihood of gravel scour and the dislocation of rearing juvenile steelhead. The loss of side-channel habitats has also reduced important areas for spawning, juvenile rearing, and overwintering habitats. Estuarine areas have been dredged and filled, resulting in the loss of important juvenile steelhead rearing areas (NMFS 2013a).

2.3 Action Area

“Action area” means all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR 402.02). The action area for this proposed action is the Dungeness River watersheds, its tributaries, and nearshore marine waters of Dungeness Bay, as described in the 2016 BiOp.

As discussed in the 2016 BiOp, NMFS also considered whether the marine areas of Puget Sound outside of Dungeness 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 Dungeness River Hatchery salmon production, and mixed stock fisheries harvest, and density-dependent interactions 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.

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 that 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).

2.4.1 Habitat

Coastal shorelines and tidal wetlands throughout Puget Sound have been impacted by human population growth and development. The Dungeness river basin is located in an area with an expanding population and has seen increased residential and commercial development (NWIFC 2020). Development includes armoring of the marine shoreline that has increased by 2% in the most recent five-year period to 501,550 feet contributing to the reduction and elimination of productive beaches and shallow water habitats. This diminishes habitats for fish and shellfish including forage fishes such as sand lance and surf smelt, which spawn on upper intertidal beaches made of sand and gravel. These small schooling fishes are important prey for larger predatory fish and wildlife in the marine food web (NWIFC 2020).

Channelization and flow diversions of the Dungeness River as well as the draining of freshwater wetlands beginning in the early 1960's has led to excessive flooding, declining salmon populations, loss of important physical processes, and riparian functions. Peak flow for the Dungeness River has increased from 1924 to 2016 with the average peak flow being approximately 79.3 cubic meters per second in 1924 and 113.3 cubic meters per second in 2016 in part due to channelization and draining of the wetlands directing more of the flow into the stream (NWIFC 2020). Clear-cut logging and logging roads within the Dungeness watershed have contributed to increased peak flow into the channel, and land management activities including channelization, dewatering of wetlands, loss of large wood, and floodplain access have led to increased peak flow runoff. Over the past 15 years, the irrigators have reduced their withdrawal by over 45% but Dungeness flows are still inadequate for sustaining ESA-listed salmon species (NWIFC 2020).

Development has also degraded water quality within the Dungeness watershed. Fecal coliform bacteria has been increasing in Dungeness Bay since 1997 and exceeds EPA standards (Hall et al. 2019). Residences throughout the Dungeness watershed are served by individual or community septic systems, which are likely contributing to the observed marine bacterial pollution (NWIFC 2020).

Habitat restoration projects being conducted in the Action Area by the Jamestown S'Klallam Tribe and their partners aim to increase habitat complexity and re-connect the floodplain (Jamestown S'Klallam Tribe 2007; NWIFC 2020; Brooks 2021). Currently, river diking has left only 196 acres of the original 730 acre Dungeness floodplain intact. These levees reduce the habitat available to salmon and eliminate natural river processes. The goals of the Lower Dungeness River Floodplain Restoration Project goals are to restore habitat-forming processes within two miles of the Dungeness River by setting back and removing levees causing the loss of floodplain processes and restore 150 acres of former agricultural land to healthy floodplain. Restoration of the floodplain includes placement of large woody debris and reconnection of the river so the lower two miles of the Dungeness River will be fully functioning and uninhibited by the river levees with high quality salmon habitat, functioning side channels and diverging channels that meander through a publicly owned, permanently protected floodplain forest (NWIFC 2020). Setting back the levee will create room for channel migration and allow side channels and branches to form, creating diverse and productive salmon habitats. The wider floodplain will reduce water velocities in the main channel, decreasing bed scour and the destruction of salmon spawning redds during floods. Decreased water velocities also allow for increased retention of large woody debris (LWD), which dissipates stream energy and forms pools (Brooks 2021). Analysis of watersheds across Puget Sound indicates that juvenile Chinook salmon productivity increases with greater habitat complexity likely because more complex habitats provide more protection against high flow events and rearing capacity (Hall et al. 2018). Funding for these restoration efforts in the lower Dungeness River floodplain to restore and improve nearshore, estuary and floodplain conditions while reducing downstream flood risk has been secured from the Puget Sound Acquisition and Restoration Fund and the Floodplains by Design initiative. The project was funded in 2015 and includes plans for levee setbacks and habitat restoration to reconnect 112 acres of floodplain that is expected to be completed as early as 2025 (NWIFC 2020).

2.4.2 Fisheries

The fishing seasons and regulations developed specifically to harvest salmon produced by hatchery programs operating in Puget Sound have previously been reviewed under the ESA, and NMFS's authorization for 'take' from fisheries is part of an already completed consultation (NMFS 2022). There are no directed fisheries for natural-origin or hatchery-origin Chinook, chum, or summer- or fall-run pink salmon, or natural-origin steelhead in the action area. Dungeness Chinook and fall-run pink salmon are propagated through the proposed hatchery programs for conservation purposes, and contribution to fisheries harvest is not an objective. As described by NMFS (2001) and (NMFS 2022), listed Hood Canal summer chum salmon, Puget Sound Chinook salmon, and steelhead are caught incidentally in fisheries targeting coho salmon and un-listed, hatchery winter steelhead within the action area. Incidental harvest of Dungeness Chinook, Hood Canal summer chum, and Dungeness steelhead in marine areas, outside of this action area, are currently managed to reduce risk to the viability and recovery of these populations and species through separate ESA authorizations— NMFS (2001) for summer chum and NMFS (2022) for Chinook and steelhead. Under current ESA-authorized harvest management plans, total incidental fisheries impact on Dungeness River summer chum salmon is limited to a "Base Conservation Rate" of 5% or less of the total annual run size (WDFW and PNPTT 2000). This harvest level is considered sufficiently conservative to allow preservation and restoration of Dungeness River origin summer chum salmon (NMFS 2001).

To help protect and recover the Dungeness Chinook salmon population, the total allowable annual exploitation rate in all Southern U.S. (SUS) fisheries is currently limited to 10% or 6% when below the 500 individual critical escapement level. Between 2009 and 2016, actual annual SUS exploitation rates on Dungeness Chinook salmon averaged just 4%. Total harvest rates—SUS and harvest in Canada and Alaska—are higher, averaging 15% over the same period. Seventy-two percent of the harvest of Dungeness Chinook salmon occurs in fisheries in Canada and Alaska. Although the total harvest rate remains above the rebuilding exploitation rate objective (5%), production from the proposed conservation hatchery program buffers short-term demographic risks and preserves the genetic legacy of the population as degraded habitat is recovered (NMFS 2022).

Although specific incidental impact data are lacking for Dungeness River native steelhead, surrogate terminal steelhead harvest rates were calculated for a set of five reference Puget Sound watersheds for natural-origin steelhead and averaged 1.43 percent annually in Puget Sound fisheries during the 2007/2008 to 2017-2018 time period (NMFS 2019e). Currently, Puget Sound freshwater fisheries are managed to an aggregate, average rate of 4.2 percent. This limit was developed at the time of the Puget Sound steelhead DPS (2007), when NMFS determined that the current harvest management strategy that had eliminated direct harvest of natural-origin steelhead in Puget Sound had largely addressed the threat of decline to the listed DPS posed by harvest (72 FR 26722, May 11, 2007). The rate represents the average harvest rate, across the five reference watersheds, from 2001-02 through 2006-07. The steelhead fishery in the Dungeness River, which targets hatchery-origin fish produced from the proposed action, has only diminished in scale as the hatchery release numbers have been reduced since the Puget Sound Steelhead DPS listing. In summary, and as mentioned in Section 1.3.2, NMFS analyzed the effects of all fisheries on listed Dungeness River watershed salmon and steelhead, and concluded that fisheries harvest actions within and outside of the action area are not likely to jeopardize the continued existence of the Hood Canal Summer Chum Salmon ESU (NMFS 2001), or the Puget Sound Chinook Salmon ESU and the Puget Sound Steelhead DPS (NMFS 2020; 2021c; 2022), or adversely modify designated critical habitat for these listed species.

Within the action area, Jamestown S'Klallam tribal commercial and ceremonial and subsistence fisheries for Dungeness River natural-origin and hatchery-origin coho salmon occur seasonally in Dungeness Bay and the lower Dungeness River, contingent on the availability of natural-origin fish surplus to natural spawning escapement needs. A WDFW-managed non-tribal commercial skiff gillnet fishery in Dungeness Bay also targets returning coho salmon surplus to escapement needs.

2.4.3 Hatcheries

Hatcheries can provide benefits to the status of Puget Sound Chinook and steelhead by reducing demographic risks and preserving genetic traits for populations at low abundance in degraded habitats. In addition, hatcheries help to provide harvest opportunity, which is an important contributor to the meaningful exercise of treaty rights for the Northwest tribes. In the past, hatcheries have been used to compensate for factors that limit anadromous salmonid viability (e.g., harvest, human development) by maintaining fishable returns of adult salmon and steelhead. A new role for hatcheries emerged during the 1980s and 1990s as a tool to conserve the genetic resources of depressed natural populations and to reduce short-term extinction risk (e.g., Snake River sockeye salmon). Hatchery programs also can be used to help improve viability by supplementing natural population abundance and expanding spatial distribution. However, the long-term benefits and risks of hatchery supplementation remain untested (Christie et al. 2014). Therefore, addressing the factors limiting viability is essential for long-term viability.

Hatchery production of Puget Sound steelhead has declined in recent years across the DPS, especially for non-listed stocks, and the fraction of hatchery spawners on spawning grounds are low for many rivers. Increasing estimates of productivity for a few steelhead populations from the 2011-2015 time frame are encouraging but included only one to a few years, thus, the patterns of improvement in productivity were not widespread, or considered certain to continue into the 2015-2019 time frame (Hard et al. 2015). Total harvest rates continue to be at the low levels considered in the last two status updates (NWFSC 2015; Ford 2022). These rates are unlikely to increase substantially in the foreseeable future. Recovery efforts in conjunction with improved ocean and climatic conditions have resulted in improved status for the majority of populations in this DPS; however, absolute abundances are still low, especially summer-run populations, and the DPS remains at high to moderate risk (NWFSC 2015; Ford 2022).

Chinook salmon stocks are artificially propagated through 41 programs in Puget Sound—programs with completed section 7 consultations are summarized in Table 14. Currently, most of Chinook salmon hatchery programs produce fall-run (also called summer/fall) stocks for fisheries harvest augmentation purposes. Supplementation programs implemented as conservation measures to recover early returning Chinook salmon operate in the White, Dungeness (NMFS 2016e), and North Fork Nooksack Rivers, and for summer Chinook salmon on the North Fork Stillaguamish (NMFS 2019b) and Elwha Rivers (NMFS 2014a). Supplementation or re-introduction programs are in operation for early Chinook salmon in the South Fork Nooksack River, fall Chinook salmon in the South Fork Stillaguamish River (NMFS 2019b), and spring and late-fall Chinook salmon in the Skokomish River.

Table 14. Summary of completed Section 7 consultations for hatchery programs in Puget Sound.

Biological Opinion	Programs Authorized in Opinion	Signature Date	Citation
Lake Ozette Sockeye Salmon	Umbrella Ck Supplementation/Reintroduction	June 9, 2015	NMFS (2015a); (NMFS 2015b)
Elwha	Lower Elwha Hatchery Native Steelhead	December 15, 2014	NMFS (2014b)
	Lower Elwha Hatchery Elwha Coho		
	Elwha Channel Hatchery Chinook		
	Lower Elwha Hatchery Elwha Chum		
	Lower Elwha Hatchery Pink		
Dungeness	Dungeness River Hatchery Spring Chinook	May 31, 2016 September 24, 2019	NMFS (2016f); (NMFS 2019d)
	Dungeness River Hatchery Coho		
	Dungeness River Hatchery Fall Pink		
Early Winter steelhead #1	Kendall Creek Winter Steelhead	April 15, 2016	NMFS (2016c)
	Dungeness River Early Winter Steelhead		
	Whitehorse Ponds Winter Steelhead		

Biological Opinion	Programs Authorized in Opinion	Signature Date	Citation
Early Winter Steelhead #2	Snohomish/Skykomish Winter Steelhead	April 15, 2016	NMFS (2016e)
	Snohomish/Tokul Creek Winter Steelhead		
Stillaguamish	Stillaguamish Fall Chinook Natural Stock Restoration	June 20, 2019	NMFS (2019c)
	Stillaguamish Summer Chinook Natural Stock Restoration		
	Stillaguamish Late Coho		
	Stillaguamish Fall Chum		
Snohomish	Tulalip Hatchery Chinook Sub-yearling	September 27, 2017 May 3, 2021	NMFS (2017a) NMFS (2021b)
	Wallace River Hatchery Summer Chinook		
	Wallace River Hatchery Coho		
	Tulalip Hatchery Coho		
	Tulalip Hatchery Fall Chum		
	Everett Bay Net-Pen Coho		
Hood Canal	Hoodsport Fall Chinook	September 30, 2016	NMFS (2016b)
	Hoodsport Fall Chum		
	Hoodsport Pink		
	Enetai Hatchery Fall Chum		
	Quilcene NF Hatchery Coho		
	Quilcene Bay Net-Pens Coho		
	Port Gamble Bay Net-Pens Coho		
	Port Gamble Hatchery Fall Chum		
	Hamma Hamma Chinook Salmon		
	Hood Canal Steelhead Supplementation		
Duwamish/Green	Soos Creek Hatchery Fall Chinook	April 15, 2019	NMFS (2019f)
	Keta Creek Coho (w/ Elliott Bay Net-pens)		
	Soos Creek Hatchery Coho		
	Keta Creek Hatchery Chum		
	Marine Technology Center Coho		
	Fish Restoration Facility (FRF) Coho		
	FRF Fall Chinook		
	FRF Steelhead		
	Green River Native Late Winter Steelhead		
	Soos Creek Hatchery Summer Steelhead		
Skykomish Summer Steelhead	South Fork Skykomish Summer Steelhead	October 21, 2021	NMFS (2021a)
Lake Washington	University of Washington Aquatic Research Facility Hatchery – Fall Chinook salmon	December 23, 2021	NMFS (2021d)
	University of Washington Aquatic Research Facility Hatchery coho		
	Issaquah Fall Chinook Hatchery Program		
	Issaquah coho Hatchery Program		
	Lake Washington Sockeye Program		

Dungeness River Hatchery Programs

The Dungeness River Hatchery spring Chinook and fall-run pink salmon hatchery programs were initiated for integrated recovery purposes to conserve and restore the indigenous Chinook and fall-run pink salmon populations in the Dungeness River. The coho salmon program at Dungeness River Hatchery operates for fisheries harvest augmentation purposes to partially mitigate for lost natural-origin coho salmon resulting from degradation and loss of habitat as a result of human developmental activities in the watershed. The Dungeness River Hatchery Chinook salmon program was initiated as a supplementation effort in 2004, after functioning as a captive broodstock-based program since 1992. The conservation program for fall-run pink salmon at the hatchery began in 2007. The Dungeness River Hatchery coho salmon program has released smolts into the lower river since about 1902.

Past operation of the Chinook, fall-run pink, and coho salmon hatchery programs in the Dungeness River watershed may have affected the viability of listed natural-origin Chinook salmon and steelhead populations as well as the diversity, spatial structure, and productivity of the natural-origin Chinook salmon population that is the subject of the conservation effort.

Collection of adult fish from the river and selection of fish for spawning may have reduced within-population diversity of the propagated population relative to the naturally spawning aggregation if all the adults collected for broodstock were not completely genetically representative of the natural population. Creation of a captive population as a brood source may have further contributed to within-population diversity loss. However, in creating the original captive broodstock, eggs were collected from redds to establish the captive brood program to ensure that the brood source would exhibit no genetic differences from the natural spawning population. The captive broodstock program was terminated in 2004, and the program was transitioned to a supplementation program. By limiting the length of the original captive broodstock program (1992-1997 brood years), the potential for adverse genetic effects on the listed natural fish resulting from selection in the hatchery were reduced. For the supplementation program, measures were implemented to collect and spawn adult fish representative of the run-at-large in terms of run timing, fish size, age class, and sex ratio may have reduced this genetic risk. Release of juvenile fish predominantly from Dungeness River Hatchery may have affected population spatial structure as a result of fish homing to and spawning near the lower river release location. Construction of smolt acclimation ponds in the upper watershed to enhance adult fish homing to upstream areas more suitable to natural spawning was designed reduced this risk. Propagation of Dungeness Chinook salmon in the hatchery may have reduced productivity of adult fish returning to spawn naturally relative to natural-origin fish. The Chinook salmon program has likely benefited the abundance of the Dungeness Chinook salmon population by increasing egg-to-emigrating smolt survival rates relative to naturally spawning Chinook salmon, considering the degraded state of natural fish habitat, which suppresses natural-origin fish productivity in the action area. The hatchery program for Chinook salmon has likely helped preserve the Dungeness Chinook population and bolstered the population’s total abundance.

The three salmon hatchery programs, along with a non-listed, early winter steelhead smolt release program operating at Dungeness River Hatchery (WDFW 2014), may have adversely affected listed Chinook salmon and steelhead through ecological effects. Predation on migrating and rearing juvenile Chinook salmon by hatchery yearling Chinook and coho salmon as well as steelhead may occur in the lowest portion of the Dungeness River downstream of Dungeness River Hatchery. The timing of hatchery yearling releases has coincided with the out-migration timing of natural-origin Chinook salmon of an average size vulnerable to predation. The magnitude of predation effects is unknown, but the practice of releasing migration-ready smolts into the lowest portions of the watershed limits the level and duration of interaction with juvenile natural-origin fish, which rear and migrate from areas throughout the watershed. Natural-origin juvenile steelhead of sizes vulnerable to predation by the hatchery yearlings emerge from upper-river redds later in the season, and are unlikely to be encountered or preyed upon. Sub-yearling Chinook salmon produced through the Dungeness River Hatchery program have been released in May or June, after the majority of natural-origin Chinook salmon have emigrated seaward. No 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 compete with natural-origin Chinook salmon and steelhead at substantial levels for food or space. All of the hatchery salmon and steelhead are released as smolts that will quickly emigrate seaward, and are only released in the lower portion of the watershed. For these reasons, the duration of, and opportunities for, interactions that would lead to competition with listed juvenile fish have been limited.

Dungeness River hatchery facility operations may have adversely affected the viability status of natural-origin salmon and steelhead populations in the action area. A permanent, full river-spanning weir operated at the Dungeness River Hatchery at RM 10.8 beginning in the 1930s. The weir blocked Chinook salmon access to upstream spawning areas for approximately 50 years (SSPS 2005). Although the weir was abandoned in the 1980s, its operation in prior years likely adversely affected the abundance and spatial structure of the natural-origin Dungeness Chinook population. Canyon Creek was blocked by a diversion dam to withdraw water for use in the Dungeness Hatchery until 2015. Water is withdrawn from Canyon Creek only when withdrawal of water from the main source in the Dungeness River becomes infeasible due to icing and high flows during the winter months when flows are at their highest. Water flow is too low in Canyon Creek to use the intake during the summer and fall months when flows in Canyon Creek are at their lowest. A fish ladder was constructed in December 2015 to allow fish passage past the diversion dam allowing access to several miles of Canyon Creek, some of which might be suitable habitat for salmonid spawning and rearing. The Canyon Creek intake now meets NMFS most current screening standards (NMFS 2013b).

The effects of salmon and steelhead hatchery programs outside of the action area on Dungeness River Chinook salmon and steelhead are likely minimal. The closest hatchery programs outside of the action area are located in the Elwha River. Juvenile and adult fish from the Elwha River are unlikely to interact with Dungeness River Chinook salmon and steelhead in the action area at a level leading to making substantial ecological effects. Data indicates the Elwha Chinook salmon or steelhead stray into the Dungeness River at low levels with three Elwha hatchery origin Chinook salmon encountered in the Dungeness River in 2020 as fish from the Elwha programs are marked to allow for monitoring (NMFS 2014a; WDFW 2020). Among-population diversity reduction risks associated with out-of-basin hatchery salmon and steelhead straying into the Dungeness River are not likely and can be monitored with the co-managers proposed genetic monitoring program along with analysis of CWT data.

2.4.4 Climate Change

Climate change has negative implications for designated critical habitats in the Pacific Northwest (Climate Impacts Group 2004; Scheuerell and Williams 2005; Zabel et al. 2006; ISAB 2007). The distribution and productivity of salmonid populations in the region are likely to be affected (Beechie et al. 2006). Average annual Northwest air temperatures have increased by approximately 1ºC since 1900, or about 50% more than the global average over the same period (ISAB 2007). The latest climate models project a warming of 0.1 ºC to 0.6 ºC per decade over the next century. According to the Independent Scientific Advisory Board (ISAB), these effects pose the following impacts over the next 40 years:

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

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

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

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

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

The effects of climate change in the Dungeness river basin, in addition to the broader effects across the region, are likely to include higher air and water temperatures, decreased snowpack, changing seawater chemistry due to ocean acidification, and rising sea level consistent with impacts expected throughout Puget Sound (Mauger et al. 2015). Salmon are also expected to experience declines in abundance and productivity by the change in timing and amount of winter rains and flooding, scouring of egg redds during high flows, thermal stress from higher water temperature, and less water availability in the summer (NWIFC 2020).

Within the marine areas surrounding the Dungeness River basin, models predict sea levels to rise by 0.6 m under a moderate scenario and up to 2.0 m under an accelerated scenario (Ramirez and Simenstad 2018a). Sea level rise and human development of the nearshore put wetlands at risk of submergence, with(Ramirez and Simenstad 2018b) the extensive tidal flats associated with the Dungeness River delta projected to decline by nearly 80 percent of its 600 hectares of tidal flat by 2100 under 0.6 m sea level rise and nearly 90 percent under the 2.0 m sea level rise scenario. These mud and sand flats support invertebrate species such as clams, oysters, and crabs that are of economic and cultural importance, as well as species salmon feed on including shrimp, amphipods, and insect larvae (Ramirez and Simenstad 2018a). This reduction of tidal wetland habitat would cause population declines and changes in the composition of the prey species present in the tidal mud flats and nearshore areas as large areas of tidal flats are lost, which could lead to declines in abundance of salmon populations.

Current restoration activities in the Dungeness River basin are focused on re-establishing the floodplain. This will be important in mitigating the effects of climate change as floodplains offer additional rearing capacity for fishes and are especially important during wet months in providing increased growth and survival for juvenile salmon by offering abundant prey, optimal rearing temperatures, and refuge from predators. Floodplains also provide juvenile fish protection from floods by attenuating high flows and providing refuge habitats from high flow conditions in the mainstem river (Hall et al. 2018). The probable effects of climate change emphasizes how important increasing habitat complexity through restoration projects will be in protecting the productivity of sub-yearling Chinook in Puget Sound rivers including the Dungeness as Chinook salmon populations are more resilient and productive during periods of environmental variation in watersheds with greater habitat complexity (Hall et al. 2018). The addition of large woody debris from the restoration project will produce deep, complex pools connected with hyporheic flows that will cool the river water (Brooks 2021). This cooler habitat will be essential for adult and juvenile salmon to survive periods of increased thermal stress precipitated by climate change.

2.5 Effects of the Action

Under the ESA, "effects of the action" are all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action. 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).

2.5.1 Factors That Are Considered When Analyzing Hatchery Effects

NMFS has substantial experience with hatchery programs and has developed and published a series of guidance documents for designing and evaluating hatchery programs following best available science (Hard et al. 1992; McElhany et al. 2000; NMFS 2004b; 2005c; Jones 2006; NMFS 2008a; 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[3]. These factors are:

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

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

2.5.2 Effects of the Proposed Action

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

While the increased Chinook salmon production may benefit SRKW diet, and, therefore, result in increased predation by SRKW on these fish, the degree to which SRKW would feed on this Chinook salmon production is unknown. Therefore, in assessing the hatchery factors on natural-origin salmonids, we assume in this analysis that the hatchery fish would be eaten by SRKW at

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[3] Of note, seven factors were used in the 2016 BiOp. Factors 3 and 4 in the 2016 BiOp is now analyzed as one factor under Factor 3, with the subsequent factors remaining the same categories of analysis.

approximately the same rate as in previous years and so would return to the Dungeness River watershed at a similar rate as in previous years.

The pink salmon program will continue to operate as described in the 2016 BiOp with the effects remaining the same as described there. The coho salmon program will operate as described in the 2016 and 2019 BiOps with the effects remaining the same as described in those documents. The analysis here will focus on the potential effects of the proposed changes to the Chinook salmon program.

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

The Dungeness Chinook salmon hatchery program will have a beneficial effect on Chinook salmon genetics and demographics as compared to the currently operating program because the 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 number of natural- and hatchery origin adults collected from the Dungeness River to use as broodstock will increase from up to 112 to up to 130. Using more spawners will increase the genetic effective population size and act to maintain genetic variation (Barton et al. 2018). It is expected that natural-origin Chinook salmon will make up 20-30% of the broodstock as is consistent with the proportion of natural-origin Chinook salmon (PNI) in the adult escapement. Integrating natural-origin Chinook will ensure genetic drift and domestication do not lead to genetic differences between the natural and hatchery components of the population (Waters et al. 2015).

The collection of adult natural-origin Dungeness spring Chinook salmon as part of in-river collection activities as well as those volunteering to the weir and hatchery trap for use as broodstock will result in fewer natural-origin spawners escaping to spawning grounds. However, the co-managers will limit the total number of fish collected to 130 adults with the proportion of natural-origin fish in the broodstock collection representative of that in the total escapement as in past years. Data collected from 2006-2020 indicated that on average 19 percent of the natural origin Chinook salmon escapement is collected for broodstock (Table 8). In the most recent years there has been a trend toward a lower percentage of natural-origin adults being collected to use as broodstock allowing more natural-origin adults to spawn naturally (Table 8). NMFS expects this supplementation program will increase overall spawner abundance as well as spatial diversity over the long term, which will offset the effects of any spawners that are taken into the hatchery as has been observed in watersheds with similar programs operating (Fast et al. 2015; Berejikian and Doornik 2018).

The release of salmon produced as part of captive broodstock programs can provide a demographic benefit to a population experiencing low numbers (Kalinowski et al. 2012). For a period of eight years, the estimated duration of two Chinook salmon generations, release numbers will be increased to 600,000 using a captive rearing program to produce the increase of 400,000 juvenile Chinook salmon. While there can be negative genetic effects related to captive brood programs due to domestication and loss of genetic variation, with appropriate rearing standards captive rearing programs are also successful in increasing the number of spawners, which reduces the loss of genetic variation due to genetic drift in small populations (Berejikian and Doornik 2018; Johnson et al. 2020). Limiting the captive brood program to this time period will allow for a demographic boost without long term genetic effects associated with adaptation to the captive rearing environment (Kalinowski et al. 2012). To maintain genetic variation in the captive brood component, up to 20 fertilized eggs will be retained from approximately 40 – 50 river spawned families. Vent-clipped or otherwise differentially marked Chinook salmon would not be used as broodstock to avoid domestication due to spawning multiple generations of hatchery rearing—they would be released upstream to spawn in the wild. This would ensure fish spawned in the hatchery were only one generation removed from in-river fish. All these measures will ensure that the captive brood program provides beneficial effects by increasing the numbers of potential spawners in the population and maintaining genetic variation while avoiding detrimental genetic effects.

Incidental collection of Chinook salmon not needed for broodstock generally does not occur. The co-managers account for the number of adult Chinook salmon that have volunteered at the hatchery in order to collect only the number needed from the river. NMFS expects most years will result in only the 130 adults required for broodstock being handled. However, in the past, up to 80 adult Chinook salmon over the number required for broodstock either volunteered to the Dungeness Hatchery trap or were captured at the river weir. These fish were returned to the river unharmed (Gufler 2022). NMFS expects that, in most years, incidental handling of adult Chinook salmon would not occur or would be minimal and these fish will be returned to the river unharmed.

The collection of Dungeness Chinook salmon is not expected to affect Puget Sound steelhead as steelhead do not enter the hatchery trap and steelhead are rarely observed when the operators are netting adults in the river. In rare cases that steelhead are present during netting activities, operators can readily avoid them (Coutu 2022). Any steelhead incidentally captured during broodstock collection activities would be returned to the river unharmed. NMFS expects that in years when steelhead are encountered and released during broodstock collection activities, only low numbers of steelhead will be encountered (e.g., 0-10 individuals) and they will be returned to the river unharmed.

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

Although the proposed Chinook hatchery program may pose both genetic and ecological risks, the Dungeness Chinook salmon population may benefit from this integrated program, as it is currently operated as well as the updated program, designed to supplement the natural population, providing an overall beneficial effect on within-population diversity and to viability. Only ecological and physical broodstock collection effects are relevant for Puget Sound steelhead because the proposed program does not propagate steelhead. The overall ecological effect is negligible, and the broodstock collection effect is low, as discussed below.

2.5.2.2.1 Effects on Chinook salmon

The complete analysis of projecting pHOS and PNI into the Dungeness River spring Chinook salmon population is presented in Haggerty (2022). A summary of those results is presented here.

Natural-origin Chinook salmon escapement to the natural spawning areas in the Dungeness River has been trending upward since a low of 21 adult Chinook salmon in 2014 and has averaged 176 adults over the last five years (2016-2020). Natural-origin productivity has been very low, averaging only 0.44 returning natural origin Chinook salmon for each naturally spawning Chinook salmon (BY 2004-2013). A more recent analysis of these data, updated through brood year 2016 shows higher productivity, averaging 0.60 returnees per spawner (R/S; BY 2004-2016). The most recent 5-year average returnees per spawner had increased to 0.83 indicating productivity in the watershed is improving although productivity is still below the replacement level.

The Dungeness Basin Chinook salmon hatchery program is designed for returning hatchery-origin adults to spawn in the natural spawning environment and not home into the hatchery facilities. Since very few hatchery-origin fish return to the hatchery facilities pHOS is projected to be at the levels of ~90%. From 2016 through 2020, the natural-origin run-size to the Dungeness River has averaged 200 fish per year with 176 naturally spawning and 24 being used as brood stock (WDFW unpublished escapement estimates 2022, and following). During this same time period, the hatchery run-size has averaged 578 with 499 naturally spawning and the remainder being used as hatchery brood stock. This has resulted in a five-year average pHOS of 74% and a pNOB of 23.3%. Based on these values it was estimated that during the last five years PNI has averaged 27.8%. PNI during the period effected by the captive brood program is estimated to average 21.0%, which is a reduction relative to current levels. pHOS is expected to be increased from current levels of approximately 74% to 90% as hatchery-origin adults produced as part of the captive brood component return to the natural spawning grounds.

Dungeness spawning habitat is thought to be under-utilized (SSPS 2007; Hall et al. 2019). Habitat capacity has been increased due to removing barriers to fish passage and increasing connectivity throughout the Watershed (NMFS 2013b; Hall et al. 2019; Brooks 2021). As habitat improvements lead to increased rearing habitats productivity may increase as the Watershed becomes able to support higher numbers of fish (Anderson and Topping 2018). The co-managers’ goal of increasing production is to produce more returning adults escaping to the Dungeness spawning grounds, which, if successful, would result in lower pHOS and increased PNI as the natural-origin progeny of the increased numbers of hatchery-origin adult Chinook salmon return to spawn naturally. As productivity has been increasing in the Dungeness Basin, it is reasonable to expect that this goal will be achieved and, long-term, the Dungeness Chinook salmon hatchery program will provide beneficial demographic effects by producing more adults to spawn naturally and beneficial genetic effects by increasing effective size, which will maintain genetic variation.

In the short term, NMFS recognizes that negative genetic effects such as domestication or loss of genetic variation are possible with using a captive brood program to increase production. Rearing salmon in captivity for a long period of time can lead to domestication, which reduces genetic variation, and adaptive potential, which can negatively affect the adaptive potential of the population (Frankham 2008; Fraser 2008). However, the Dungeness Chinook salmon program integrates natural-origin fish as broodstock, which minimizes genetic risk by minimizing genetic divergence from the natural source population (Waters et al. 2015; Waters et al. 2018) as well as reducing adaptation to captivity (Janowitz-Koch et al. 2018). The low PNI of the Dungeness Chinook salmon hatchery program is influenced by high pHOS rather than the lack of natural-origin broodstock. As this program has been consistently integrated, the hatchery and natural-origin spawners are genetically indistinguishable. Thus, the negative genetic effects generally associated with high pHOS and low PNI are likely not as detrimental for this population as continued population decline and the increased numbers of hatchery origin spawners are likely providing benefits to genetic variation by increasing the effective size of the spawning population. From a genetics standpoint, the most detrimental scenario for Dungeness River spring Chinook salmon is genetic drift caused by continued low numbers of spawners leading to loss of genetic variation (Willi et al. 2006; Kardos et al. 2021).

To further lower the genetic risks of captive rearing and increased numbers of hatchery spawners, the co-managers are limiting the increased production to a period of eight years, equal to two generations of Chinook salmon based on the age structure of the Dungeness River population. This will allow the numbers of spawners to be increased and then, when the captive broodstock component is terminated, allow for natural spawners to populate the watershed (Berejikian and Doornik 2018; Janowitz-Koch et al. 2018). Returning adults produced as part of the captive brood component will be differentially marked with a visible mark and they will not be collected to use as hatchery broodstock, which will also limit any genetic effects of the captive brood program. The co-managers have secured funding for genetic monitoring and research through the PST process and have proposed a genetic monitoring program where samples are collected from hatchery, captive brood, and natural Chinook salmon for genetic analysis, which will ensure the increased production is not leading to loss of genetic variation and guide the co-managers in hatchery management while the captive broodstock component of the program is operational (WDFW 2022).

2.5.2.2.2 Effects on steelhead

Hatchery-origin Chinook salmon and their progeny on the spawning grounds are not expected to affect Dungeness steelhead. Adult chinook salmon spawn before steelhead arrive on the Dungeness spawning grounds. Juvenile Chinook salmon emerge and migrate towards the estuary before juvenile steelhead emerge (WDFW 1994a; SSPS 2007). As discussed in the above section, steelhead are not encountered during in-river Chinook salmon broodstock collection and do not volunteer to collection facilities.

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

The action area includes freshwater habitats of the Dungeness River basin and marine habitats of the Puget Sound and the Pacific Ocean. Based on the science available, the ability to detect the effects of releasing hatchery steelhead smolts is somewhat proportional to the size of the habitat fish will occupy. NMFS uses a quantitative methodology to analyze effects of juvenile hatchery Chinook salmon in freshwater migratory and rearing areas of the Dungeness River basin because

ESA-listed Chinook salmon and steelhead are present in the freshwater for a limited timeframe and reliable quantitative methods exist for determining the effects of predation and competition in these habitats. Much less is known about interactions between natural- and hatchery-origin salmonids in marine habitats, because the size and scope of marine habitats include the Puget Sound and the northeast Pacific Ocean. NMFS believes that using a qualitative approach is a more reliable method to evaluate competition and predation in marine habitats given the available information, and the high degree of complexity and uncertainty.

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

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

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

Similar to the use of models for biological systems elsewhere, this model cannot possibly account for all the variables that could influence competition and predation on natural-origin juveniles. For example, the model assumes that if a hatchery fish is piscivorous and stomach capacity is available, the hatchery fish will consume natural-origin prey. In reality, hatchery-origin fish could choose to eat a wide variety of invertebrates, such as other fish species (e.g., minnows), and other hatchery-origin fish in addition to natural-origin steelhead smolts. However, NMFS believes that with this model we are estimating, to the best of our ability, a worst-case estimate for the effects on natural-origin juvenile steelhead.

Some of the parameter inputs were assumed to be consistent with other consultations in which this model was used (Table 15). A 100 percent population overlap was assumed between hatchery Chinook salmon and age-1 and older ESA-listed natural-origin Chinook salmon and steelhead. A 100 percent population overlap in microhabitats is likely an overestimation, but represents the worst-case scenario. As will be discussed below in greater detail, for some age classes (e.g., typically age-0 fish) the proportion of population overlap was modified to a value less than 1 where data supported doing so. Hatchery fish release windows were considered and included only the proportion of steelhead fry that would have emerged assuming that hatchery fish are all released on the last day of their release window and assuming that all hatchery fish take the full length of travel time to the mouth of the Dungeness River.

Table 15. Parameter input values used to model predation, competition, and delayed mortality interactions with hatchery-origin Chinook salmon.

Parameter	Value
Habitat Complexity	0.1
Population overlap	1.0
Habitat segregation	0.3 for conspecifics, 0.6 for all other species
Dominance mode	3
Probability dominance results in weight loss	0.05
Proportion of weight loss causing death	0.5
Maximum encounters per day	3
Predatory:prey length ratio for predation	0.33
Mean temperature across release sites	43°F/6°C (April 1) and 48°F/9.1°C (June 1)

Habitat complexity was assumed to be low at only 10 percent to conservatively account for habitat degradation in the Dungeness River basin. Habitat segregation estimates were of 0.3 for conspecifics, and 0.6 for other Chinook salmon, a dominance mode of 3 and maximum encounters per day of 3, based on what was decided in the HETT (2014) database for hatchery programs of the same life stage and species. Other assumptions about parameter inputs for natural-origin populations were consistent with all of the other consultations where this model was used (Appendix Table 14 for list of all parameters).

In-river temperature measurements in the Dungeness River (RM 0.2) were collected from 204-2014 to calculate a mean temperature of 6°C (43°F) during the five-day yearling release period beginning on April 1 and 9.1°C (48°F) during the ten-day sub-yearling release period beginning on June 1 (Figure 5). Daily mean temperature of the Dungeness River (RM 0.2) from 2004-

2014.). In-river migration rates of hatchery Chinook salmon are based on measurements by Topping et al. (2008b). The release of yearling Chinook salmon during the mid-point for yearling and sub-yearling Chinook salmon, respectively (e.g., April 1 through April 5 for yearlings; June 1 through June 10 for sub-yearlings) was used in the model. The Dungeness basin is a steep, north-facing watershed with relatively few large tributaries in low elevation areas. As a result, environmental conditions in the lower elevations where hatchery facilities are located is relatively homogenous.

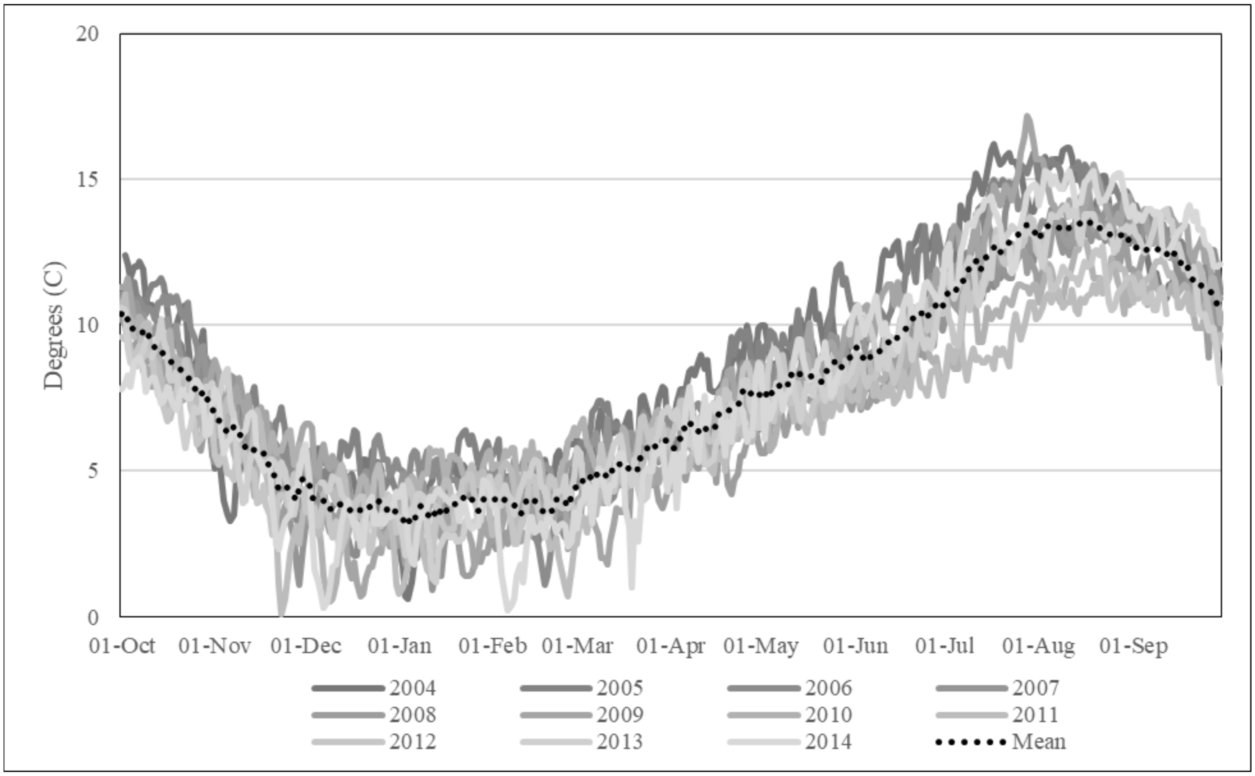

Figure 5. Daily mean temperature of the Dungeness River (RM 0.2) from 2004-2014.

The effect of interactions among hatchery-origin fish and natural-origin young-of-year Chinook salmon and steelhead was examined by analyzing seasonal emigration rates of Chinook salmon and modeled emergence rates of steelhead. The proportion of the natural-origin Chinook salmon population subjected to interactions with hatchery-origin fish was estimated by summarizing trends in the daily number of unmarked Chinook salmon collected in the WDFW-operated smolt trap near RM 0.2 of the Dungeness River (Figure 6). All natural-origin Chinook salmon were assumed to have emerged and were a minimum size of 45mm at the time hatchery fish were released (e.g., April 1 for yearlings and June 1 for sub-yearlings).

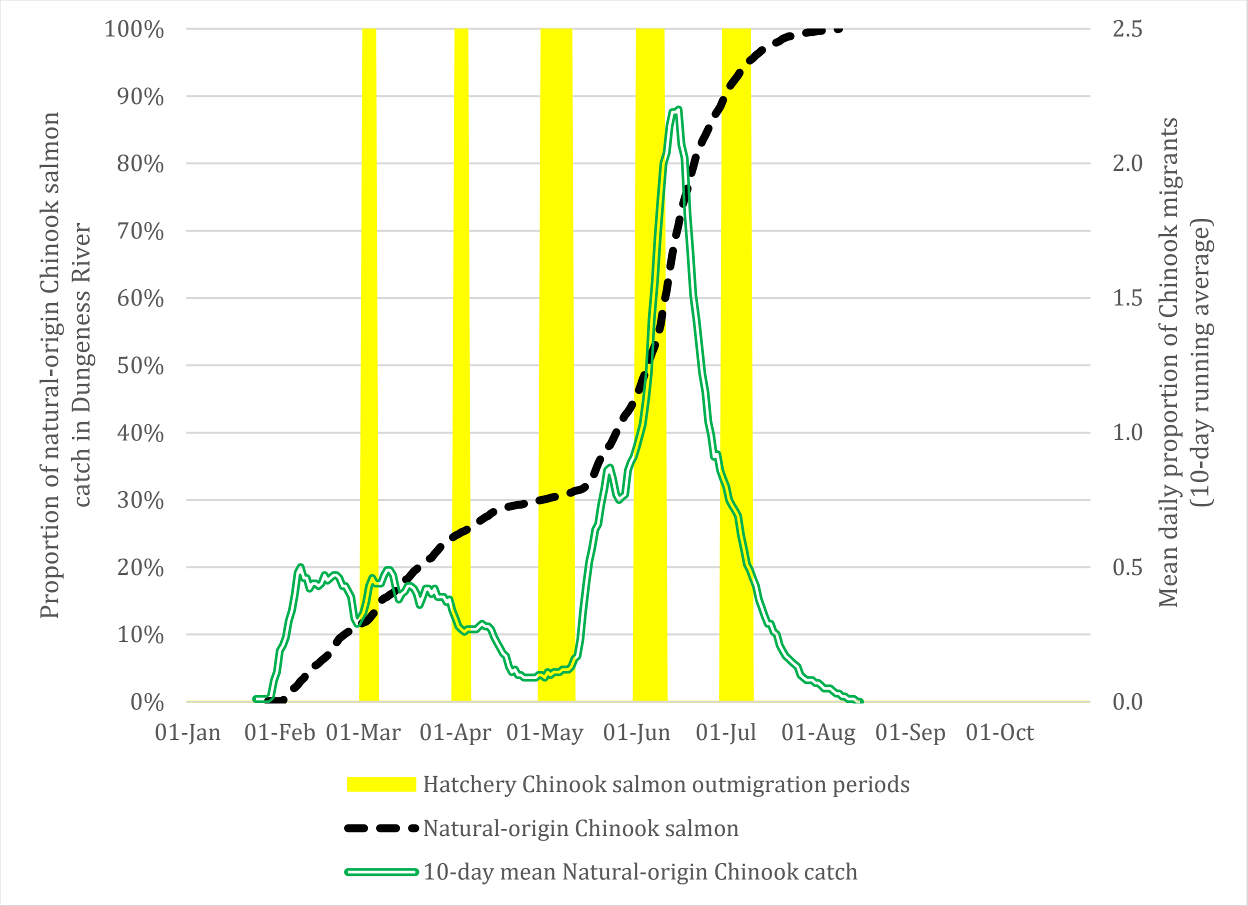

Figure 6. Daily migration of natural-origin Chinook salmon in the Dungeness River. We used seasonal Chinook migration data to determine the proportion of fish available to migrating hatchery-origin Chinook salmon (denoted in yellow).

Unlike Chinook salmon, juvenile steelhead do not migrate as sub-yearlings and typically reside in freshwater for a minimum of one year prior to migrating to saltwater. These juvenile steelhead remain in low-elevation reaches of the Dungeness River where they may interact with hatchery fish. Seasonal emergence of steelhead fry was modeled using spawn timing based on redd survey data collected by WDFW in 2015 (Figure 7). The proportion of steelhead fry emerged was estimated across a range of 900-1200 accumulated thermal units (ATUs). Steelhead fry emergence typically occurs during mid-May. As a result, only small proportions of steelhead fry (3-14 percent on average) may interact with hatchery Chinook salmon across the range of release dates (i.e., March 1 to June 30).

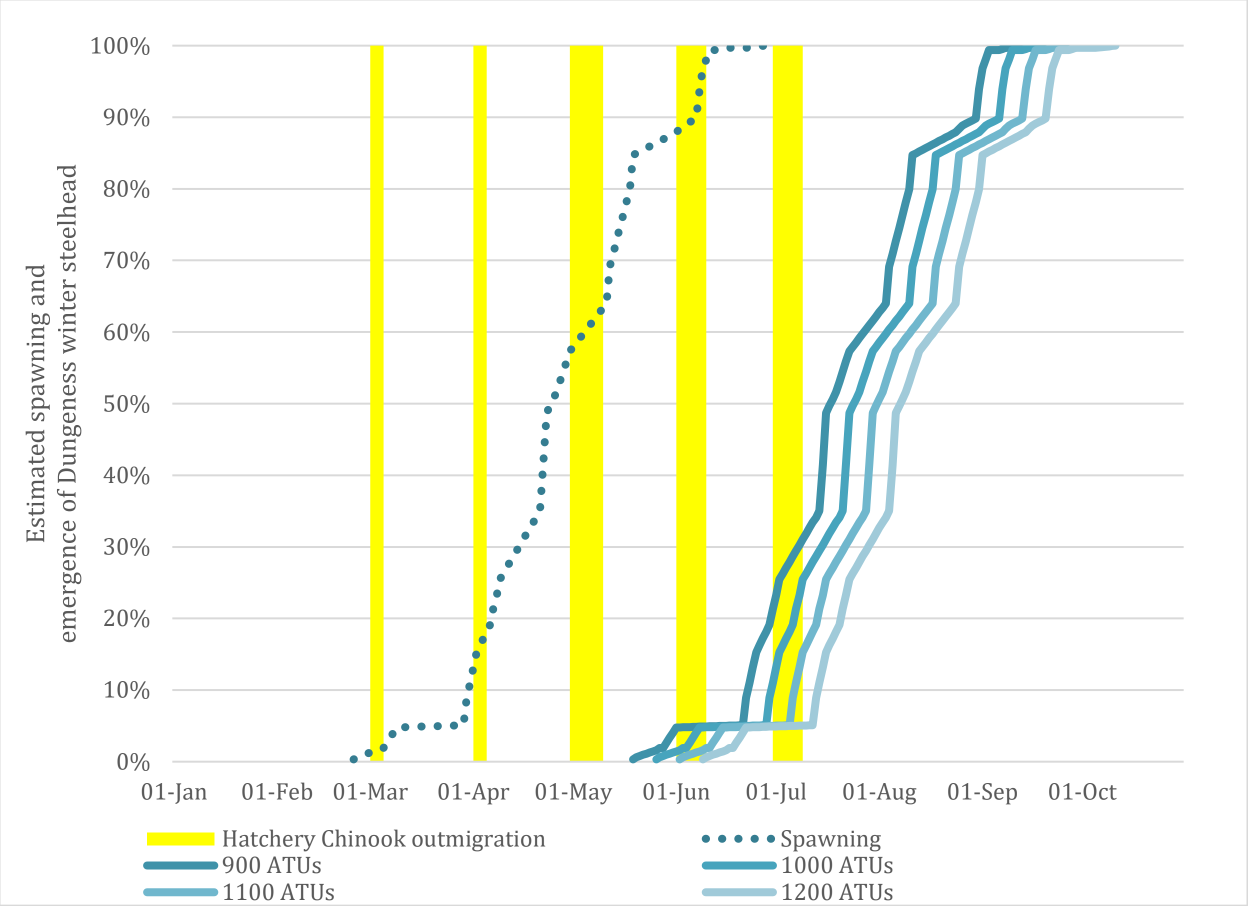

Figure 7. Modeled redd construction and fry emergence of natural-origin steelhead in the Dungeness River. The mean date of modeled emergence based upon ambient water temperature across a range of accumulated thermal units (ATUs) for egg hatching was used to estimate the proportion of the subyearling individuals vulnerable to outmigrating hatchery Chinook salmon.

The number of fish available for competitive and predatory interactions was modeled using five-year mean production estimates for Chinook salmon and steelhead in the Dungeness River basin adjusted by life stages applicable to juvenile outmigration (e.g., parr, subyearling, yearling, etc.) (Table 16). Survival of each year-class was adjusted by applying a common smolt-to-adult return rate for each species (Chinook salmon = 0.48 percent; steelhead = 2 percent), and assuming nearly all steelhead emigrated during their second or third year of freshwater residency. The number of natural-origin fish from each year class for modeled series was estimated using published data from Topping et al. (2008a).

Table 16. Age, size, and occurrence of listed natural-origin Chinook salmon and steelhead encountered by hatchery steelhead released in the Dungeness River Basin.

Hatchery-origin Chinook salmon			**Natural-origin Chinook salmon and steelhead**				
Release number	Timing	Age class (size)	Species	Age class	Number of fish in PCD Model	Size (mm)	Percent emerged/ migrated
100,000	April 1	Yearling (182mm)	Chinook salmon	subyearling	58,327	70	25
			Steelhead	fry	158,512	35	0
			Steelhead	parr	39,628	100	100
			Steelhead	age 2+	9,907	165	100
			Steelhead	age 3+	227	210	100
			Steelhead	age 4+	5	230	100
100,000 – 500,000	June 1	Subyearling (110mm)	Chinook salmon	subyearling	141.5	70	51
			Steelhead	fry	158,512	35	3
			Steelhead	parr	39,628	100	100
			Steelhead	age 2+	9,907	165	100
			Steelhead	age 3+	227	210	100
			Steelhead	age 4+	5	230	100

Results from the first modeled hatchery release scenario (i.e., 100,000 of both yearling and subyearling Chinook salmon) has relatively little effect on steelhead (i.e., mortality of 3.42 adult equivalent) (Table 17). This is likely owing to differences in emergence timing of steelhead fry, but also differences in size and habitat use between Chinook salmon and steelhead migrants. The model predicts most mortality will occur to natural-origin Chinook salmon (i.e., 6 adult equivalents) when yearling hatchery Chinook salmon are released. In comparison, releases of an equal number of subyearling Chinook salmon results in only one adult equivalent mortality of natural-origin Chinook salmon.

Table 17. Estimated mortality of natural-origin Chinook salmon and steelhead from predation, competition, and delayed mortality resulting from interactions with 200,000 hatchery-origin Chinook salmon (100,000 yearling and 100,000 sub-yearling).

Hatchery-origin Chinook salmon			Natural-origin				
Release number	Timing	Age class	Species	Age class	Mortality	Adult equivalent	Total mortality
100,000	April 1	yearling	Chinook salmon	age 0	1249.9	6	**6**
			Steelhead	age 0	0	0	**0.80**
			Steelhead	age 1	110.9	0.58	
			Steelhead	age 2	8.7	0.196	
			Steelhead	age 3	0	0	
			Steelhead	age 4	0	0	
100,000	June 1	subyearling	Chinook salmon	age 0	141.5	1	**1**
			Steelhead	age 0	1438.5	1.96	**2.62**
			Steelhead	age 1	112.9	0.617	
			Steelhead	age 2	1.9	0.043	
			Steelhead	age 3	0.1	0	
			Steelhead	age 4	0	0	

The second modeled hatchery release scenario (100,000 yearling and 500,000 subyearling Chinook salmon) has similar effects on both natural-origin Chinook salmon and steelhead despite a five-fold increase in the number of sub-yearling Chinook salmon release. This scenario yields a maximum of 7 adult equivalent mortalities and 3.47 steelhead adult equivalent mortality (Table 18). The minimal overlap between steelhead fry during the June 1 release period (approximately 3 percent) reduces the exposure of the year class that is most vulnerable to interaction with hatchery fish, even considering the increase of sub-yearling hatchery Chinook salmon. Using two model estimates, we predict a maximum total adult equivalent mortality of natural-origin fish to be 7 Chinook salmon and about 3.47 steelhead.

Table 18. Estimated mortality of natural-origin Chinook salmon and steelhead from predation, competition, and delayed mortality resulting from interactions with 600,000 hatchery-origin Chinook salmon (100,000 yearling and 500,000 sub-yearling).

Hatchery-origin Chinook salmon			Natural-origin				
Release number	Timing	Age class	Species	Age class	Mortality	Adult equivalent	Total mortality
100,000	April 1	yearling	Chinook salmon	age 0	1249.9	6	**6**
			Steelhead	age 0	0	0	**0.80**
			Steelhead	age 1	110.9	0.606	
			Steelhead	age 2	8.7	0.196	
			Steelhead	age 3	0	0	
			Steelhead	age 4	0	0	
500,000	June 1	sub-yearling	Chinook salmon	age 0	148.6	1	**1**
			Steelhead	age 0	1476.6	2.02	**2.67**
			Steelhead	age 1	114.1	0.623	
			Steelhead	age 2	1.3	0.029	
			Steelhead	age 3	0	0	
			Steelhead	age 4	0	0	

The displacement of natural-origin fish by hatchery steelhead might alter behavioral patterns and habitat use of natural-origin fish, making them more susceptible to predators. Hatchery-origin fish may also alter naturally produced salmonid migratory responses or movement patterns, leading to a decrease in foraging success (Hillman and Mullan 1989; Steward and Bjornn 1990). Actual impacts on naturally produced fish would thus depend on the degree of dietary overlap, food availability, size-related differences in prey selection, foraging tactics, and differences in microhabitat use (Steward and Bjornn 1990).

Naturally-produced progeny competition

Hatchery-origin Chinook salmon are intended to spawn naturally in the Dungeness River to provide demographic benefits and to maintain genetic diversity. Naturally spawning hatchery-origin salmon and steelhead are likely to be less efficient at reproduction than their natural-origin counterparts (Ford et al. 2009; Williamson et al. 2010; Crewson et al. 2017), 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 Dungeness River Chinook salmon program 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 monitoring 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.

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 Dungeness 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 2012a). 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; WWTIT and WDFW 2006).

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

The Dungeness Chinook salmon hatchery program includes RM&E to monitor the success of the program, monitor compliance with this opinion, and to reduce risks to ESA-listed Dungeness River basin Chinook salmon and steelhead. The RM&E included in the HGMP analyzed in this biological opinion is expected to lead to a better understanding of the status of ESA-listed species in the Dungeness River watershed, and what factors affect their abundance and productivity. Data gathered through the RM&E activities will greatly supplement best available information regarding how to help recover ESA-listed Dungeness Chinook salmon and steelhead. While some lethal and sub-lethal effects on listed species are expected to occur as a result of implementing RM&E actions, the knowledge gained through these actions allow for better conservation and management of these stocks, which has an overall benefit to the Dungeness Chinook salmon population.

The co-managers conduct numerous ongoing monitoring programs including catch, escapement, marking, tagging, and fish health testing to evaluate genetic and ecological interactions with listed Dungeness Chinook and steelhead. The co-managers conduct annual spawning surveys throughout the watershed and inspect any carcasses found for marks and tags to evaluate adult returns and to detect fish from other programs escaping to the Dungeness spawning grounds. The co-managers may collect carcasses, otoliths, scales, and tissue samples during spawning ground surveys and transport these materials to laboratories for analysis. Samples for genetic analysis may be collected from carcasses. All salmon reared in the three Dungeness hatchery programs would be monitored and sampled for mortality rates by life stage, fish health, and for population census. All hatchery-origin fish would be marked and/or tagged prior to their release to allow assessment of smolt to adult survival rates and to determine the origin of adult returns.

The primary monitoring and evaluation objective for the two conservation hatchery plans for Chinook salmon and pink salmon is assessment of the status of the target Dungeness River populations and the success of the programs in achieving restoration goals for the species (WDFW 2013b; 2018; 2020). Monitoring and evaluation actions that would be implemented to determine whether this objective is met include spawning ground/redd surveys and hatchery escapement monitoring to determine total Chinook and pink salmon adult returns to the Dungeness River and the hatcheries. The number and distribution of tagged, untagged, and otolith-marked fish escaping to the watershed each year would be monitored to determine the status of the natural- and hatchery-origin salmon returns relative to goal levels. In addition to regular foot surveys to census salmon spawning abundance, count redds, and sample carcasses to identify fish origin in natural spawning areas, adult fish abundance, origin, and distribution data would be collected through monitoring of weir counts at Dungeness River Hatchery and at the Dungeness River mainstem weir. Adult fish returns, timing, age class, sex ratio, and fish health condition data would be collected at the hatchery and weir locations to monitor the effects of the programs in increasing adult returns and maintaining the run traits of the target populations. Juvenile fish outmigrant data collected through annual operation of a downstream-migrant trap in the mainstem Dungeness River would allow for assessment of the natural spawning success of the salmon populations. Operated by WDFW's Wild Salmon Production Evaluation Unit, and permitted for listed fish takes through a separate ESA review process, juvenile outmigrant trapping would provide data regarding abundance by species and origin, and salmon migrational behavior (seasonal timing, migration rate, and migration duration). These data are essential for identifying Chinook and pink salmon survival and productivity, and the effects of the conservation hatchery programs in assisting in the restoration of viable populations.

The demographic and ecological effects of the three salmon programs on listed salmon and steelhead populations in the Dungeness River are also monitored. The primary objective would be to determine whether the programs were harming juvenile and adult Chinook salmon, summer chum salmon, or steelhead as a result of hatchery operations, broodstock collection, and production of juvenile fish. In general, actions taken at the hatcheries to meet this objective would include monitoring of water withdrawal and effluent discharge to ensure compliance with permitted levels; monitoring of broodstock collection, egg take, fish survival rates, and smolt release levels for each program to determine compliance with program goals; and fish health monitoring and reporting in compliance with co-manager Fish Health Policy (WDFW and NWIFC 1998; WWTIT and WDFW 2006) requirements. Data collected through operation of the WDFW juvenile out-migrant trap in the lower river, and a juvenile coho salmon outmigrant trap in Matriotti Creek operated by the Jamestown S'Klallam Tribe, would allow assessment of emigrating natural- and hatchery-origin fish abundance and overlap in timing between natural-origin species and newly released hatchery-origin fish. Other data collected through the two trapping programs that would be used to assess hatchery effects are fish size, origin (marked/tagged vs. unmarked/untagged) and other biological data (e.g., tissue samples for genetic analyses). To ensure proper care and maintenance of trapped fish as a means to minimize take of listed fish, the trap would be checked by WDFW daily and multiple times per day when large numbers of fish are observed entering the trap or are present in the area surrounding the trap to reduce holding duration, and trapping would be suspended during high flow events to reduce the risk of fish injury and mortality (WDFW 2013a). Other risk aversion measures that are currently implemented to minimize take are specified in annual NMFS 4(d) Evaluation and Determination documents authorizing tribal research in Puget Sound (NMFS 2017b).

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

The majority of the water supply systems used for salmon rearing in the proposed programs are designed and operated such that groundwater extraction and surface water withdrawals are not expected to reduce survival, spatial distribution, and productivity of natural-origin Dungeness River Chinook salmon and steelhead.

Since the 2016 BiOp was completed, the Canyon Creek water intake has been updated to comply with the most recent screening requirements and a fish ladder has been constructed allowing fish passage above the small dam and access to upstream spawning habitat (NMFS 2013b; WDFW 2022). The Canyon Creek fish ladder was constructed to ensure that a minimum creek flow of 22 cubic feet per second (cfs) enters the fishway. The hatchery will never withdrawal 100 percent of the flow, as use of the water by the hatchery would only occur when flows are highest during the winter months and floods or icing of the main intakes on the Dungeness River prevent their use. Flow maintained at least at this level will maintain sufficient in-stream flow in the fish ladder and in the reach downstream of the dam to allow fish passage (NMFS 2013b; WDFW 2022).

In February 2021, construction was completed to bring the main intake at Dungeness River Hatchery into compliance with the most current fish passage and screening requirements (NMFS 2011a; WDFW 2022). This has reduced the potential take by this facility of Dungeness Chinook salmon and steelhead compared to what was considered in the 2016 BiOp. Due to the updated screening, the effect of the operation of the Dungeness River Hatchery for the programs in the proposed action is negligible to Chinook salmon and steelhead.

The intake screen in Hurd Creek for the Hurd Creek Hatchery does not meet current federal water intake screening criteria (WDFW 2022). An on-site evaluation of the Hurd Creek Hatchery surface water intake screen indicates adverse effects on any migrating salmonids are unlikely (Carlson and Williams 2015). The intake is a horizontal inclined screen positioned at the bottom of a pond created in a Hurd Creek side-channel that is away from creek areas where downstream-migrating salmon and steelhead would be present. Rather than operating the intake by directing water flow over (and through) the screen, water is instead backwatered over the screen by the placement of stop logs at the downstream end of the screen. WDFW indicates that, because the intake is positioned and operated in an off-channel pond that is not likely attracting migrating fish, it is unlikely that the intake screen would contact or cause impingement by natural-origin salmon or steelhead. The Hurd Creek Hatchery facility uses a combination of groundwater withdrawn from five wells, and surface water withdrawn from Hurd Creek for fish rearing and as an emergency back-up source. Under its State water right permit, Hurd Creek Hatchery may withdraw up to 1.4 cfs from Hurd Creek. Under worst case circumstances, in the unlikely event that this amount were withdrawn during the September low flow period for the creek, up to 70 percent of the water in the Hurd Creek could be withdrawn for fish rearing for the Chinook and fall-run pink salmon programs. Although unlikely to occur because use of surface water at the full permitted amount is not necessary for fish rearing during the annual low flow period, withdrawal of this proportion of the total flow in the creek could potentially affect the ability of adult fish to migrate upstream. WDFW plans to upgrade fish screens at Hurd Creek Hatchery to ensure compliance with NMFS fish passage criteria with work anticipated being complete by fall 2024.

As noted in Section 1.3.1.5, Dungeness River Hatchery uses surface water exclusively, currently withdrawn through the water intakes on the mainstem Dungeness River, in addition to the water intake on Canyon Creek. Dungeness River Hatchery may withdraw up to 40 cfs of surface water from the Dungeness River and up to 8.5 cfs from Canyon Creek (Table 4). Assuming hatchery water withdrawals at maximum permitted levels, up to 62 percent of the water during the lowest streamflow on record (65 cfs) or 50 percent of the 99 percent exceedance low flow (80 cfs) in the Dungeness River could be temporarily diverted into Dungeness River Hatchery to support the three salmon hatchery programs, and 13 percent of the water in the river could be withdrawn during median flows (299 cfs) (WDFW 2013a; 2022). Water in Canyon Creek could potentially be temporarily diverted into Dungeness River Hatchery for discharge into the Dungeness River at the hatchery outfall. As noted above, minimum flow criteria were developed in connection with a NMFS consultation on the construction of the Canyon Creek fish ladder and water intake, in order to reduce the risk of migration impedance in Canyon Creek that might result from water withdrawal (NMFS 2013b).

The Gray Wolf Acclimation Pond is supplied with surface water that is gravity fed from the Gray Wolf River. Up to 1.0 cfs may be withdrawn from the Gray Wolf River for operation of the Gray Wolf Acclimation Pond program, which is no more than 0.5 percent of the flow in the Gray Wolf River at that point. The Upper Dungeness Acclimation Ponds is supplied with surface water pumped from the Dungeness River. The Upper Dungeness River Acclimation Pond program could potentially use up to 1.0 cfs, which is no more than 0.3 percent of the surface water in the Dungeness River at the point of water withdrawal. Water used in both acclimation ponds is non-consumptive and is returned to the river it was withdrawn from close to the point of withdrawal. NMFS does not anticipate this small percentage of water usage will affect Dungeness Chinook salmon or steelhead.

The maximum percentage water withdrawal levels described above assume hatchery use of available surface water up to allowable maximums under Washington State surface water withdrawal permits issued for the programs. Actual surface water withdrawal percentages as applied to minimum and mean surface water flows are much lower. Fish biomass in the hatcheries, and required water withdrawal amounts, would reach maximum permitted levels only in the late winter and spring months just prior to fish release dates, when flows in river and tributary sources reach annual maximums. Fish biomass and water requirements for fish rearing at the hatcheries are lowest in the late summer and fall months, when annual minimum flows in surface water sources occur. For these reasons, withdrawal of surface and groundwater for use in the hatchery programs would not lead to substantial effects on listed fish. All water used by the hatcheries would be returned to the watercourses near the points of withdrawal. No stream reaches would be dewatered to the extent that natural-origin fish migration and rearing would be impaired, and there would be no net loss in river or tributary flow volumes. NMFS does not expect water withdrawal for use at the hatcheries to result in take of listed salmonids through dewatering of any stream reaches.

Fish rearing at Dungeness River Hatchery is implemented consistent with National Pollutant Discharge Elimination System (NPDES) permit number WAG 13-1037 issued by Washington Department of Ecology (WDOE). Under its NPDES permit, Dungeness River Hatchery operates an off-line settling pond and artificial wetland to remove effluent before the water is released back into the Dungeness River (WDFW 2022). Although under the 20,000 pounds per year fish production criteria set by WDOE as the limit for concern regarding hatchery effluent discharge effects, at Hurd Creek Hatchery, WDFW has constructed a two-bay pollution abatement pond to treat water prior to its release into Hurd Creek. The fish rearing ponds on the Gray Wolf River and the Upper Dungeness River also have low annual fish production levels, below those for which a NPDES permit is required. The effects of hatchery effluent discharge on downstream aquatic life, including listed Chinook salmon and steelhead, have been adequately minimized through compliance with federal and state permit requirements.

Structures and measures proposed for adult salmon broodstock collection would not substantially affect migration or spatial distribution of natural-origin juvenile and adult Chinook salmon and steelhead. Chinook salmon broodstock would be collected predominantly as volunteers to Dungeness River Hatchery. The facility is off-channel, removed from listed Chinook salmon and steelhead migration and rearing areas, and there would be no effects resulting from operation of broodstock collection actions at the hatchery. Listed Chinook salmon adults would be affected by mainstem Dungeness River weir located in the lower river at approximately RM 2.5 (when operating), and supplemented through netting, gaffing, noodling, or snagging implemented to collect broodstock in the lower river. These actions are proposed as part of the supportive breeding program for the species to augment broodstock collection at the hatchery off-channel trap. Any effects on Chinook salmon or the species' habitat would be minimized through implementation of best management practices. For the weir, these practices include use of a removable weir structure that rests on the river bottom and banks with minimal disruption of riverine habitat; placement and operation of the removable weir from May through September based on flow, only as needed to collect adult Chinook salmon for broodstock, and monitoring the weir and trap to ensure proper operation and to safeguard fish trapped; twice daily sorting of fish from the trap to minimize trap holding times, and implementation of fish capture and handling methods that protect the health of fish retained as broodstock or released back into the river. Any netting, gaffing, noodling, or snagging implemented as back-up methods to collect broodstock would be limited to three days per week, and conducted to protect redds and actively spawning fish from disruption, and reduce the risk of incidental harm to Chinook salmon and non-target species. All Chinook salmon adults collected from the river and retained as broodstock would be transferred to Hurd Creek Hatchery and held in high quality well water to enhance their survival to spawning. The majority of Dungeness River steelhead migrate into the river in winter after salmon broodstock collection activities have ended for the season; therefore, any impacts on the listed steelhead would be negligible.

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

There are no fisheries that exist because of the Proposed Action and therefore no effects caused by the proposed action via fisheries. There are fisheries in the action area that 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 (2022) concluded that the fisheries will not appreciably reduce the likelihood of survival and recovery for the listed species.

2.5.3 Effects of the Action on Critical Habitat

The proposed increase in the Dungeness salmon hatchery programs will not have additional effects on critical habitat than those described in the 2016 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 included as part of the proposed actions considered in this opinion.

- Facility effects are the only component of the proposed action of operating the Dungeness River Chinook salmon program that could potentially lead to adverse effects on critical habitat. As discussed in section 2.5.2.5, above, neither water withdrawals nor discharge will adversely impact critical habitat.
- 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.

2.6 Cumulative Effects

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

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

The federally approved Shared Strategy for Puget Sound Recovery Plan for Puget Sound Chinook Salmon (NMFS 2006) 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 Dungeness River Basin. Future tribal, state, and local government actions will likely be in the form of legislation, administrative rules, policy initiatives, and land use and other types of permits. Government and private actions may include changes in land and water uses, including ownership and intensity, which could affect listed species or their habitat.

Non-Federal actions are likely to continue affecting listed species. State, tribal, and local governments have developed plans and initiatives to benefit listed species (Elwha-Dungeness Planning Unit 2005; Jamestown S'Klallam Tribe 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 (SSPS 2007; NMFS 2018) would likely continue to help lessen the effects of non-Federal land and water use activities on the status of listed fish species. The temporal pace of such decreases would 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).

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

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

2.7 Integration and Synthesis

The Integration and Synthesis section is the final step in 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.

In assessing the overall risk of the proposed action on each species, NMFS considers the risks of each factor discussed in Section 2.5, above, in combination, considering their potential additive effects with each other and with other actions in the area (environmental baseline and cumulative effects). This combination serves to translate the threats posed by each factor of the proposed action into a determination as to whether the proposed action as a whole would appreciably reduce the likelihood of survival and recovery of the listed species.

2.7.1 Puget Sound Chinook Salmon

The best available information indicates that the Puget Sound Chinook Salmon ESU remains threatened (NWFSC 2015; Ford 2022). Dungeness Chinook salmon spawner abundance is currently depressed with escapement below the rebuilding threshold and recovery planning abundance target but above the critical threshold (Ford 2022). The Dungeness River Chinook salmon population currently has a primary role for recovery of the Puget Sound ESU (NMFS 2010). Our environmental baseline considers the effects of dams, habitat condition, fisheries, and hatcheries on Puget Sound Chinook salmon. Although all may have contributed to the listing of Puget Sound Chinook salmon, there have been improvements in the way these factors are managed or operated. As we continue to deal with a changing climate, management of these factors may also alleviate some of the potential adverse effects, as is the case for the Dungeness Chinook salmon hatchery program considered here, which serves as a genetic reserve for the natural population.

Effects of the proposed action include effects such as handling, monitoring, and operation of facilities that occur immediately, as well as those that will occur over time, including genetic and ecological effects. The co-managers have proposed ongoing monitoring activities to assess productivity, diversity, and abundance of both hatchery- and natural-origin fish and may adapt aspects of the hatchery program, including release location, number of juveniles released, and the use of captive reared Chinook salmon to limit impacts on VSP parameters in the ESU.

Broodstock collection requires ongoing annual handling of a portion of the population (juvenile and adult) and handling mortality is low. Broodstock collection is an essential component of the action. Broodstock collection is not expected to affect the Dungeness steelhead population and, therefore, would not have an adverse effect at the ESU level.

The ongoing effects of the Proposed Action on this ESU are genetic and ecological in nature, with small, localized effects from facility operation. Effects from RM&E are expected to be low and the information gained from conducting the work is essential for understanding the effects of the hatchery programs on natural-origin Chinook salmon populations.

Genetic effects on the Dungeness Chinook salmon population are limited by integrating natural-origin Chinook salmon into broodstock to ensure the hatchery population is genetically representative of the natural-origin population. Use of a captive brood program is intended to increase the number of natural spawners to avoid loss of genetic variation due to inbreeding and genetic drift. The Dungeness River population is a tier 1 population essential to the recovery of the ESU and the actions taken to protect the genetic variation of this population will reduce impacts on Puget Sound Chinook Salmon ESU. The Proposed Action is unlikely to have an adverse effect at the ESU level as this hatchery program takes measures to preserve the genetic integrity of the population. Moreover, considering the population’s degraded status, the program’s intent to boost abundance as a way to preserve the genetic integrity of the population is on balance a benefit to the program that outweighs the expected negative effects.

Ecological effects on natural-origin juvenile Chinook salmon associated with hatchery program releases are equivalent to an estimated loss of seven Chinook salmon adult equivalents from the Dungeness Chinook salmon population. Based on current information, this is likely to be a maximum loss because of the conservative assumptions and simplicity inherent in the model, and, while it could result in a decrease in adult abundance, this decrease is 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 Dungeness River population, and many of those populations are situated in basins that are contributing more to the overall species survival and eventual recovery than the Dungeness, because they tend to have substantially better habitat than the Dungeness River (e.g., Nisqually). In addition, most Chinook salmon populations besides the Dungeness are above the critical threshold and are on their way to the rebuilding threshold, even taking into factors such as climate change into account. As we continue to improve the model, these estimates will become more refined in the future, and will likely indicate a smaller percentage of adults that are lost from this worst-case scenario.

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

2.7.2 Puget Sound Steelhead

Any effects of the Proposed Action on the Dungeness steelhead population would occur incidentally during RM&E activities and these effects are likely to be minimal even at the population level. The effects would be infrequent and there is potential for years with no interactions. Because steelhead are not a target species, if a steelhead is ever encountered, it would be released unharmed. Thus, there is very little incidental effect on steelhead, and it is unlikely that the proposed action would lead to a decrease in the abundance, productivity, spatial structure, or diversity of the DPS. Ecological effects on juvenile steelhead associated with Dungeness Chinook salmon hatchery program releases are equivalent to an estimated loss of 3.47 adult steelhead equivalents from the Dungeness population. Based on current information, this is likely to be a maximum loss because of the assumptions and simplicity inherent in the model, and, while it could result in a decrease in adult abundance, this decrease is at a level that is likely to have little effect on the DPS.

The Hood Canal and Strait of Juan de Fuca MPG is one of three MPGs that comprise the Puget Sound DPS and, of these, the Northern Cascades MPG is a stronghold for diversity, abundance, and viability, with a relatively lower extinction risk than the other two major population groups in the Puget Sound DPS. Abundance is generally low among the small populations in the Hood Canal and Strait of Juan de Fuca, although escapement in the Elwha populations and Skokomish winter-run population is increasing. Any potential decreases in abundance and productivity due to the effects of the Proposed Action are small when scaled up to the DPS level. Thus, this analysis leads to a determination that the effects of Chinook salmon hatchery programs in the proposed action will not appreciably reduce the viability of the DPS. The DPS is reliant on other MPGs, and the Hood Canal and Strait of Juan de Fuca MPG is sustained by contributions from watersheds such as Elwha and the three Hood Canal populations where abundance is increasing rather than the contributions from Dungeness. Therefore, viability of the DPS would not be impacted by effect from the proposed action.

2.7.3 Critical Habitat

Critical habitat for ESA-listed Puget Sound Chinook salmon and Puget Sound steelhead is described in Sections 2.2.1.2 and 2.2.1.4 of this opinion. In reviewing the proposed action and evaluating its effects, NMFS has determined that the proposed action will not degrade habitat designated as critical for listed fish. The existing hatchery facilities have not led to altered channel morphology and stability, reduced or degraded floodplain connectivity, excessive sediment input, or the loss of habitat diversity, and no new facilities or changes to existing facilities are proposed. The proposed actions include compliance with limits and strict criteria for withdrawing and discharging water used for fish rearing, and the actions will not result in any adverse modification of critical habitat.

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

2.8 Conclusion

After reviewing the current status of the listed species, the environmental baseline within the action area, the effects of the proposed actions, including effects of the Proposed Actions that are likely to persist following expiration of the proposed actions, and cumulative effects, it is NMFS' biological opinion that the proposed actions are not likely to jeopardize the continued existence of Puget Sound Chinook Salmon and Puget Sound Steelhead or to destroy or adversely modify designated critical habitat.

2.9 Incidental Take Statement

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

This Incidental Take Statement includes much of that of the 2016 and 2019 BiOps and incorporates the take associated with the proposed increased release levels and changes to the Chinook salmon program.

2.9.1 Amount or Extent of Take

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

- Handling of adults at adult collection facilities

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[4] NMFS recognizes the benefit of providing guidance on the interpretation of the term "harass". As a first step, for use on an interim basis, NMFS will interpret harass in a manner similar to the USFWS regulatory definition for non-captive wildlife: "Create the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns, which include, but are not limited to, breeding, feeding, or sheltering." NMFS interprets the phrase "significantly disrupt normal behavioral patterns" to mean a change in the animal's behavior (breeding, feeding, sheltering, resting, migrating, etc.) that could reasonably be expected, alone or in concert with other factors, to create or increase the risk of injury to an [ESA-listed] animal when added to the condition of the exposed animal before the disruption occurred. See Weiting (2016) for more information on the interim definition of "harass."

- Genetic and ecological effects of hatchery adults on the spawning grounds
- Ecological effects of juveniles during emigration
- Facility effects of water intake structures

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

During Chinook salmon broodstock collection, up to 130 ESA-listed Chinook salmon are intentionally collected, retained, and lethally spawned in the hatchery. ESA-listed steelhead are not generally encountered at Chinook salmon broodstock collection activities and facilities but would be released unharmed in the unlikely event they were encountered. Incidental mortality from handling of fish encountered during broodstock collection is expected to be fewer than ten individuals annually. During broodstock collection for the Dungeness coho salmon program, up to 18 ESA-listed Chinook salmon and 21 ESA-listed steelhead are expected to be handled and released unharmed.

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

Implementation of the Dungeness River Hatchery Chinook salmon program has the potential to result in some degree of genetic change and fitness reduction in hatchery fish produced through the program, in the progeny of naturally spawning hatchery fish, and in the natural population.

It is not possible to ascertain the exact amount of take by genetic effects related to hatchery fish spawning naturally, because it is not possible to meaningfully observe and measure the number of interactions, nor their precise effects. Therefore, NMFS will rely on a surrogate take indicator that measures the productivity of the listed population – a primary factor in determining genetic diversity and fitness reduction effects. Productivity goals may go unmet for a variety of reasons apart from hatchery-related genetic effects (most notably, the degraded state of freshwater habitat in the basin, and the effects of climate change on ocean productivity), but the selected indicator would trigger further analysis to determine the causes of low productivity, with effects attributed to the hatchery program considered along with other factors such as habitat-related conditions, environmental factors, and harvest-related effects. NMFS will rely on the estimated recruits per spawner (R/S) (i.e., spawner-to-spawner) rate averaged over the most recent five consecutive years as a surrogate take indicator for genetic effects that relates to the productivity of the listed Chinook salmon population. The 2004-2016 estimated average spawner-to-spawner recruits for the Dungeness Chinook salmon population is 0.6 (Haggerty 2022), so NMFS will apply a rate of 0.6 spawner-to-spawner recruits, calculated annually as a five-year rolling average to indicate a possible adverse effect on productivity by the proposed action.

The take estimates described above associated with spawning ground competition and redd superimposition can be reliably monitored via spawning ground surveys to track incidences of hatchery pink and coho salmon displacing or adversely affecting listed Chinook salmon through these pathways.

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

NMFS has determined that juvenile hatchery-origin Chinook and yearling coho salmon compete with and prey upon rearing and migrating natural-origin Chinook salmon and steelhead in freshwater areas downstream of the release sites. As described in Section 2.5.2.3, hatchery-origin Chinook and coho salmon may overlap spatially and temporally with natural-origin Chinook salmon and steelhead juveniles as hatchery-origin fish exit the Dungeness River seaward; competition between natural-origin and hatchery-origin fish would occur for food and space, and predation would occur if listed Chinook salmon and steelhead juveniles are sizes vulnerable to predation while outmigrating. To reduce the risk of spatial and temporal overlap between juvenile hatchery-origin and listed natural-origin fish that might lead to competition effects, hatchery management practices would be implemented to minimize the duration of interaction between newly released hatchery-origin Chinook salmon and yearling coho salmon and natural-origin Chinook salmon and steelhead.

It is not possible to quantify the take associated with competition in the action area, because it is not possible to meaningfully measure the number of interactions between hatchery-origin Chinook and coho salmon and natural-origin Chinook salmon and steelhead juveniles. Therefore, NMFS will rely on a surrogate take indicator that relates to the proportion of the total abundance of emigrating juvenile salmonids comprised of hatchery-origin Chinook salmon or coho salmon in the lower Dungeness River for the period after the hatchery fish are released. The surrogate take indicator is a proportion of all hatchery- and naturally-produced juvenile salmon and steelhead emigrating seaward in the Dungeness River downstream of the hatchery release sites on or after the 10th day after the last release of the hatchery-origin Chinook salmon and coho salmon, respectively, that is represented by hatchery-origin Chinook salmon or coho salmon; this proportion should remain smaller than 10 percent.

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

Factor 5: Take by Facility Effects

The existing Dungeness River Hatchery water intake structures on Hurd Creek may lead to the take of Puget Sound Chinook salmon and Puget Sound steelhead. 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 structures. Currently, the intake structures affect a very small proportion of total fish habitat available to salmon and steelhead in the watershed. The mainstem intakes present risks of entrainment for juvenile fish in no more than a total of 4 square meters of migration and rearing area adjacent to the intakes. Measuring the amount of habitat affected has a rational connection to the take caused by this pathway because the size of habitat affected is directly related to how many fish can occur in that area. This take can be reliably measured by continuing to observe effects associated with the water intakes.

2.9.2 Effect of the Take

In Section 2.8, NMFS determined that the level of anticipated take, coupled with other effects of the Proposed Action, is not likely to jeopardize the continued existence of the Puget Sound Chinook Salmon ESU or Puget Sound Steelhead DPS or result in the destruction or adverse modification of their designated critical habitat.

2.9.3 Reasonable and Prudent Measures

"Reasonable and prudent measures" are nondiscretionary measures to minimize 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. NMFS, USFWS, and the BIA shall:

1. Ensure that the effects on Dungeness Chinook salmon genetic diversity associated with implementation of the Dungeness River Hatchery Chinook salmon program are minimized.
2. Ensure that spawning ground competition and redd superimposition effects caused by Dungeness River Hatchery pink and coho salmon are minimized.
3. Ensure that hatchery water intake structures are operated in such a way as to be adequately screened and provide unimpeded upstream and downstream migration for listed Chinook salmon and steelhead.
4. Ensure that broodstock collection operations do not adversely impact natural-origin steelhead.
5. Indicate the performance and effects of the hatchery salmon programs, including compliance with the Terms and Conditions set forth in the opinion, through completion and submittal of annual reports.

2.9.4 Terms and Conditions

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

1a. Ensure that annual surveys are conducted to determine the migration timing, abundance, distribution, and origin (hatchery- and natural-origin) of Chinook salmon spawning naturally and escaping to hatchery release sites in the Dungeness River watershed. 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. Ensure that demographic, morphometric, mark/tag, and/or genetic data are collected, and analyses are conducted, necessary to indicate the total annual adult contribution, by origin, of Dungeness Chinook salmon to fisheries and escapement.

1c. Ensure that the take surrogate returns per spawner (R/S) (i.e., spawner-to-spawner) rate averaged over five consecutive years is not lower than 0.6. The returns for spawner will be included in annual reports (see item 5c., below).

1d. Ensure that annual reports are submitted by the co-managers to NMFS, including estimates of natural and hatchery escapement levels, contributions to fisheries for natural and hatchery-origin Dungeness Chinook salmon, and estimates of total recruit per spawner levels for the period when the hatchery Chinook salmon program is implemented (see item 5c., below).

1e. Ensure that captive reared Chinook salmon are released for no longer than an eight-year period with the first release being in 2022 and the last in 2029. Co-managers will include an evaluation of the captive brood program including survival at all life stages and abundance and productivity in the watershed for all years that captive reared fish are returning. Co-managers will provide an analysis showing the beneficial effects of the captive brood component if they want to resume this component of the hatchery program after the eight years of captive brood releases has been completed.

1f. Ensure that, for the eight-year period that captive brood reared Chinook salmon are released, no more than 660,000 juvenile Chinook salmon are released annually and that the five-year running average of the total number of juvenile Chinook salmon released does not exceed 630,000 fish. Once the progeny of all fish held as captive broodstock have been released after this eight-year period, ensure that no more than 220,000 juvenile Chinook salmon are released annually and that the five-year running average of the total number of Chinook salmon released does not exceed 210,000 fish.

1g. Ensure the co-managers carry out their proposed Chinook salmon genetic monitoring program. A summary of genetic data will be either included in annual reports or be provided to NMFS in a separate reports as new analyses are completed.

2a. Ensure that annual surveys are conducted to determine the migration timing, abundance, and distribution of Dungeness River Hatchery pink salmon that spawn naturally relative to naturally spawning Chinook salmon migration timing, abundance, and distribution. The co-managers shall submit any revisions of protocols described in the proposed HGMPs for annual spawning ground surveys for NMFS concurrence on or before June 1 of each year.

2b. Ensure that annual surveys are conducted to determine the location and extent of any superimposition of Chinook salmon redds by hatchery-origin pink salmon and levels of hatchery-origin pink salmon spawning in Chinook salmon natural spawning areas. As part of this monitoring, the co-managers shall report the annual pHOS and observations of pink salmon displacing or adversely affecting Chinook salmon.

2c. Ensure that annual surveys are conducted to determine the location and extent of any superimposition of Chinook salmon redds by hatchery-origin coho salmon and levels of hatchery-origin coho salmon spawning in Chinook salmon natural spawning areas. As part of this monitoring, the co-managers shall track Chinook and coho redd locations through GPS data annually when streamflow is less than 300 cfs. Redd superimposition from the coho program will be tracked in a rolling average of a minimum of 4 out of 5 years on the percentage of smolts out migrating, and estimated loss of juvenile Chinook migrants is not anticipated to exceed 2% of the outmigrating natural-origin juvenile Chinook salmon; if the data indicates exceedance, the co-managers will notify NMFS. If data cannot be obtained for more than 1 year out of the last 5 years due to stream flow, applicants shall notify NMFS. The co-managers shall report: (1) the estimated number of juveniles lost using Method 1, (2) the number of outmigrating smolts, and (3) results of (1) divided by results of (2).

3a. Ensure that all intake structures supplying water for the three Dungeness River Hatchery programs comply with the NMFS Anadromous Salmonid Passage Facility Design criteria (NMFS 2011a) as soon as funding has been allocated and permitting has been completed.

3b. Ensure that the co-managers monitor and annually report hatchery facility compliance with NMFS fish passage criteria until all intake screening is compliant with current NMFS guidelines.

4a. Ensure that the co-managers survey migration conditions in the bypass reaches between the Dungeness hatchery water intake structure and hatchery outfall as well as the downstream section between the Canyon Creek intake and Dungeness River, and notify the NMFS SFD, within 24 hours, of any injuries, mortalities, or blockages or delays in upstream and downstream migration observed in juvenile or adult Chinook salmon and steelhead.

4b. Ensure that the co-managers immediately release unharmed any natural-origin steelhead incidentally encountered in the course of salmon broodstock collection operations at the point of capture. Hatchery-origin steelhead, identifiable by a clipped adipose fin, that are collected during salmon broodstock collection operations shall be removed and not returned to the river to reduce the threat of genetic and ecological effects on the native Dungeness River steelhead population.

4c. Ensure that the co-managers monitor and annually report the number, location, and disposition of any steelhead encountered during salmon broodstock collection operations (see item 5c., below).

5a. Ensure that the hatchery programs are implemented as described in the HGMPs and 2019 addenda, including marking and/or tagging of all juvenile salmon released through the programs. NMFS's Sustainable Fisheries Division (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. As part of this monitoring, the co-managers shall report the proportion of hatchery-origin Chinook salmon or coho salmon versus total juvenile fish abundance calculated by statistical week, commencing 10 days post-hatchery release and continuing until no hatchery-origin Chinook salmon and coho salmon are captured, as identified either through expanded estimates or catch per unit effort (CPUE).

5b. Ensure that annual reports are submitted by the co-managers to NMFS describing the results of the pink salmon and coho salmon spawner surveys described in 2a, 2b, and 2c (See item 5c., below)

5c. Provide one comprehensive annual report to NMFS SFD on or before May 1st of each year that includes the RM&E actions described in the above Term and Conditions. The numbers of hatchery-origin salmon released – by age/stage, release dates, and release location – and tag/mark information, encounters with other species, and other information pertinent to program operation effects on ESA-listed resources shall be included in the annual report. All reports, as well as all other notifications required, shall be submitted electronically to the SFD point of contact for this program: Morgan Robinson (*morgan.robinson@noaa.gov*).

2.10 Conservation Recommendations

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

1. The co-managers, in cooperation with the NMFS and other entities, should investigate the relative reproductive success, and relative survival, of hatchery-origin and natural-origin Chinook salmon in the Dungeness River watershed 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.

2.11 Re-initiation of Consultation

This concludes formal consultation for the Dungeness River salmon hatchery programs.

Under 50 CFR 402.16(a): "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: (1) the amount or extent of incidental take is exceeded, (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion, (3) the agency action is subsequently modified in a manner that causes an effect on the listed species or critical habitat that was not considered in this opinion, or (4) a new species is listed or critical habitat designated that may be affected by the action."

2.12 Not Likely to Adversely Affect Determinations

2.12.1 Hood Canal Summer Chum Salmon ESU

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

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

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

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

Because the only anticipated effects of the proposed action on Hood Canal Summer Chum are discountable, NMFS determines that the proposed action is not likely to adversely affect the ESA.

2.12.2 Ozette Lake Sockeye Salmon ESU

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

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

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

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

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

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

Section 305(b) of the MSA directs Federal agencies to consult with NMFS on all actions or proposed actions that may adversely affect EFH. Under the MSA, this consultation is intended to promote the conservation of EFH as necessary to support sustainable fisheries and the managed species' contribution to a healthy ecosystem. For the purposes of the MSA, EFH means "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity", and includes the 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 descriptions of EFH for Pacific coast salmon (PFMC 2014) contained in the fishery management plans developed by the Pacific Fishery Management Council (PFMC) and approved by the Secretary of Commerce.

3.1 Essential Fish Habitat Affected by the Project

The proposed action is the implementation of three hatchery salmon programs in the Dungeness River watershed, 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.

Other fish species for which EFH has been designated in the vicinity of the action area, but whose EFH would not be affected by the proposed action, are identified in Appendix Table 1. Regarding EFH Habitats of Particular Concern (HAPC), the action area encompasses Dungeness Bay, which includes sea grass and estuary HAPCs for West Coast Groundfish (NOAA Fisheries 2015). The only activities that would occur in Dungeness Bay are seaward and river-ward migration by juvenile and adult salmon, respectively, produced by the hatchery programs.

HAPCs for West Coast Groundfish would not be adversely affected by hatchery salmon migration through Dungeness Bay.

The areas affected by the proposed action include the Dungeness River from RM 0.0 to the upstream extent of anadromous fish access at RM 18.7; the Gray Wolf River from its confluence with the Dungeness River at RM 15.8 to the upstream extent of anadromous fish access at RM 5.1; Hurd Creek from its confluence with the Dungeness River at RM 2.7 to the upstream extent of anadromous fish spawning; and Dungeness Bay (see Figure 1, above).

Freshwater EFH for Pacific salmon includes all those streams, lakes, ponds, wetlands, and other water bodies accessible, currently or historically, 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 2014). As described by PFMC (2014), 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 Dungeness River and its 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 Dungeness River watershed; 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 Dungeness River watershed, including its estuary and adjacent nearshore marine areas.

3.2 Adverse Effects on Essential Fish Habitat

The release of salmon through the proposed hatchery programs may lead to effects on EFH through effects of competition for spawning habitat or redd superimposition. The biological opinion describes impacts the hatchery programs might have on naturally spawning salmon populations in Section 2.5.2. Because the intent of the hatchery coho salmon program is to produce fish that will augment harvests for marine and freshwater commercial and recreational fishing areas. Therefore, the majority of coho salmon produced through the programs will be harvested in pre-terminal and terminal area fisheries, reducing the number of salmon that would escape to spawn in freshwater EFH. A substantial proportion of hatchery-produced coho salmon escaping terminal area fisheries home to their hatchery releases sites, further reducing the number of hatchery salmon that escape into natural spawning areas that are part of EFH in the basin.

The Proposed Action is likely to affect freshwater EFH for Chinook, coho, and pink salmon through the effluent discharge from the hatchery facilities. As described in Section 2.5.2.5, effluent discharge from hatchery facilities can adversely affect water quality by raising temperatures, reducing dissolved-oxygen levels, and potentially affecting pH. The proposed hatchery programs minimize each of these effects through compliance with the NPDES permits, where applicable.

As described in section 2.5.2.5 and Table 4, water withdrawal for hatchery operations can adversely affect salmon by reducing streamflow, impeding migration, or reducing other stream-dwelling organisms that could serve as prey for juvenile salmonids. Water withdrawals can also kill or injure juvenile salmonids through impingement upon inadequately designed intake screens or by entrainment of juvenile fish into the water diversion structures. The proposed hatchery programs include designs that minimize each of these effects. In general, water withdrawals are small enough in scale that changes in flow would be undetectable, and impacts would not occur.

Also, competition/predation in the migration corridors would not lead to effects on EFH through predation on and competition with listed salmon and steelhead. Competition for food resources in Puget Sound marine areas between hatchery-origin Chinook salmon and steelhead is not likely a substantial risk factor. Spatial and temporal differences in emigration behaviors and residence time in Puget Sound between Chinook salmon, and steelhead (Rensel et al. 1984; Duffy 2003; Fresh 2006), size differences at release, and partitioning of available food resources in marine areas (Duffy 2003) limit the risk of any substantial competition effects.

Regarding hatchery facility operation effects on salmon EFH, the 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. Our analysis of facility effects did not reveal any substantial concerns related to screening, water withdrawal, or effluent (see Section 2.5.2.5).

Regarding hatchery facility operation effects on salmon EFH, the Dungeness and Canyon Creek hatchery water intake screens on the Dungeness River and Canyon Creek, respectively, are in compliance with state and federal guidelines (NMFS 1995; 1996), and the screens meet current NMFS Anadromous Salmonid Passage Facility Design Criteria (NMFS 2011a) designed to protect natural-origin salmon from injury and mortality. The water intake screening at Hurd Creek has been updated to be in compliance with current NMFS Anadromous Salmonid Passage Facility Design Criteria (NMFS 2011a) and the co-managers are awaiting an inspection to certify the update. The co-managers will submit a certificate of compliance to NMFS as soon as it becomes available.

3.3 Essential Fish Habitat Conservation Recommendations

Because of the pathways by which hatchery programs can potentially affect EFH (specific to applicable management plans), and given the relatively small magnitude of effects (if any) on EFH of the Proposed Action, it is difficult to specify the best approaches to avoid or minimize potential adverse effects. For the current Proposed Action, NMFS recognizes that the HGMPs and the ITS (section 2.9), while describing steps beyond those necessary to address EFH effects, include all reasonable steps to address any potential adverse EFH effects. Therefore, beyond the measures included in the proposed action, NMFS has no additional EFH conservation recommendations.

3.4 Statutory Response Requirement

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

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

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

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. NMFS has determined, through this ESA section 7 consultation, that operation of the 5 hatchery programs in the Dungeness River watershed as proposed will not jeopardize ESA-listed species, will not destroy or adversely modify designated critical habitat, and will adversely affect essential fish habitat. Therefore, NMFS can issue an ITS. The intended users of this opinion are the Jamestown S'Klallam Tribe and WDFW (operators); NMFS (regulatory agency); USFWS and BIA (funders). The scientific community, resource managers, and stakeholders benefit from the consultation through adult returns of program-origin salmon to the Dungeness River and Puget Sound, and through the collection of data indicating the potential effects of the hatchery programs on the viability of natural populations of Puget Sound Chinook salmon and Puget Sound steelhead. This information will improve scientific understanding of hatchery-origin salmon effects on natural populations that can be applied broadly within the Pacific Northwest area for managing benefits and risks associated with hatchery operations. The document will be available through the

NOAA Institutional Repository approximately two weeks after signature. The format and naming adheres to conventional standards for style.

4.2 Integrity

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

4.3 Objectivity

Information Product Category: Natural Resource Plan

Standards: This consultation and supporting documents are clear, concise, complete, and unbiased; and were developed using commonly accepted scientific research methods. They adhere to published standards including the NMFS ESA Consultation Handbook, ESA regulations, 50 CFR 402.01 et seq., and the MSA implementing regulations regarding EFH, 50 CFR 600.

Best Available Information: This consultation and supporting documents use the best available information, as referenced in the References section. The analyses in this opinion and EFH consultation contain more background on information sources and quality.

Referencing: All supporting materials, information, data and analyses are properly referenced, consistent with standard scientific referencing style.

Review Process: This consultation was drafted by NMFS staff with training in ESA and MSA implementation, and reviewed in accordance with West Coast Region ESA quality control and assurance processes.

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APPENDIX A: EFFECTS OF HATCHERY PROGRAMS ON SALMON AND STEELHEAD POPULATIONS: REFERENCE DOCUMENT FOR NMFS ESA HATCHERY CONSULTATIONS (REVISED FEBRUARY 2022)[5]

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

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

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

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

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

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

difficult to access. For this reason, we generally avoid citing master's theses and doctoral dissertations, unless they provide unique information.

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

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.

2.1.Genetic effects

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

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

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

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

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

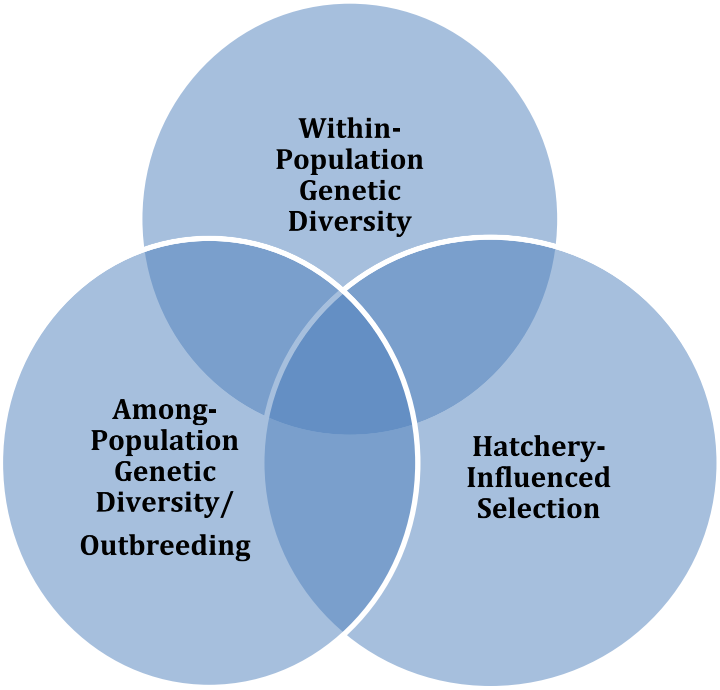

Figure A-1. Major categories of hatchery program genetic effects analyzed by NMFS.

2.1.2. Key Terms

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

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

- **Natural-origin (NO)**- refers to fish that have resulted from spawning in nature, regardless of the origin of their parents. A series of acronyms parallel to those for HO fish has been developed for subclasses of NO fish:
    - **Natural-origin recruits (NOR)** – NO fish returning to freshwater as adults or jacks. Usage varies, but typically the term refers to post-harvest fish that will either spawn in nature or used for hatchery broodstock.
    - **Natural-origin spawners (NOS)**- natural-origin fish spawning in nature.
    - **Natural-origin broodstock (NOB)**- natural-origin fish that are spawned in the hatchery (i.e., are used as broodstock). An important derivative term is **pNOB**, the proportion of a hatchery program's broodstock consisting of NO fish.

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

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

2.1.3. 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.

2.1.3.1. Genetic drift

Genetic drift is random loss of diversity due to population size. The rate of drift is determined not by the census population size (N_c), but rather by the effective population size (N_e). The effective size of a population is the size of a genetically "ideal" population (i.e., equal numbers of males and females, each with equal opportunity to contribute to the next generation) that will display as much genetic drift as the population being examined (e.g., Falconer and MacKay 1996; Allendorf et al. 2013)[7].

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[7] 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.

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

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

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

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

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

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

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

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

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

2.1.3.2. Biased/nonrepresentational sampling

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

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

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

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

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

2.1.3.3. Among-population diversity/ Outbreeding effects

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

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

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

Gene flow from other populations can increase genetic diversity (e.g., Ayllon et al. 2006), which can be a benefit in small populations, but it can also alter established allele frequencies (and co-adapted gene complexes) and reduce the population’s level of adaptation, a phenomenon called outbreeding depression (Edmands 2007; McClelland and Naish 2007). In general, the greater the geographic separation between the source or origin of hatchery fish and the recipient natural population, the greater the genetic difference between the two populations (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 et al. 2011; Satterthwaite and Carlson 2015). Eldridge et al. (2009) found that among-population genetic diversity had decreased in Puget Sound coho salmon populations during several decades of intensive hatchery culture.

As discussed in Section 1.2.1.4, pHOS[8] is often used as a surrogate measure of gene flow. Appropriate cautions and qualifications should be considered when using this proportion to analyze outbreeding effects.

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

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

2.1.3.4. Hatchery-influenced selection effects

Hatchery-influenced selection (often called domestication[9]), the third major area of genetic effects of hatchery programs that NMFS analyses, occurs when selection pressures imposed by

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[8] 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.

[9] 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., Frankham 2008), and becoming more common in the fish literature (Christie et al. 2011; Allendorf et al. 2013; Fisch et al. 2015) is more precise for species that have been

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

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

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

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

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

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

All three factors should be considered in evaluating risks of hatchery programs. However, because gene flow is generally more readily managed than the selection strength of the hatchery environment, current efforts to control and evaluate the risk of hatchery-influenced selection are currently largely focused on gene flow between NO and HO fish[10]. Strong selective fish culture with low hatchery-wild interbreeding can pose less risk than relatively weaker selective fish culture with high levels of interbreeding.

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subjected to semi-captive rearing for a few decades. We feel "hatchery-influenced selection" is even more precise, and less subject to confusion.

[10] 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.

2.1.3.5. 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. 2014) for at least three reasons:

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

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

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

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

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

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

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

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

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

Detecting a genetic component of fitness loss in one species and not another suggests that perhaps the impacts of hatchery-influenced selection on fitness differs between Chinook salmon and steelhead.[11] 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.

2.1.3.6. 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), a congressionally funded group of federal, state, tribal, academic, and unaffiliated scientists that existed from 2020 to 2020. Because HSRG concepts have been so influential regionally, 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.

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[11] 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).

2003).[12] (Table 1). 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 A-19. HSRG gene flow guidelines (HSRG 2009b).

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

Although they are controversial, the HSRG gene flow guidelines have achieved a considerable level of regional acceptance. They were adopted 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)[13].

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 are the only scientifically based quantitative gene flow guidelines available for reducing the risk of hatchery-influenced selection. NMFS has considerable experience with the HSRG guidelines. They are based on a model (Ford 2002) developed by a NMFS geneticist, they have been evaluated by a NMFS-lead scientific team (RIST 2009), and NMFS scientists have

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

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

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.

2.1.3.6.1. 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.

2.1.3.6.2. 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:

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

where RRS is the reproductive success of HO fish relative to that of NO fish. They then recommend using this value in place of $\mathrm{pHOS}_{\mathrm{census}}$ 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 $\mathrm{RRS} < 1$ (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.

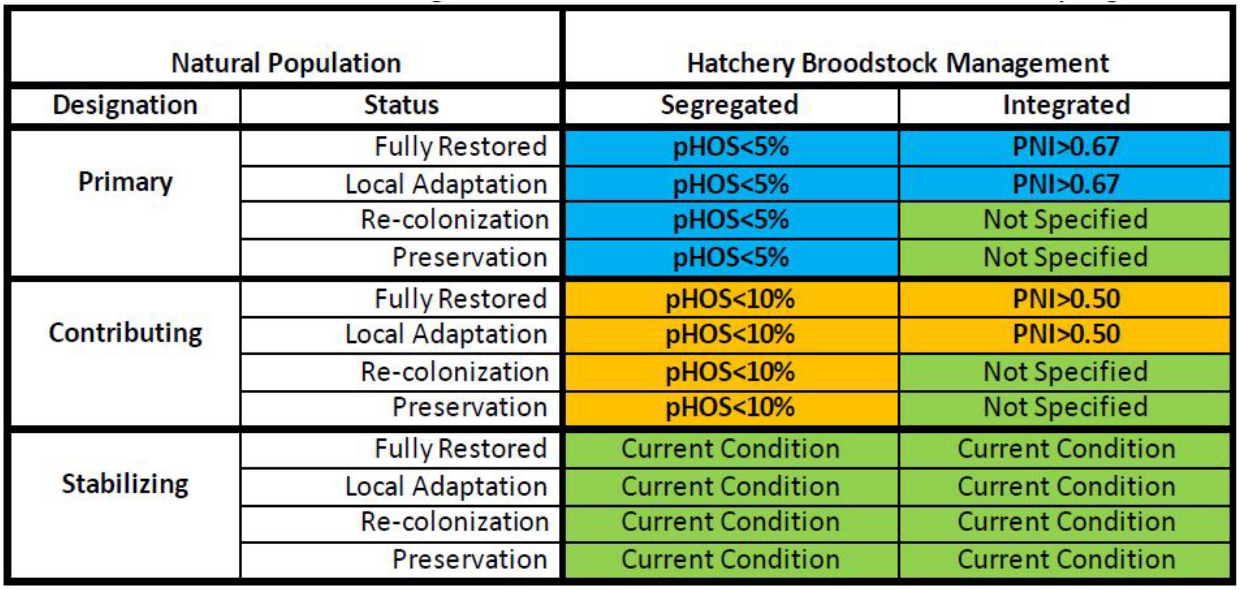
2.1.3.6.3. Gene flow guidelines in phases of recovery

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

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

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

Table A-20. HSRG gene flow guidelines/standards for conservation and harvest programs, based on recovery phase of impacted population (Table 2 from HSRG 2015).



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

We have two concerns regarding the phases of recovery approach. First, although the phase structure is intuitively appealing, no scientific evidence was presented the HSRG for existence of the phases. Second, while we agree that conservation of populations at perilously low abundance may require prioritization of demographic over genetic concerns, we are concerned that high pHOS/low PNI regimes imposed on small recovering populations may prevent them from advancing to higher recovery phases[14]. A WDFW scientific panel reviewing HSRG principles and guidelines reached the same conclusion (Anderson et al. 2020). In response, the HSRG in issued revised guidance for the preservation and recolonization phases (HSRG 2020):

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

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

2.1.3.7. 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 (Figure 3). It seems logical that this would result in less impact to the natural population than if the segregated program used only its own returnees as broodstock, but because the two-population implementation of the Ford model did not apply, there was no way to calculate PNI for this system.

Extending Ford's recursion equations (equations 5 and 6) to three populations allowed us to calculate PNI for a system of this type. We successfully applied this approach to link two spring Chinook salmon hatchery programs: Winthrop NFH (segregated) and Methow FH (integrated). By using some level of Methow returnees as broodstock for the Winthrop program, PNI for the natural population could be increased significantly[15](Busack 2015). We have since used the multi-population PNI model in numerous hatchery program consultations in Puget Sound and the

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[14] 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).

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

Columbia basin, and have extended to it to include as many as ten hatchery programs and natural production areas.

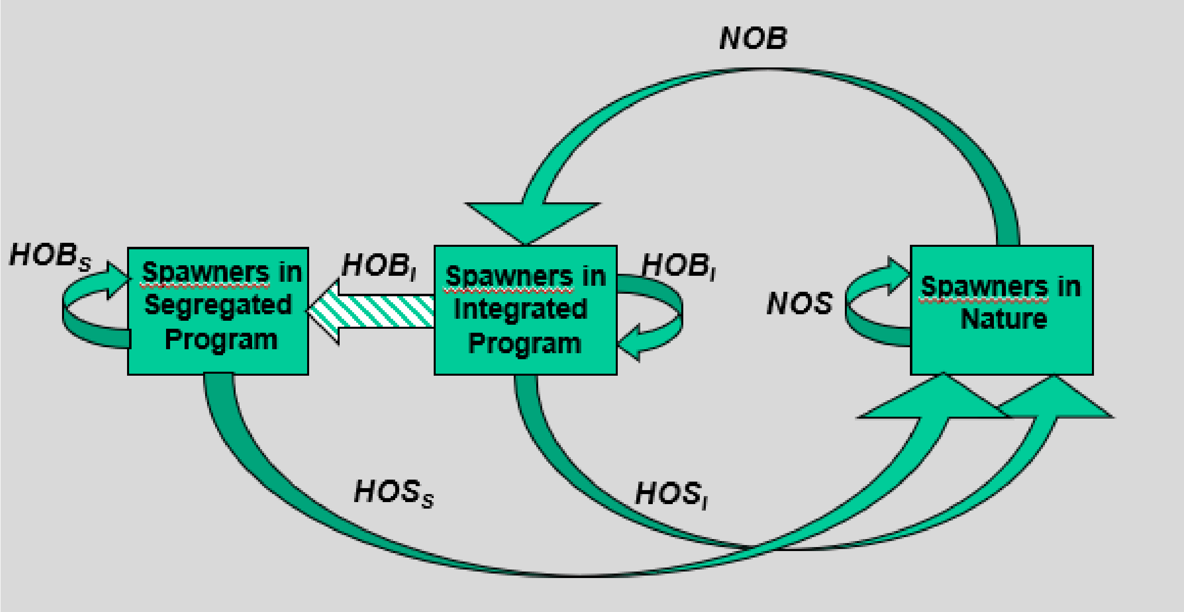

Figure A-2. Example of genetically linked hatchery programs. The natural population is influenced by hatchery-origin spawners from an integrated (HOS_I) and a segregated program (HOS_S). The integrated program uses a mix of natural-origin (NOB) and its own returnees (HOB_I) as broodstock, but the segregated uses returnees from the integrated program (HOB_I above striped arrow) as all or part of its broodstock, genetically linking the two programs. The system illustrated here is functionally equivalent to the HSRG's (HSRG 2014)"stepping stone" concept.

2.1.3.8. 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.

2.1.4. Ecological effects

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

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

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

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

2.1.5. 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.

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.

3.1. Competition

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

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

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

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

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

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

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

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

Critical information for analyzing competition risk is quality and quantity of spawning and rearing habitat in the action area,[16] 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.

3.2. Predation

Predation is another potential ecological effect of hatchery releases. Predation, either direct (consumption by hatchery fish) or indirect (increases in predation by other predator species due to enhanced attraction), can result from hatchery fish released into the wild. Here we consider predation by hatchery-origin fish, by the progeny of naturally spawning hatchery fish, and by birds and other non-piscine predators attracted to the area by an abundance of hatchery fish.

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

Predation may be greatest when large numbers of hatchery smolts encounter newly emerged fry or fingerlings, or when hatchery fish are large relative to natural-origin fish (Rensel et al. 1984). Due to their location in the stream, size, and time of emergence, newly emerged salmonid fry are likely to be the most vulnerable to predation. Their vulnerability is greatest immediately upon

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[16] "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.

emergence from the gravel and then decreases as they move into shallow, shoreline areas (USFWS 1994). Emigration out of important rearing areas and foraging inefficiency of newly released hatchery smolts may reduce the degree of predation on salmonid fry (USFWS 1994).

Some reports suggest that hatchery fish can prey on fish that are as large as 1/2 their length (Hargreaves and LeBrasseur 1986; Pearsons and Fritts 1999; HSRG 2004 and references therein), but other studies have concluded that salmonid predators prey on fish up to 1/3 their length (Horner 1978; Hillman and Mullan 1989; Beauchamp 1990; Cannamela 1992; CBFWA 1996; Daly et al. 2009). Hatchery fish may also be less efficient predators as compared to their natural-origin conspecifics, reducing the potential for predation impacts (Sosiak et al. 1979; Bachman 1984; Olla et al. 1998).

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

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

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

There are two key measures that hatchery programs can implement to reduce or avoid the threat of predation:

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

The two measures just mentioned will reduce minimize residualism as well as predation. The following measures can also help minimize residualism:

- Allowing smolts to exit the hatchery facility volitionally rather than forcing them out
- Ensuring that hatchery rearing regimes and growth rates produce fish that meet the minimum size needed for smolting, but are not so large as to induce desmoltification or early maturation

- Removing potential residuals based on size or appearance before release. This is likely impractical in most cases

3.3. Disease

The release of hatchery fish, as well as hatchery effluent, into juvenile rearing areas can lead to pathogen transmission; and contact with chemicals, or altering environmental conditions (e.g., dissolved oxygen) can result in disease outbreaks. Fish diseases can be subdivided into two main categories:

- Infectious diseases are those caused by pathogens such as viruses, bacteria, and parasites.
- Noninfectious diseases are those that cannot be transmitted between fish and are typically caused by environmental factors (e.g., low dissolved oxygen), but can also have genetic causes.

Pathogens can be categorized as exotic or endemic. For our purposes, exotic pathogens are those that have little to no history of occurrence within the boundaries of the state where the hatchery program is located. For example, *Oncorhynchus masou* virus (OMV) would be considered an exotic pathogen if identified anywhere in Washington state because it is not known to occur there. Endemic pathogens are native to a state, but may not be present in all watersheds.

In natural fish populations, the risk of disease associated with hatchery programs may increase through a variety of mechanisms (Naish et al. 2007), discussed below:

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

The last two terms above require some explanation. A continual pathogen reservoir is created when a standing crop of susceptible hosts keeps the pathogen from burning itself out. For example, stocking certain susceptible strains of trout can ensure that the pathogen is always present. Pathogen amplification occurs when densities of pathogens that are already present increase beyond baseline levels due to hatchery activities. A good example is sea lice in British Columbia (e.g., Krkošek 2010). The pathogen is endemic to the area and is normally present in wild populations, but salmon net pens potentially allow for a whole lot more pathogen to be produced and added to the natural environment.

Continual pathogen reservoir and pathogen amplification can exist at the same time. For example, stocked rainbow trout can amplify a naturally occurring pathogen if they become infected, and if stocking occurs every year, the stocked animals also can act as a continual pathogen reservoir.

Pathogen transmission between hatchery and natural fish can occur indirectly through hatchery water influent/effluent or directly via contact with infected fish. Within a hatchery, the likelihood of transmission leading to an epizootic (i.e., disease outbreak) is increased compared to the natural environment because hatchery fish are reared at higher densities and closer proximity than would naturally occur. During an epizootic, hatchery fish can shed relatively large amounts of pathogen into the hatchery effluent and ultimately, the environment, amplifying pathogen numbers. However, few, if any, examples of hatcheries contributing to an increase in disease in natural populations have been reported (Steward and Bjornn 1990; Naish et al. 2007). This lack of reporting is because both hatchery and natural-origin salmon and trout are susceptible to the same pathogens (Noakes et al. 2000), which are often endemic and ubiquitous (e.g., *Renibacterium salmoninarum,* the cause of Bacterial Kidney Disease).

Several state, federal, and tribal fish health policies, in some cases combined with state law, limit the disease risks associated with hatchery programs (IHOT 1995; ODFW 2003; USFWS 2004; WWTIT and WDFW 2006). Specifically, the policies govern the transfer of fish, eggs, carcasses, and water to prevent the spread of exotic and endemic pathogens. For example, the policy for Washington (WWTIT and WDFW 2006) divides the state into 14 Fish Health Management Zones[17] (FHMZs), and specifies requirements for transfers within and across FHMZs. Washington state law lists pathogens for which monitoring and reporting is required (regulated pathogens), and the Washington Department of Fish and Wildlife typically requires monitoring and reporting for additional pathogens. Reportable pathogen occurrence at a Washington hatchery is communicated to the state veterinarian, but also to fish health personnel at a variety of levels: local, tribal, state, and federal.

For all pathogens, both reportable and non-reportable, pathogen spread and amplification are minimized through regular monitoring (typically monthly) removing mortalities, and disinfecting all eggs. Vaccines may provide additional protection from certain pathogens when available (e.g., *Vibrio anguillarum*). If a pathogen is determined to be the cause of fish mortality, treatments (e.g., antibiotics) will be used to limit further pathogen transmission and amplification. Some pathogens, such as *infectious hematopoietic necrosis virus* (IHNV), have no known treatment. Thus, if an epizootic occurs for those pathogens, the only way to control pathogen amplification is to cull infected individuals or terminate all susceptible fish. In addition, current hatchery operations often rear hatchery fish on a timeline that mimics their natural life history, which limits the presence of fish susceptible to pathogen infection and prevents hatchery fish from becoming a pathogen reservoir when no natural fish hosts are present.

In addition to the state, federal, and tribal fish health policies, disease risks can be further minimized by preventing pathogens from entering the hatchery through the treatment of incoming water (e.g., by using ozone), or by leaving the hatchery through hatchery effluent (Naish et al. 2007). Although preventing the exposure of fish to any pathogens before their release into the natural environment may make the hatchery fish more susceptible to infection after release into the natural environment, reduced fish densities in the natural environment

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[17] Puget Sound consists of five FHMZs, the Columbia basin only 1.

compared to hatcheries likely reduces the risk of fish encountering pathogens at infectious levels (Naish et al. 2007).

Treating the hatchery effluent reduces pathogen amplification, but does not reduce disease outbreaks within the hatchery caused by pathogens present in the incoming water supply. Another challenge with treating hatchery effluent is the lack of reliable, standardized guidelines for testing or a consistent practice of controlling pathogens in effluent (LaPatra 2003). However, hatchery facilities located near marine waters likely limit freshwater pathogen amplification downstream of the hatchery without human intervention because the pathogens are killed before transmission to fish when the effluent mixes with saltwater.

Noninfectious diseases are typically caused by environmental factors (e.g., low dissolved oxygen). Hatchery facilities routinely use a variety of chemicals for treatment and sanitation purposes. Chlorine levels in the hatchery effluent, specifically, are monitored with a National Pollutant Discharge Elimination System (NPDES) permit administered by the Environmental Protection Agency. Other chemicals are discharged in accordance with manufacturer instructions. The NPDES permit also requires regular monitoring of settleable and unsettleable solids, temperature, and dissolved oxygen in the hatchery effluent to ensure compliance with environmental standards and to prevent fish mortality.

In contrast to infectious diseases, which typically are manifest by a limited number of life stages and over a protracted time period, non-infectious diseases caused by environmental factors typically affect all life stages of fish indiscriminately and over a relatively short time period. Because of the vast literature available on rearing of salmon and trout in aquaculture, one group of non-infectious diseases that are expected to occur rarely in current hatchery operations are those caused by nutritional deficiencies

3.4. Ecological Modeling

While competition, predation, and disease are important effects to consider, they are events which can rarely, if ever, be observed and directly measured. However, these behaviors have been established to the point where NMFS can model these potential effects to the species based on known factors that lead to competition or predation occurring. In our Biological Opinions, we use the Predation, Competition, and Delayed Mortality (PCD) Risk model version 4.1.0 based on Pearsons and Busack (2012). PCD Risk is an individual-based model that simulates the potential number of ESA-listed natural-origin juveniles lost to competition, predation, and delayed mortality (from disease, starvation, etc.) due to the release of hatchery-origin juveniles in the freshwater environment.

The PCD Risk model has undergone considerable modification since 2012 to increase supportability, reliability, transparency, and ease of use. Notably, the current version no longer operates as a compiled FORTRAN program in a Windows environment. The current version of the PCD Risk model (Version 4.1.0) is an R package (R Core Team 2019). A macro-enabled Excel workbook is included as an interface to the model that is used as a template for creating model scenarios, running the model, and reporting results. Users with knowledge of the R programming language have flexibility to develop and run more complex scenarios than can be created by the Excel template. The current model version no longer has a probabilistic mode for defining input parameter values. We also further refined the model by allowing for multiple hatchery release groups of the same species to be included in a single run.

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

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

3.5. Acclimation

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

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

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

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

- Timing acclimation so that a majority of the hatchery juveniles are going through the parr-smolt transformation during acclimation
- A water source distinct enough to attract returning adults
- Whether hatchery fish can access the stream reach where they were released
- Whether the water quantity and quality are such that returning hatchery fish will hold in that area before removal and/or their harvest in fisheries.

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

NMFS also analyzes proposed research, monitoring, and evaluation (RM&E) for its effects on listed species and on designated critical habitat. Negative effects from RM&E are weighed against the value of new information, particularly information that tests key assumptions and that reduces uncertainty. RM&E actions that can cause harmful changes in behavior and reduced survival include, but are not limited to:

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

NMFS also considers the overall effectiveness of the RM&E program. There are five factors that we take into account when it assesses the beneficial and negative effects of hatchery RM&E:

- Status of the affected species and effects of the proposed RM&E on the species and on designated critical habitat
- Critical uncertainties concerning effects on the species

- Performance monitoring to determine the effectiveness of the hatchery program at achieving its goals and objectives
- Identifying and quantifying collateral effects
- Tracking compliance of the hatchery program with the terms and conditions for implementing the program.

After assessing the proposed hatchery RM&E, and before it makes any recommendations to the action agency(s) NMFS considers the benefit or usefulness of new or additional information, whether the desired information is available from another source, the effects on ESA-listed species, and cost.

4.1. Observing/Harassing

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

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

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 2000a; 2008a) that have been incorporated as terms and conditions into section 7 opinions and section 10 permits for research and enhancement. Additional monitoring principles for supplementation programs have been developed by Galbreath et al. (2008).

4.3. Fin clipping and tagging

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

In addition to fin clipping, two commonly available tags are available to differentially mark fish: passive integrated transponder (PIT) tags, and coded-wire tags (CWTs). PIT tags consist of small radio transponders that transmit an ID number when interrogated by a reader device.[18] CWTs are small pieces of wire that are detected magnetically and may contain codes[19] that can be read visually once the tag is excised from the 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 and Park 1984; Prentice et al. 1987; Rondorf and Miller 1994). In a study between the tailraces of Lower Granite and McNary Dams (225 km), Hockersmith et al. (2000) concluded that the performance of yearling Chinook salmon was not adversely affected by orally or surgically implanted sham radio tags or PIT tags. However, (Knudsen et al. 2009) found that, over several brood years, PIT tag induced smolt-adult mortality in Yakima River spring Chinook salmon averaged 10.3 percent and was at times as high as 33.3 percent.

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

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[18] The same technology, more commonly called RFID (radio frequency identification), is widely used in inventory control and to tag pets.

[19] Tags without codes are called blank wire tags (BWTs).

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.

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.

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. 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 2005b). 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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