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

Five Hatchery Programs for Salmon in the Lake Washington Drainage

NMFS Consultation Number: WCRO-2021-02104

Action Agencies: National Marine Fisheries Service (NMFS)

Affected Species and Determinations:

ESA-Listed Species	Status	Is the Action Likely to Adversely Affect Species?	Is the Action Likely To Jeopardize the Species?	Is the Action Likely Adversely Affect Critical Habitat?	Is the Action Likely To Destroy or Adversely Modify Critical Habitat?
Puget Sound Steelhead	Threatened	Yes	No	No	No
Puget Sound Chinook Salmon	Threatened	Yes	No	Yes	No
Summer chum Salmon	Threatened	No	No	No	No
Lake Ozette Sockeye Salmon	Threatened	No	No	No	No

Fishery Management Plan That Describes EFH in the Project Area	Does the Action Have an Adverse Effect on EFH?	Are EFH Conservation Recommendations Provided?
Pacific Coast Salmon	No	No
Pacific Coastal Pelagic Species	No	No
Pacific Coast Groundfish	No	No

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

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Date: December 23, 2021

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1. INTRODUCTION

This introduction section provides information relevant to the other sections of the document and is incorporated by reference into Sections two and three, below. The underlying activities that drive the Proposed Actions are the operation and maintenance of five hatchery programs rearing and releasing salmon into Lake Washington. The hatchery programs are operated by state and/or tribal agencies as described in Table 1. Each program is described in detail in a Hatchery and Genetic Management Plan (HGMP) submitted to the National Marine Fisheries Service (NMFS) for review.

Table 1. Lake Washington watershed HGMPs submitted to NMFS for evaluation of ESA-listed salmon and steelhead effects. MIT = Muckleshoot Indian Tribe; SAFS = School of Aquatic and Fisheries Sciences; SPU = Seattle Public Utilities; WDFW = Washington Department of Fish and Wildlife.

Hatchery and Genetics Management Plan	Program Operator	Program Funder
University of Washington Aquatic Research Facility Hatchery – Fall Chinook salmon	SAFS	TBD
University of Washington Aquatic Research Facility Hatchery coho	SAFS	TBD
Issaquah Fall Chinook Hatchery Program	WDFW	WDFW, MIT
Issaquah coho Hatchery Program	WDFW	WDFW, MIT
Lake Washington Sockeye Program	SPU; WDFW	SPU, WDFW

1.1. Background

NMFS prepared the biological opinion (opinion) and incidental take statement portions of this document in accordance with section 7(b) of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531, *et seq*.), and implementing regulations at 50 CFR 402. The opinion documents consultation on the actions proposed by Muckleshoot Indian Tribe (MIT) and Washington Department of Fish and Wildlife (WDFW). We also completed an Essential Fish Habitat (EFH) consultation on the proposed action, in accordance with section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801, *et seq*.) and implementing regulations at 50 CFR 600.

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

1.2. Consultation History

The first hatchery consultations in Puget Sound followed the listing of the Puget Sound Chinook salmon Evolutionarily Significant Unit (ESU) under the ESA (64 FR 14308, March 24, 1999). In 2005, WDFW and the Puget Sound Tribes ("co-managers") completed two resource management plans (RMP) as the overarching frameworks for 114 HGMPs (PSIT and WDFW 2004; PSTT and WDFW 2004).

The HGMPs described how each hatchery program would operate including effects on listed fish in the Puget Sound region. In 2004, the co-managers submitted the two RMPs and 114 HGMPs to NMFS for ESA review under limit 6 of the ESA 4(d) rule (50 C.F.R. 223.203). Of the 114 HGMPs, 75 were state-operated, including 27 Chinook salmon programs, 22 coho salmon programs, 2 pink salmon programs, 4 chum salmon programs, 2 sockeye salmon programs, and 18 steelhead programs. The Puget Sound Tribes submitted 38 HGMPs, including 14 for Chinook salmon, 13 for coho salmon, 9 for chum salmon, and 2 for steelhead. USFWS submitted one HGMP for its coho salmon program at Quilcene National Fish Hatchery.

Subsequent to the submittal of the plans to NMFS, the Puget Sound Steelhead Distinct Population Segment (DPS) was listed as "threatened" (72 FR 26722, May 11, 2007). On September 25, 2008, NMFS issued a final 4(d) rule adopting protective regulations for the listed Puget Sound steelhead DPS (73 FR 55451). In the final rule, NMFS applied the same 4(d) protections for steelhead as were already adopted for other ESA-listed Pacific salmonids in the region. Accordingly, the co-manager hatchery plans are now also subject to review for effects on listed steelhead.

Among the Puget Sound region HGMPs that have been submitted for NMFS' consideration under the ESA are five plans developed by the MIT, WDFW, and University of Washington Aquatic Research Facility (UW ARF) describing hatchery programs for Chinook salmon, coho salmon and sockeye salmon in the Lake Washington watershed. On April 30, 2019, NMFS received four HGMPs with a request for review under limit 6 of the 4(d) rule for coho and Chinook salmon programs at UW ARF and coho and Chinook salmon programs at the Issaquah Hatchery. Subsequently, a fifth HGMP was submitted for review under 4(d) rule, limit 6, describing a program for Lake Washington sockeye.

During pre-consultation, the co-managers have also had an opportunity to further assess the potential for expanded hatchery programs at a variety of locations in the Lake Washington Basin. Although the assessment is ongoing, indications are that, in the short-term, the University of Washington Aquatic Research Facility (UW ARF) could be used as a satellite rearing station for the Issaquah Hatchery, and in the mid- to long-term has the potential for adult collection, egg incubation, juvenile rearing, and to be a release site. This biological opinion is based on information provided in the five HGMPs and from discussions and detailed analyses with the co-managers of alternative options for the hatchery production of salmon in the Lake Washington Basin.

1.3. Proposed Action

"Action," as applied under the ESA, means all activities, of any kind, authorized, funded, or carried out, in whole or in part, by Federal agencies (50 CFR 402.02). For EFH consultation, "Federal action" means any on-going or proposed action authorized, funded, or undertaken by a Federal Agency (50 CFR 600.910). Because the actions of the Federal agencies are subsumed within the effects of the hatchery program and any associated research, monitoring and evaluation, the details of each hatchery program are summarized in this section.

The Proposed Action for this consultation is NMFS' determination under limit 6 of the ESA 4(d) rules. The objective of this Proposed Action is to determine whether the HGMPs presented meet the requirements of limit 6 so that the operation and maintenance of the five salmon hatchery programs operating in Lake Washington (Figure 1) can be exempted from the ESA's take prohibitions. Specifically, this document evaluates whether the Proposed Action complies with the provisions of Section 7(a)(2) of the ESA and ESA Section 4(d) Limit 6 for resource management plans developed jointly by states and tribes within the *U.S. v. Washington* construct. The duration of the Proposed Action is intended to be ongoing.

We considered, under the ESA, whether or not the proposed action would cause any other activities. The proposed hatchery programs analyzed in this opinion also contribute to regional fisheries outside of the Lake Washington watershed and marine terminal areas. The effects of all fisheries that incidentally harvest ESA-listed fish species originating from the action area hatcheries, including fisheries directed at WDFW hatchery and Muckleshoot and Suquamish tribal hatchery salmonids, have been evaluated through a separate NMFS ESA consultation (NMFS 2021c) and are included

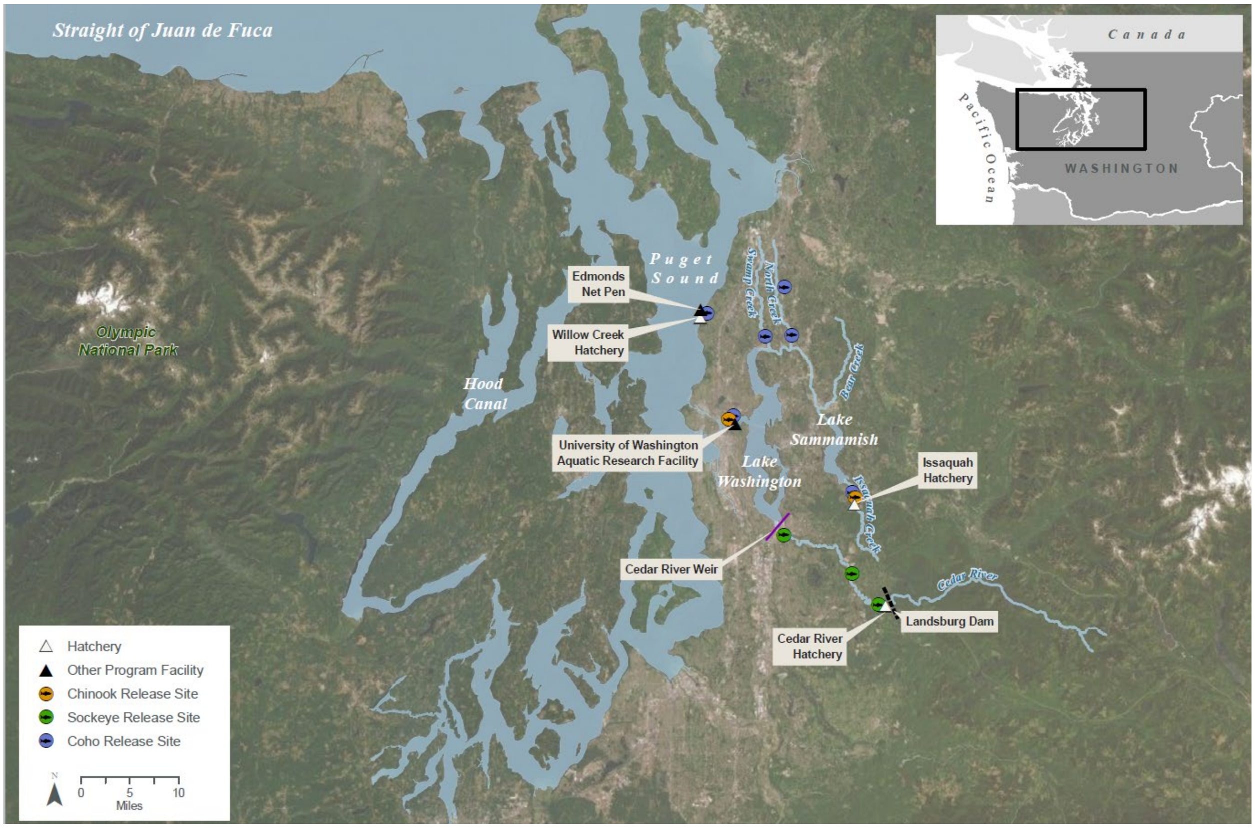

Figure 1. Map depicting the Lake Washington the location of facilities related to the programs in the Proposed Action.

1.3.1. Proposed hatchery broodstock collection

Details of broodstock origin, collection, duration, and number are listed in

Table 2. Broodstock for releases of Chinook and coho salmon at all locations may originate from any of the collection locations identified. NMFS defines "integrated" as a program for which the intent is to use natural-origin fish in the broodstock and "segregated" or "isolated" as a program for which the intent is to only use hatchery-origin fish in the broodstock. Additionally, programs can operate as a genetically-linked program one where the integrated program uses a mix of natural-origin and hatchery-origin fish as broodstock, but the segregated program uses returnees from the integrated program as all or part of its broodstock, genetically linking the two programs (Section 5.2.1.4.3; Figure).

The Issaquah Coho Hatchery program is integrated and has two satellite components that receive eggs or fingerlings from the main hatchery: Edmonds net pen, and Willow Creek Hatchery

The Issaquah Fall Chinook Hatchery program will run as a segregated program unless the NOR population size meets a minimum trigger (WDFW and Muckleshoot Indian Tribe 2020c). Under this segregated program, only HORs will be spawned at the hatchery and NORs will be passed upstream to spawn naturally in upper Issaquah Creek. The Issaquah Fall Chinook Hatchery program will transition into a genetically-linked program when the minimum trigger is reached. This will occur when the population of NORs in Issaquah Creek is expected to exceed 500 fish for a third straight year. This assumes the two preceding years had more than 500 adult natural-origin returns and that the current pre-season forecast also exceeds that trigger (Table 3). Under this scenario, Issaquah Hatchery's goal will be to release 200,000 sub-yearling Chinook derived solely from natural origin parents. These juvenile Chinook will be 100% coded-wire tagged (CWT). Any NORs excess to this program will be released upstream. A higher trigger occurs when the NOR population exceeds 800 for three straight years. When this occurs, the only change is that the integrated production will be doubled to 400,000 sub-yearlings. If the specific trigger is not met at the 800 natural-origin adult Chinook salmon level, but meets the 500 natural-origin level, the integrated program would revert back to 200,000 sub-yearling Chinook salmon. If the specific trigger is not met at the 500 natural-origin adult Chinook salmon level, the Issaquah Chinook salmon program would revert back to running as a segregated program.

The Issaquah Fall Chinook Hatchery program would use Chinook salmon collected at the Ballard Locks or at Issaquah Creek. In the event of a broodstock shortfall, eggs sufficient to fill that shortfall would be transferred from hatcheries on the Green River, if available. This would follow the WWITT and WDFW (2006) Salmon Disease Control Protocol. More specific details of the program are outlined in Table 2 and Table 4

Initially, UW ARF will be used as an acclimation and/or release site for Issaquah coho and Chinook and will rely on juveniles from Issaquah Hatchery. As the UW ARF Hatchery programs come on line, the programs would likely require eggs transferred from the Issaquah Hatchery and/or using returning adults from juveniles previously released at the UW ARF as the initial source for coho and Chinook salmon broodstock. Once more established, the UW ARF programs would operate with a segregated broodstock management strategy with all broodstock anticipated to be obtained from the UW ARF volitional-entry adult collection pond at Portage Bay. In the event of a shortfall, eggs will be transferred from Issaquah Hatchery.

The Lake Washington sockeye program is an integrated program that has used local in-basin fish collected from the Cedar River Weir (river mile (RM) 1.0) and Landsburg Dam on the Cedar River (RM 27.1). Broodstock collections may occur at the Cedar River Weir, Landsburg Dam, Bear Creek, Issaquah Creek, Cedar River, and the Ballard Locks. Recent declines in escapement might require using supplemental sources to meet broodstock targets. Supplemental sources for broodstock might include: Alaska, Baker Lake, Quinault River, Lake Wenatchee, or upper Columbia River.

Table 2. Broodstock collection details for five hatchery programs in the Lake Washington watershed. UW = University of Washington Aquatic Research Facility; N/A = Not applicable.

Program	Local source	Collection Location(s)	Collection Method	Collection/Holding Target (adults)	Egg Take goal	Collection Duration	pNOB
Issaquah Fall Chinook Hatchery Program (genetically-linked)[1]	Natural and hatchery	Issaquah Creek[2]	Air-bladder weir diverts fish into volitional entry ladder and holding ponds	3,360	7,000,000	September - December	0
		Ballard Locks[3]	Dip net from fish ladder			July - September	
Issaquah Coho Hatchery Program (integrated)	Natural and hatchery	Issaquah Creek[2]	Air-bladder weir diverts fish into volitional entry ladder and holding ponds	1,130	985,000	October - December	up to 1
UW ARF Hatchery Fall Chinook Salmon (segregated)	Hatchery	Portage Bay[3]	Volitional-entry ladder and holding pond; beach seine	180	360,000	September – October	0
UW ARF Hatchery Coho (segregated)	Hatchery	Portage Bay[3]	Volitional-entry ladder and holding pond; beach seine	180	167,000	September - December	0
Lake Washington Sockeye (Integrated)	Natural and hatchery	Landsburg Dam[3] Cedar River Weir[3]; Bear Creek[3,4]; Issaquah Creek[3], Other[3,5]	Ladder, weir, and holding ponds	24,000 [6]	34,000,000	September - November	at least 0.5[7]
		Ballard Locks[3]	Dip net from fish ladder			June – August	
		Cedar River[3]	Gill net, angling, fyke nets, hoop traps, and other experimental gear			September - November	

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[1] Issaquah fall Chinook hatchery program will initially begin as a segregated program and, through a trigger approach (detailed in the text and **Error! Reference source not found.**), will transition into a genetically-linked program.
[2] Eggs from hatcheries on the Green River may be used to backfill a shortfall in egg take.
[3] Eggs may be transferred to Issaquah Hatchery.
[4] This weir would be used as a contingency plan for the collection of sockeye during low sockeye salmon run sizes.

[5] The use of egg transfer from Alaska, Baker Lake, Quinault River, Lake Wenatchee, or upper Columbia River would be considered if
prevents meeting egg take goals.

[6] Collection target at weir and other locations will be adjusted to reflect average pre-spawning mortality.

[7] The co-managers expectation is that when adult sockeye spawning escapement goals in the Cedar River are met, the long term expect
of the fry entering Lake Washington will be naturally produced and at least 50% of the adults returning to the basin are from natural pr
spawning escapements fall below this goal, the fry entering Lake Washington will be increasingly dominated by hatchery origin recruit
sizes of adult sockeye entering the Cedar River, up to the full spawning population will be targeted for broodstock collection.

1.3.1.1. Weirs and Traps

The hatchery programs in this biological opinion use weirs and fish ladders to collect returning hatchery-origin fish. The Issaquah Hatchery programs collect coho, Chinook, and sockeye salmon that return to a trap located at the facility. The weir is operated approximately August through Mid-November and is checked daily. In addition, Chinook and sockeye may be dip-netted from the Ballard Locks fish ladder for broodstock collection. The Lake Washington sockeye hatchery collects sockeye at a temporary floating resistance board weir (seasonally installed) located at RM 1.0. The co-managers are in the process of expanding operations at the weir; upgrades will undergo separate Section 7 consultations to ensure ESA compliance. Additionally, the fish passage facility located at Landsburg Dam (RM 21.7) removes adult sockeye (ESA section 10(a)(1)(B) permit 1235) to prevent water quality issues that may occur as a result of fish carcasses that are passed upstream. Some of these fish will be provided to the Lake Washington sockeye hatchery for use in broodstock (described in the HGMP). A seasonal weir may also be installed on Bear Creek for sockeye broodstock collection. Additional Cedar River locations may be used for sockeye broodstock collection.

The ladder to the volitional-entry adult broodstock collection pond at the UW ARF facility is located in Portage Bay. It is open for broodstock collection from September through December and closed the rest of the year.

1.3.2. Proposed Mating Protocols (listed fish only)

Chinook salmon that would be spawned at Issaquah Hatchery for broodstock would be selected randomly from the returning fall Chinook salmon population. Every attempt would be made to ensure that the egg-take would be representative of the entire run. All male Chinook salmon collected, including jacks, would be considered for spawning. Males would be chosen randomly from the held population, and jacks would be incorporated into spawning at a rate of up to 2% of spawned males. Mating would be conducted using matrix-spawning protocols where each male fish may be crossed (spawned) with five female fish of the opposite sex. If the male is not ripe or has little milt, another male would be selected to assure fertilization.

The UW ARF Hatchery Chinook salmon program would use adipose fin-clipped, mature fall Chinook salmon. Using a 1:1 sex ratio, fish would be spawned 3-5 times each week depending on the ripeness of fish.

1.3.3. Proposed Adult Management

While the Issaquah Fall Chinook Hatchery program is run as a segregated program, the co-managers would not use NOR in broodstock and all unclipped fish would be passed upstream above the weir to spawn naturally. While the Issaquah Fall Chinook Hatchery program is run as a genetically-linked program, the co-managers would incorporate up to 50% of unmarked fish that return to the Issaquah adult pond holding facility into the broodstock of the integrated component (Table 3). Up to 3,000 coho above broodstock needs will be released upstream of the hatchery to spawn naturally. Some coho may be out-planted to other streams in the greater Lake Washington Basin. The remainder will be sold to a carcass buyer. For the Lake Washington Sockeye Hatchery, any fish not collected for broodstock are left in the river below Landsburg Dam to spawn naturally. Excess sockeye will be returned to the river. Sockeye are not passed above the dam in order to protect the municipal water supply and are collected at the fish ladder for hatchery broodstock.

1.3.4. Proposed hatchery rearing and juvenile release

The details of hatchery juvenile rearing and release, including release numbers, marking/tagging, rearing and release locations, and release timing can be found in Table 4.

The Chinook Hatchery programs in Lake Washington basin would rear up to 6,000,000 sub-yearlings. Potential release locations of Issaquah Hatchery Chinook would include Issaquah Creek, Lake Washington Ship Canal, Sammamish Slough and tributaries, Portage Bay, and the Kenmore Boat Ramp (north Lake Washington), and other downstream sites yet to be developed. A portion of these fish would be CWT and ad-clipped to track the dispersion of fish throughout the watershed. MIT and WDFW conducted a research study using two alternative release locations (Lake Washington Ship Canal and Kenmore boat ramp) of Chinook smolts released from Issaquah Hatchery in 2016-2018 to evaluate survival of fish at these off-station locations. Smolts were released directly and were not acclimated at these release sites. Some of this release cohort began returning to the watershed as age 4 adults in 2019 and the complete cohort would return by 2022. Results are not yet available as the evaluation of these sites is ongoing co-managers would provide the final report to NMFS for further discussion and review.

Initially, UW ARF will be used as an acclimation and/or release site for Issaquah Chinook and will rely on juveniles from Issaquah Hatchery. As the UW ARF program comes online, rearing and release of juveniles would also occur at that location (Table 4).

The coho hatchery programs in the Lake Washington basin would rear up to 775,000 yearlings, 420,000 fry (340,000 of these are for educational activities), and 90,000 sub-yearlings. Potential release locations of Issaquah Hatchery coho would include Issaquah Creek, Lake Washington Ship Canal, Sammamish Slough and tributaries, Portage Bay, and the Kenmore Boat Ramp (north Lake Washington), and other downstream sites yet to be developed. A portion of these fish would be CWT and ad-clipped to track the dispersion of fish throughout the basin. Prior to release fish are checked to determine the degree of smolting. The degree of smolting is somewhat variable and is based on several factors including; fish size, weather patterns such as pressure changes and fronts, water flow patterns, and temperature. The release timing of coho yearlings is based on the degree of smoltification observed in the fish. As the fish enters a smolting period, parr marks begin to disappear, the fish begin to develop a silvery coloration, scales are more easily lost, they go off of feed, and they begin circling the rearing raceways looking for a way out of the rearing ponds (Brodie Antipa WDFW personal communication). Generally, Issaquah Hatchery operators begin to see coho smolting in mid to late March with a typical peak in early to mid-April.

Initially, UW ARF will be used as an acclimation and/or release site for Issaquah coho and will rely on juveniles from Issaquah Hatchery. As the UW ARF program comes on line, rearing and release of juveniles would also occur at that location (Table 4). Coho reared at Cooperative/School programs, Willow Creek Hatchery, or Laebugten/Edmonds Net Pen would be released to the Lake Washington Basin, Puget Sound Independent Tributaries, or Puget Sound Table 4

The Lake Washington Sockeye program would release up to 34,000,000 fry. A portion of these fish may be reared to larger size classes at the Cedar River Hatchery, Issaquah Hatchery, and UW ARF (Table 4).

1.3.5. Health

Fish health is monitored throughout the incubation and rearing cycle for signs of disease. Similar practices, with a few noted exceptions, are used for coho and Chinook salmon programs at Issaquah Hatchery and the Lake Washington Sockeye Hatchery. Daily fish health would be evaluated following protocol defined in the Salmonid Disease Control Policy of the Fisheries Co-managers of Washington State (NWIFC and WDFW 2006 updated 2006). Additionally, monthly health checks would be conducted by WDFW Fish Health Specialist and a final health check would be conducted prior to release.

Coho and Chinook salmon eggs received at UW ARF would be hatched, reared, and released on site. During rearing, daily fish health will be evaluated by staff with expertise in fish health. Prior to release, a final health assessment will be conducted, the adipose fin would be removed, and, in some fish, a CWT would be implanted (Table 4).

Table 3. Proposed annual release protocols for the Genetically linked Fall Chinook program at Issaquah Hatchery.

Issaquah Creek NOR 3-year Trigger[1]	Program component	Release Number[2], Life Stage, and Size (fpp)	Marking and Tagging
≥ 500	Segregated	Up to 5,800,000; sub-yearling; 80-110	AD
	Integrated	200,000; sub-yearling; 80-110	AD 100% CWT
≥ 800	Segregated	Up to 5,600,000; sub-yearling; 80-110	AD
	Integrated	400,000; sub-yearling; 80-110	AD 100% CWT

[1] See text for full description of decision rule for integrated program.
[2] The planned total Chinook salmon releases would not exceed 6M; i.e., if the planned UW ARF release was 0.18M, the Issaquah Fall Chinook Hatchery planned release would be 5.82M.

Table 4. Proposed annual release protocols for coho, Chinook, and sockeye salmon hatchery programs in Lake Washington watershed. The sockeye salmon program could be managed in three phases, and releases in the third phase are italicized. AD = adipose fin clip; CWT = coded-wire tag; fpp = fish per pound.

Program	Release number, Life Stage, and Size (fpp)	Marking and Tagging	Rearing, Acclimation Site?	Release Location	Volitional Release?	Release Time
Issaquah Chinook (Genetically-linked[1])	Up to 6,000,000[2]; sub-yearling; 80-110	AD CWT[3]	Issaquah Hatchery, Sammamish Slough and tributaries, UW ARF[2], downstream sites	Issaquah Creek, Lake Washington Ship Canal, Sammamish Slough and tributaries, Kenmore boat ramp, Portage Bay, downstream sites**Error! Bookmark not defined.**, 4	No[5]	April-June
Issaquah coho (integrated)	750,000; yearling; 17	AD, AD+CWT[3]	Issaquah Hatchery, UW ARF, Sammamish Slough and tributaries, downstream sites	Issaquah Creek; Lake Washington ship canal; Portage Bay, Sammamish Slough and tributaries, Kennmore boatramp, downstream sites**Error! Bookmark not defined.**	No[5]	March - June
	340,000; fry; 200 – 1,500	unmarked	Cooperative and School programs	Lake Washington basin	No	May-June
	25,000; yearling; 10	AD	Laebugten/Edmonds Net Pen	Puget Sound	No	May - June
	10,000; fry; 100	unmarked	Willow Creek Hatchery	Lake Washington Basin,	No	June
	70,000; fry; 500	unmarked		WIRA 8 Independent Tributaries[6]	No	April-May
UW ARF-Chinook salmon (segregated)	180,000[2]; sub-yearling; 20-110	AD CWT**Error! Bookmark not defined.**3	UW ARF, Issaquah Hatchery	Portage Bay	Yes	April - June

UW ARF-Coho (segregated)	90,000; sub-yearling (0 age smolts); 30-50	AD CWT[3]	UW ARF, Issaquah Hatchery	Portage Bay	Yes	April - June
Lake Washington Sockeye (Integrated)	<34,000,000[7]/*34,000,000*; fry; 2,000	Otolith	Cedar River Sockeye Hatchery, Issaquah Hatchery, UW ARF	Cedar River, Lake Washington,	No	Jan. – May
	<480,000/*1,000,000*; sub-yearling; 150-800	AD[8], Otolith	Cedar River Sockeye Hatchery, Issaquah Hatchery, net pen (s)[9], UW ARF	Cedar River, Lake Washington, Lake Washington Ship Canal, Portage Bay, net pen(s)[8]		May – June
	<300,000/*1,000,000*; sub-yearling; 80-150	AD[8,3], Otolith				Sept. – Oct.
	< 40,000/*1,000,000*; yearling; 15-80	AD[8,3], Otolith				April – May

[1] Issaquah Fall Chinook hatchery program will initially begin as a segregated program and, through a trigger approach that is detailed in the text **Error! Reference source not found.** and Table 4, will transition into a genetically-linked program.

[2] The planned total Chinook salmon releases in Lake Washington watershed would not exceed 6M; i.e., if the planned UW ARF release was 0.18M, the Issaquah Fall Chinook planned release would be 5.82M.

[3] Released fish may be implanted with a coded wire tag (CWT) in the future depending on research and/or Co-manager needs

[4] Pilot study and evaluation is in progress for releases at multiple locations in the Lake Washington Basin including: the Kenmore boat ramp, the 14th Street boat ramp in the Lake Washington ship canal, and the UW ARF Pond with releases into Portage Bay. Other sites such as the NOAA facility at Sand Point may be used in the future pending continued discussions amongst the co-managers and NMFS.

[5] Volitional releases may occur at locations other than the Issaquah Hatchery depending on the release location and acclimation site design.

[6] Fry are released from the Willow Creek Hatchery program into several creeks that drain directly to Puget Sound: Shell Creek, Willow/Shellabarger Creek (Shellabarger is a tributary to Willow), Perrinville Creek, Lunds Gulch Creek, Northstream Creek, and Boeing Creek.

[7] The planned total sockeye salmon releases in Lake Washington watershed would not exceed 34M.

[8] Fish smaller than 250 fpp cannot be reliably adipose clipped, so, if the fish are released prior to this size, they will only have an otolith mark.

[9] The co-managers may consider using net pens to rear juvenile sockeye and hold adult salmon in the future. However, those options are not part of the action under consideration in this consultation (WDFW and Muckleshoot Indian Tribe 2020b).

1.3.6. Proposed disposition of excess juvenile and adult hatchery fish, broodstock and post-spawned carcasses

At Issaquah Hatchery and associated programs, egg-take is carefully managed to minimize the likelihood of collecting surplus eggs or raising surplus fry. However, in years of high within-hatchery survival, juvenile production levels higher than the proposed release numbers may occur. The co-managers plan to limit production to no more than 10% above levels described in the HGMPs and in Table 3 and Table 4; an overage of 10% is anticipated to be a rare occurrence. If the running 5-year average production (beginning in the release year that NOAA makes a determination on the program)[1], for a species-stage in the Lake Washington Drainage is more than 5% above the level described, the co-managers will notify NMFS.

Surplus eggs at the UW ARF would be retained to offset losses incurred during the rearing process, but will be destroyed once release goals are achieved (Table 5). Surplus eggs would not be retained by the other programs listed except as needed to meet program objectives and after discussion with NMFS.

Table 5. Disposition of excess adult hatchery fish, broodstock, and post-spawned carcasses.

Program	Disposition
Issaquah Fall Chinook salmon	• Unmarked Chinook salmon above broodstock needs will be released upstream of the hatchery to spawn naturally • All other surplus fish will be sold to a carcass buyer
Issaquah coho	• Up to 3,000 above broodstock needs will be released upstream of the hatchery to spawn naturally • Remaining fish may be out-planted in Sammamish and Lake Washington watershed tributaries • All other surplus fish will be sold to a carcass buyer
UW ARF Fall Chinook salmon	• Sampled for virology • Carcasses sold to a carcass buyer, distributed to cooperative projects for nutrient enhancement in Lake Washington rivers and tributaries, or transported to a landfill.
UW ARF coho	• Sampled for virology • Carcasses sold to a carcass buyer, distributed to cooperative projects for nutrient enhancement in Lake Washington Rivers and tributaries, or transported to a landfill.
Sockeye	• Excess male broodstock may be released back into the river • Spawned carcasses are returned to the Cedar River for nutrient enhancement • Pre-spawn mortalities will be disposed of in a local landfill

[1] Additionally, if the number of fish released after one or two years is so high that attainment of the proposed release numbers across five years is not a reasonable expectation the co-managers will notify NMFS.

1.3.7. Proposed research, monitoring, and evaluation (RM&E)

Research, monitoring, and evaluation activities described below in Table 6 are activities that have been evaluated through this opinion, or have current ESA coverage through another permit or 4(d) authorization.

Table 6. Research, monitoring, and evaluation that may occur and are associated with the five salmon hatchery programs and any existing ESA coverage. This may vary for species/release site/return location. See HGMPs for more details.

Activity	Associated Program	ESA coverage
Monitor adult collection, escapement, origin, length, age, genetic samples, redd submersion, egg volume, marks/tags, catch contribution, and return timing	All	This Opinion
Monitor proportion of hatchery- and natural-origin fish in natural production areas to collect basic life history information (i.e., length, maturity, migration status, marks/tags, sex, age, origin, and condition) and estimate escapement	All	This Opinion
Smolt-to-adult survival and outmigration timing using CWT data	All	This Opinion
Within-hatchery monitoring of fish health and survival	All	This Opinion
Acoustic transmitters and/or passive integrated transponder tags in smolts to identify effects of release locations on outmigrating smolt survival and travel time	Issaquah Hatchery Coho and Chinook program	This Opinion
Lake Washington Tributary Downstream-Migrant Salmon Evaluation: Sample and estimate the abundance of juvenile salmonids using migrant traps in the Cedar River and Bear Creek; PIT tag a proportion, purse seining of juvenile sockeye in Lake Union.	• Issaquah Hatchery Coho and Chinook programs • Lake Washington Sockeye program	4(d) (annual)

1.3.8. Proposed operation and maintenance of hatchery facilities

Water at all facilities would be withdrawn in accordance with state-issued water rights. All facilities that rear over 20,000 pounds of fish must comply with the National Pollutant Discharge Elimination System (NPDES) through a general permit issued by the United States Environmental Protection Agency (See Table 7 for more details). Withdrawal as it affects streamflow will be discussed in Effects of the Action factor five (section 2.5.2.5.

Several routine (and semi-routine) maintenance activities occur in or near water that could impact fish in the area including: sediment/gravel removal/relocation from intake and/or outfall structures, pond cleaning, pump maintenance, debris removal from intake and outfall structures, and maintenance and stabilization of existing bank protection. All in-water maintenance activities considered “routine” (occurring on an annual basis) or “semi-routine” (occurring with regularity, but not necessarily on an annual basis) for the purposes of this action will occur within existing structures or the footprint of areas that have already been impacted.

Table 7. Details for those facilities that divert water for hatchery operations; NA = not applicable.

Facilities	Surface/Spring Water (cfs)	Ground Water (gpm)	Water Diversion Distance (km)	Water Source	Discharge Location	Meet NMFS Screening Criteria (Criteria year)?	NPDES Permit #	Water Right Permit #
Issaquah	NA	49	NA	Darigold/ West Farms Foods	N/A	N/A	WAG 13-3010	G1-21648C
	16	NA	0.002	Issaquah Creek	Issaquah Creek	Yes		S1-00735C
	10	NA	1.19			Yes		S1-04730C
	10	NA	0.009			Yes		S1-*20852C
Willow Creek Hatchery	1	NA	0.005	Willow Creek (Deer Creek)	Willow Creek	Yes	NA	S1-24635C
Edmonds Net Pens	NA[1]	NA	NA	Puget Sound	NA	NA	NA[2]	NA
UW ARF	5.0	NA	NA	Lake Union	Lake Union	Yes[3]	NA[2]	SI-*14169C
	NA	80	NA	Groundwater	Lake Union	Yes	NA[2]	G1-007311CL
	NA	50	NA	Groundwater	Lake Union	Yes	NA	G1-007312CL
Cedar River	NA	1.7	0.54	Unnamed Spring	Cedar River	Yes	NA	SI-23174 (WDFW)
	4.46	NA	0.21	Cedar River	Cedar River	Yes	NA	NA [4]
	1.3	NA	0.26	Unnamed Stream	Cedar River	Yes	NA	SI-28457P (SPU)
	NA	2,000	NA	Groundwater	Cedar River	NA	NA	G1-28811
	2.0	NA	0.09	Unnamed Stream	Cedar River	Yes	NA	SI-28458P (SPU)
	0.9	NA	0.44	Unnamed Stream	Cedar River	Yes	NA	SI-28500P (SPU)

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[1] Net pens use seawater, passively supplied through tidal flow, for acclamation of coho salmon, and the amount coursing through the ne
relative to the total amount of water in Puget Sound

[2] Releases less than 20,000 pounds of fish per year and/or feed fish less than 5,000 pounds of fish feed per year do not require a NPDES

[3] NMFS engineer determined that water intake at this facility is an infiltration gallery (STOP)

[4] The usage of surface water is accounted for under Seattle Public Utility drinking water withdrawal and does not require an additional

2. ENDANGERED SPECIES ACT: BIOLOGICAL OPINION AND INCIDENTAL TAKE STATEMENT

The ESA establishes a national program for conserving threatened and endangered species of fish, wildlife, plants, and the habitat upon which they depend. Section 7(a)(2) of the ESA requires Federal agencies to consult with the USFWS, NMFS, or both, to ensure that their actions are not likely to jeopardize the continued existence of endangered or threatened species or adversely modify or destroy their designated critical habitat. Section 7(b)(3) requires that at the conclusion of consultation, the Service provide an opinion stating how the agencies' actions will affect listed species and their critical habitat. If incidental take is expected, section 7(b)(4) requires the consulting agency to provide an Incidental Take Statement (ITS) that specifies the impact of any incidental taking and includes reasonable and prudent measures to minimize such impacts.

NMFS determined the proposed action is not likely to adversely affect Lake Ozette Sockeye Salmon and Hood Canal Summer Chum Salmon or their critical habitat. Our concurrence is documented in the "Not Likely to Adversely Affect" Determinations section (Section 2.11).

2.1. Analytical Approach

This biological opinion includes both a jeopardy analysis and/or an adverse modification analysis. Section 7(a)(2) of the ESA requires Federal agencies, in consultation with NMFS, to ensure that their actions are not likely to jeopardize the continued existence of endangered or threatened species, or adversely modify or destroy their designated critical habitat. The jeopardy analysis considers both survival and recovery of the species. "To jeopardize the continued existence of a listed species" means to engage in an action that would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of the species in the wild by reducing the reproduction, numbers, or distribution of that species or reduce the value of designated or proposed critical habitat (50 CFR 402.02).

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

The designations of critical habitat for the species considered in this opinion use the terms 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. We use the term PCE as equivalent to PBF or essential feature, due to the description of such features in applicable recovery planning documents.

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:

Identify the 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.

Describe the environmental baseline in the action area
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.

Analyze the effects of the proposed action on both the species and their habitat
In Section 2.5 we consider how the Proposed Action would affect the species' abundance, productivity, spatial structure, and diversity (VSP parameters) and the Proposed Action's effects on critical habitat features in Section 2.5.3

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 1.3) 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 2.8.

Reasonable and prudent alternative(s) (RPA) 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.

Other species in action area
ESA-listed anadromous salmonid species in the action area are described in section 2.2.1. The effects of take associated with implementation of Puget Sound region hatchery salmon and steelhead production on the Hood Canal Summer Chum Salmon ESU were previously evaluated and authorized by NMFS through a separate ESA section 7 consultation process (NMFS 2002a). An Environmental Assessment and FONSI were completed as part of the 2002 NMFS summer chum salmon consultation (NMFS 2002c). Effects on this ESA-listed species associated with implementation of the six salmon HGMPs will therefore not be discussed further in this opinion.

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

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

In analyzing the effects of the proposed actions on threatened Puget Sound Chinook salmon and steelhead natural populations, NMFS considers its classification of each population and the role of the population in recovery of the ESU. Under the Population Recovery Approach (PRA) (NMFS 2010), each natural population is assigned to a tier designation based on life history, production and habitat indicators, and the Puget Sound Recovery Plan biological delisting criteria (Figure 2). NMFS applies the PRA in ESA consultations for actions affecting ESA-listed Chinook salmon in Puget Sound (e.g., (NMFS 2011b; 2015c). Although recognizing prioritization of the 22 Puget Sound Chinook Salmon ESU populations is valuable, NMFS understands that there are non-scientific factors (e.g., the importance of a salmon or steelhead population to tribal culture and economics) that are important considerations in salmon and steelhead recovery.

Under the PRA, Tier 1 populations are of primary importance for preservation, restoration, and ESU recovery. Tier 2 populations play a secondary role in recovery of the ESU and Tier 3 populations play a tertiary role. When NMFS analyzes proposed actions, it evaluates impacts at the individual population scale for their effects on the viability of the ESU. Impacts on Tier 1 populations would be more likely to affect the viability of the ESU as a whole than similar impacts on Tier 2 or 3 populations, because of the primary importance of Tier 1 populations to overall ESU viability. Both the Lake Washington Chinook salmon populations are classified through the approach as Tier 3 populations (NMFS 2010). The classification for these two Chinook salmon populations that may be affected by the proposed actions are considered in NMFS's analysis with other factors (Section2.6) to derive conclusions regarding the Lake Washington watershed salmon hatcheries-related effects on the Puget Sound Chinook Salmon ESU.

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

This opinion examines the status of each species and designated critical habitat that would be affected by the Proposed Action. The species and the designated critical habitat that are likely to be affected by the Proposed Action, and any existing protective regulations, are described in Table 8. 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 helps to inform the description of the species' current "reproduction, numbers, or distribution" as described in 50 CFR 402.02. The opinion also examines the 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 8. 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 collected at appropriate levels, they maintain a population's capacity to adapt to various environmental conditions and allow it to sustain itself in the natural environment. These parameters or attributes are substantially influenced by habitat and other environmental conditions.

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

"Productivity," as applied to viability factors, refers to the entire life cycle; i.e., the number of naturally spawning adults (i.e., progeny) produced per naturally spawning parental pair. When progeny replace or exceed the number of parents, a population is stable or increasing. When progeny fail to replace the number of parents, the population is declining. McElhany et al. (2000) use the terms "population growth rate" and "productivity" interchangeably when referring to production over the entire life cycle. They also refer to “trend in abundance,” which is the manifestation of long-term population growth rate.

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

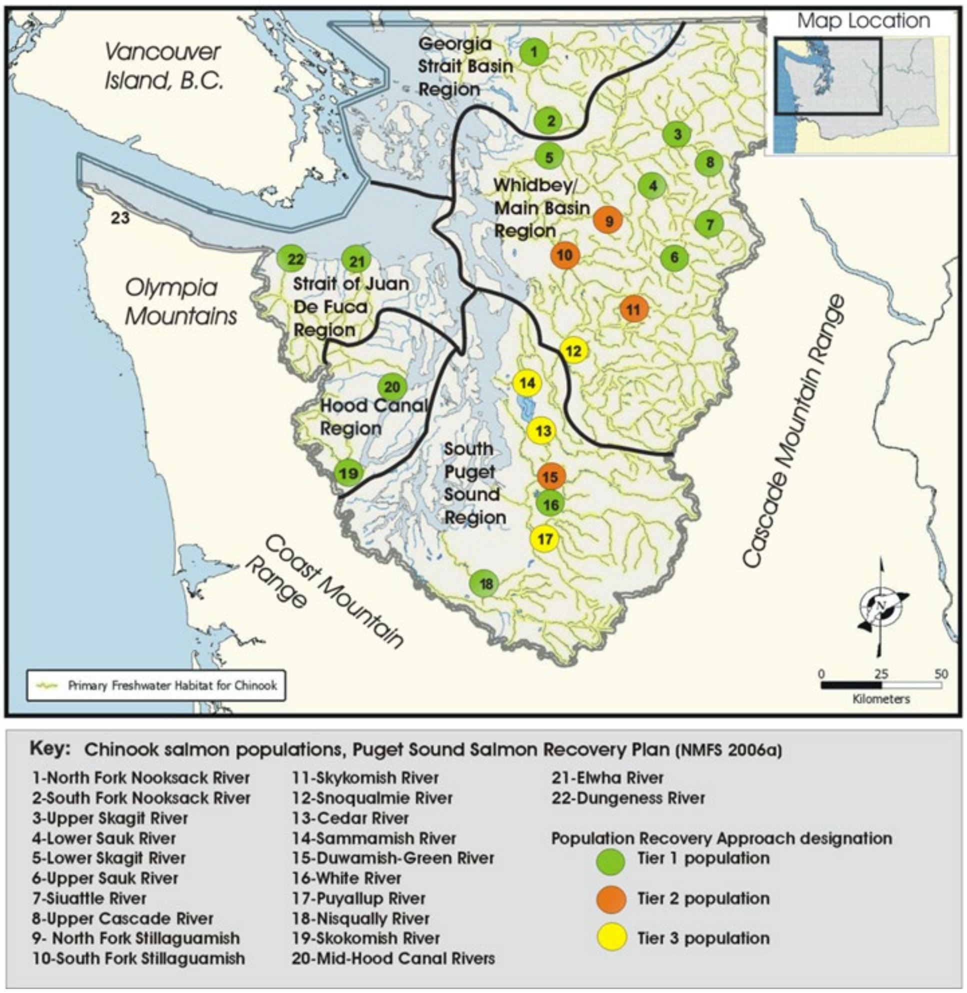

Figure 2. Populations delineated by NMFS for the Puget Sound Chinook Salmon ESU (SSPS 2007;(NMFS 2010)) and their assigned Population Recovery Approach tier status (SSPS 2007; (NMFS 2010)). Note: Dosewallips, Duckabush, and Hamma Hamma River Chinook salmon are aggregated as the “Mid Hood Canal” population.

“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).

Researchers have looked for evidence that marine area carrying capacity can limit salmonid survival (Beamish et al. 1997; HSRG 2004a). Some evidence suggests density-dependence in the abundance of returning adult salmonids (Emlen et al. 1990; Lichatowich et al. 1993; Bradford 1995), is associated with cyclic ocean productivity (Nickelson et al. 1986; Beamish and Bouillon 1993; Beamish et al. 1997). (Naish et al. 2008a)could find no systematic, controlled study of the effects of density on natural-origin salmon, or of interactions between natural- and hatchery-origin salmon, nor on the duration of estuarine residence and survival of salmon. The Salish Sea marine ecosystem was until recently believed to be stable, internally regulated and largely deterministic. The current view is that Puget Sound is dynamic, with much environmental stochasticity and ecological uncertainty (Mahnken et al. 1998; Francis 2002b). The same is true for estuaries. At best, during years of limited food supply, juvenile fish survival and size may be reduced. Thus, the influence of density-dependent interactions on growth and survival is likely small compared with the effects of large scale and regional environmental conditions.

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

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

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

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

2. At least two to four Chinook salmon populations in each of the five biogeographical regions of Puget Sound attain a low risk status over the long-term;

3. At least one or more populations from major diversity groups[1] historically present in each of the five Puget Sound regions attain a low risk status;

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

5. Production of Chinook salmon from tributaries to Puget Sound not identified as primary freshwater habitat for any of the 22 identified populations occurs in a manner consistent with ESU recovery.

Spatial Structure and Diversity. The PSTRT determined that 22 historical populations currently contain Chinook salmon and grouped them into five biogeographical regions (BGRs), based on consideration of historical distribution, geographic isolation, dispersal rates, genetic data, life history information, population dynamics, and environmental and ecological diversity (Table 9). Based on genetic and historical evidence reported in the literature, the PSTRT also determined that there were 16 additional spawning aggregations or populations in the Puget Sound Chinook Salmon ESU that are now putatively extinct[2] (Ruckelshaus et al. 2006). The Puget Sound Chinook salmon ESU includes all naturally spawned Chinook salmon originating from rivers flowing into Puget Sound from the Elwha River (inclusive) eastward, including rivers in Hood Canal, South Sound, North Sound and the Strait of Georgia. Per the Federal Register (79 FR 20802), Chinook salmon from the following 26 artificial propagation programs are also included in the listing: the Kendall Creek Hatchery Program; Marblemount Hatchery Program (spring subyearlings and summer-run); Harvey Creek Hatchery Program (summer-run); Whitehorse Springs Pond Program; Wallace River Hatchery Program (yearlings and subyearlings); Tulalip

[1] Major diversity groups of Chinook salmon are identified based on run timing, age distribution, and migration patterns. For example, early returning and late returning populations of adult Chinook salmon represent two types of major diversity groups that may be present within a biogeographical region.
[2] It was not possible in most cases to determine whether these Chinook salmon spawning groups historically represented independent populations or were distinct spawning aggregations within larger populations.

Bay Program; Issaquah Hatchery Program; Soos Creek Hatchery Program; Icy Creek Hatchery Program; Keta Creek Hatchery Program; White River Hatchery Program; White Acclimation Pond Program; Hupp Springs Hatchery Program; Voights Creek Hatchery Program; Diru Creek Program; Clear Creek Program; Kalama Creek Program; George Adams Hatchery Program; Rick's Pond Hatchery Program; Hamma Hamma Hatchery Program; Dungeness/Hurd Creek Hatchery Program; Elwha Channel Hatchery Program; and the Skookum Creek Hatchery Spring-run Program.

2.2.1.2. Puget Sound BGR Population

Chinook Salmon populations in Puget sound were listed as an Evolutionary Significant Unit by NMFS following the 1998 status review (FR March 9 1998). NMFS has convened recovery planning efforts across the Pacific Northwest to identify what actions are needed to recover listed salmon and steelhead. A recovery plan for the Puget Sound Chinook ESU was completed in 2007 (72 FR 2493, January 19, 2007). The recovery plan consists of two documents: the Puget Sound Salmon Recovery Plan prepared by the Shared Strategy for Puget Sound and NMFS' Final Supplement to the Shared Strategy Plan (NMFS 2006b; SSPS 2007). It describes the ESU's population structure, identifies populations essential to recovery of the ESU, establishes recovery goals for most of the populations, and recommends habitat, hatchery, and harvest actions designed to contribute to the recovery of the ESU (NMFS 2006b; SSPS 2007). The recovery plan adopts ESU and population level viability criteria recommended by the Puget Sound Technical Recovery Team (PSTRT) (Ruckelshaus et al. 2002; Ruckelshaus et al. 2006).

The PSTRT identified 22 historical natural populations of Chinook salmon and grouped them into five biogeographical regions (BGRs; (SSPS 2007). The ESU encompasses all runs of Chinook salmon from rivers and streams flowing into Puget Sound, the boundary of the ESU extends from the Nooksack River and the Strait of Georgia in the north, the Strait of Juan de Fuca from the Elwha River eastward, and rivers and streams flowing into Hood Canal, South Sound, North Sound (FR 20802,Figure 3).

The Technical Recovery Team (TRT) did not define the relative roles of the remaining populations in the Whidbey and Central/South Sound Basins for ESU viability. Therefore, NMFS developed additional guidance, the *Population Recovery Approach*, which considers distinctions in genetic legacy and watershed condition among other factors in assessing the risks to survival and recovery of the listed species by the proposed actions across all populations within the Puget Sound Chinook ESU. This approach carries forward the biological viability and delisting criteria described in the Supplement to the Puget Sound Salmon Recovery Plan (Ruckelshaus et al. 2002; NMFS 2006b(NMFS 2006a)), and was used to classify Puget Sound Chinook salmon populations into three tiers (Figure 3) (NMFS 2006b; 2010). The assigned tier indicates the relative role of each of the 22 populations comprising the ESU to the viability of the ESU and its recovery. Impacts on tier one populations would be more likely to affect the viability of the ESU as a whole. NMFS has incorporated this approach in previous ESA section 4(d) determinations and opinions on Puget Sound Chinook (Table 9). Sammamish and Cedar rivers support tier three populations of Chinook salmon (Figure 3).

Table 9. Extant Puget Sound Chinook salmon populations by biogeographical region (NMFS 2006b).

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

NOTE: At least one other population of each race within the Whidbey Basin (one each of the early, moderately early and late spawn-timing) and Central/South Puget Sound Basin (one late spawn-timing) regions would need to be viable for recovery of the ESU.

Indices of spatial distribution and diversity have not been developed at the population level, though diversity at the ESU level is declining. Abundance is becoming more concentrated in fewer populations and regions within the ESU. The Whidbey Basin Region is the only region with consistently high fraction natural-origin spawner abundance, in six of the 10 populations within the Region. All other regions have moderate to high proportions of hatchery-origin spawners (Figure 3).

In general, the Strait of Juan de Fuca, Georgia Basin, and Hood Canal regions are at greater risk than the other regions due to critically low natural abundance and/or declining growth rates of the populations in these regions. In addition, spatial structure, or geographic distribution, of the White, Skagit, Elwha, and Skokomish populations has been substantially reduced or impeded by the loss of access to the upper portions of those tributary basins due to flood control activities and hydropower development. Habitat conditions conducive to salmon survival in most other

Abundance and Productivity

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 10). 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 10). Additionally, most populations are consistently well below the productivity goals identified in the recovery plan. Although trends vary for individual populations across the ESU, currently 20 populations exhibit a stable or increasing trend in natural escapement (Table 10). Thirteen of the 22 populations exhibit a stable or increasing long-term trend in total natural escapement over the 18-year geometric mean (NMFS 2020a).

This updated trend analysis is based on the addition of three years of escapement data including natural-origin escapement, which are only available for the more recent return years for several populations (Elwha, Dungeness, SF fall-run Stillaguamish, Lake Washington, Cedar River, and Nisqually). With the addition of these data, natural-origin escapement trends indicate an improvement over the status as reported in the NWFSC 2021 status update and was the best available information at the time of the completion of previous opinions (NMFS 2016d; 2017a).

As of 2020 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, 2021).

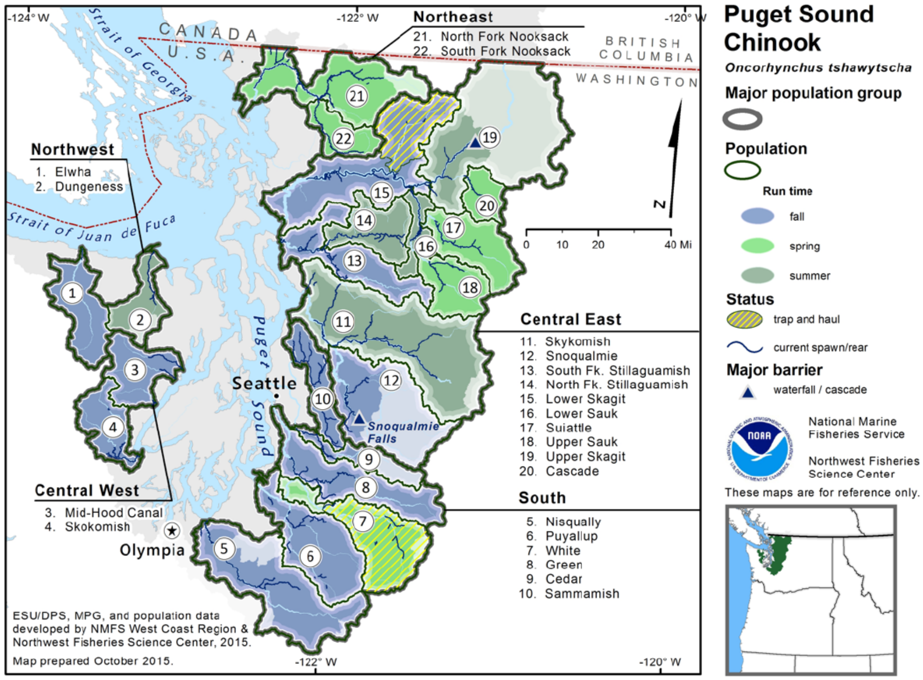

Figure 3. Map of the Puget Sound Chinook salmon ESU's spawning and rearing areas, illustrating populations and major population groups. Source: NWFSC 2015.

Table 10. Estimates of escapement and productivity (recruits/spawner) for Puget Sound Chinook populations. Natural-origin escapement information is provided where available. Populations at or below their critical escapement threshold are bolded. For several populations, hatchery contribution to natural spawning data are limited or unavailable (NMFS 2021b).

Region	Population	1999 to 2018 Geometric mean Escapement (Spawners)		NMFS Escapement Thresholds		Recovery Planning Abundance Target in Spawners (productivity)[1]	Average % hatchery fish in escapement 1999-2018 (min-max[2])
		Natural[3]	Natural-Origin (Productivity[1])	Critical[4]	Rebuilding[5]		
Georgia Basin	Nooksack MU	1,798	236	400	500		
	NF Nooksack	1,537	**180** (0.3)	*200*[6]	-	3,800 (3.4)	85 (63-97)
	SF Nooksack	266	**56** (1.9)	*200*[6]	-	2,000 (3.6)	51 (19-82)
Whidbey/Main Basin	Skagit Summer/Fall MU						
	Upper Skagit River	9,349	8,314 (2.7)	738	5,740	5,380 (3.8)	11 (2-36)
	Lower Sauk River	560	531 (3.1)	*200*[6]	371	1,400 (3.0)	5 (0-33)
	Lower Skagit River	2,090	1,845 (2.8)	281	2,131	3,900 (3.0)	9 (0-23)
	Skagit Spring MU						
	Upper Sauk River	633	624 (2.2)	130	470	750 (3.0)	1 (0-5)
	Suiattle River	379	372 (2.0)	170	223	160 (2.8)	2 (0-7)
	Upper Cascade River	289	260 (1.5)	130	148	290 (3.0)	7(0-25)
	Stillaguamish MU						
	NF Stillaguamish R.	1,029	472 (0.9)	300	550	4,000 (3.4)	51 (25-80)
	SF Stillaguamish R.	122	**58** (1.2)	*200*[6]	300	3,600 (3.3)	48 (9-79)
	Snohomish MU						
	Skykomish River	3,193	2,212 (1.5)	400	1,491	8,700 (3.4)	28 (0-62)
	Snoqualmie River	1,449	1,182 (1.3)	400	816	5,500 (3.6)	18 (0-35)
Central/South Sound	Cedar River	924	659 (2.7)	*200*[6]	282[7]	2,000(3.1)	28 (10-50)
	Sammamish River	1,073	**161** (0.5)	*200*[6]	*1,250*[6]	2,000(3.1)	80 (36-96)
	Duwamish-Green R.	4,014	1,525 (1.4)	400	1,700	1,000(3.0)	59 (27-79)
	White River[8]	1,859	625 (0.8)	*200*[6]	488[7]	-	59 (14-90)
	Puyallup River[9]	1,646	784 (1.2)	*200*[6]	797[7]	-	54 (19-83)
	Nisqually River	1,670	621 (1.5)	*200*[6]	*1,200*[10]	5,300 (2.3)	56 (17-87)
Hood Canal	Skokomish	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 (2-87)
Strait of Juan de Fuca	Dungeness River Elwha River[12]	411 1,231	**98** (1.0) **171**	*200*[6] *200*[6]	925 *1,250*[6]	1,200 (3.0) 6,900 (4.6)	72 (39-96) 74 (31-98)

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[1] 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 2006b) measured as recruits/spawner associated with the number of spawners at Maximum Sustained Yield under recovered conditions.

[2] 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) ((WDFW and PSTIT 2005; 2006; 2007; 2008; 2009; 2010; 2011; 2012; 2013; 2014; 2015; 2016; 2017; James and Dufault 2018)

[3] Includes naturally spawning hatchery fish 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).

[4]Critical natural-origin escapement thresholds under current habitat and environmental conditions ((McElhany et al. 2000; NMFS 2018a).

[5] Rebuilding natural-origin escapement thresholds under current habitat and environmental conditions (McElhany et al. 2000; (NMFS 2018a)

[6] Based on generic VSP guidance (McElhany et al. 200).

[7] Based on spawner-recruit assessment (NMFS 2021a)

[8] 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.

[9] 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 (WDFW and PSTIT 2010).

[10] Based on alternative habitat assessment.

[11] 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

[12] 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).

Limiting factors

Limiting factors described in (SSPS 2007) and reiterated in (NMFS 2006b) include:

- Degraded nearshore and estuarine habitat: Residential and commercial development has reduced the amount of functioning nearshore and estuarine habitat available for salmon rearing and migration. The loss of mudflats, eelgrass meadows, and macroalgae further limits salmon foraging and rearing opportunities in nearshore and estuarine areas.
- Degraded freshwater habitat: Floodplain connectivity and function, channel structure and complexity, riparian areas and large wood supply, stream substrate, impaired passage conditions and water quality have been degraded for adult spawning, embryo incubation, and rearing as a result of cumulative impacts of agriculture, forestry, and development. Some improvements have occurred over the last decade for water quality and removal of forest road barriers.
- Anadromous salmonid hatchery programs: Salmon and steelhead released from Puget Sound hatcheries operated for harvest augmentation purposes pose ecological, genetic, and demographic risks to natural-origin Chinook salmon populations. The risk to the species' persistence that may be attributable to hatchery-related effects has decreased since the last Status Review, based on hatchery risk reduction measures that have been implemented, and new scientific information regarding genetic effects noted above (NWFSC 2015). Improvements in hatchery operations associated with on-going ESA review and determination processes are expected to further reduce hatchery-related risks.
- Salmon harvest management: Total fishery exploitation rates have decreased substantially since the late 1990s when compared to years prior to listing (average reduction = -33%, range = -67 to +30%) (New FRAM base period validation results, August 2017), but weak natural-origin Chinook salmon populations in Puget Sound still require enhanced protective measures to reduce the risk of overharvest. The risk to the species' persistence because of harvest remains the same since the last status review for all three species. Increased harvest from the Canadian WCVI fisheries has impacted most Puget Sound populations. Further, there is greater uncertainty associated with this threat due to shorter term harvest plans and exceedance of management objectives for some Chinook salmon populations essential to recovery.
- Concerns regarding existing regulatory mechanisms: Existing regulatory mechanisms regarding water and land-use raise some concerns, including lack of documentation or analysis of the effectiveness of land-use regulatory mechanisms and land-use management plans, lack of reporting and enforcement for some regulatory programs, and certain Federal, state, and local land and water use decisions that continue to occur without the benefit of ESA review. State and local decisions have no Federal nexus to trigger the ESA Section 7 consultation requirement, and thus certain permitting actions allow direct and indirect species take and/or adverse habitat effects.

The severity and relative contribution of these factors varies by natural population. In addition, cycles or variability in environmental conditions affecting plant and animal communities—for example, increased predator abundances and decreased food resources in ocean rearing areas—likely have contributed to declines in fish populations in Puget Sound. For a comprehensive treatment of all limiting factors, please see Section **Error! Reference source not found.**, Environmental Baseline.

2.2.1.3. Cedar and Sammamish Chinook populations

The Central/South Sound BGR contains six Chinook salmon populations and most are genetically similar, reflecting the extensive influence of transplanted hatchery releases, primarily from the Duwamish-Green River population (Council 2017). Except for the White River, Chinook populations in this region exhibit a fall type life history. The six populations constitute five management units: Lake Washington (Cedar and Sammamish), Duwamish-Green, White, Puyallup, and Nisqually. Hatchery contribution to spawning escapement is moderate to high for the populations within this region. The Cedar, Sammamish, populations are in PRA Tier 3. The basins in the Central/South Sound region are the most urbanized and some of the most degraded in the ESU (SSPS 2005). The lower reaches of all these systems flow through lowland areas that have been developed for agricultural, residential, urban, or industrial use. Much of the watersheds or migration corridors for five of the six populations in the region are within the cities of Tacoma or Seattle or their metropolitan environments (Sammamish, Cedar, Duwamish-Green, Puyallup, and White). Natural production is limited by stream flows, physical barriers, poor water quality, elimination of intertidal and other estuarine nursery areas, and limited spawning and rearing habitat related to timber harvest and residential, industrial, and commercial development, as well as several dams limiting upper watershed access (Cedar, Duwamish-Green, Puyallup/White, and Nisqually).

Except for the Sammamish population, average natural-origin escapements since 1999 are well above their critical thresholds (Table 10). Rebuilding escapement thresholds were updated for the Cedar river in 2017 and 2018 based on new spawner-recruit analysis. Average natural-origin escapement in the Cedar exceeds those rebuilding escapement thresholds; observed productivity is 1.0. Total escapement trends are stable or increasing for all populations within the region except for the Puyallup River, which is declining (Table 10Table 13). Growth rates for recruits and escapement are mixed for the Cedar and Sammamish. Furthermore, natural-origin spawning escapements in 2019 are expected to be above the critical threshold for all of the populations except for the Sammamish (Table 10Table 13). The additional contribution of hatchery spawners to natural escapement for most of these populations should mitigate demographic risk.

Juveniles enter the lake from mid-January through late June (Koehler et al. 2006; Lisi 2019). There are two distinct juvenile Chinook salmon rearing life-histories that have been identified in the Lake Washington watershed. The early fish are < 50 mm and spend a few days in stream habitats before entering the lake January through March (peaking in mid-February). The late fish rear in tributary streams for several weeks before migrating to the lake April through late June, with the peak occurring in mid-May (Koehler et al. 2006). Most juveniles leave Lake Washington and enter Puget Sound in June and July (DeVries et al. 2004).

In the Sammamish River, Chinook primarily spawn in Bear Creek with intermittent spawning in Little Bear Creek. Approximately 10.0 of the 13.4 miles of Bear Creek are accessible to Chinook, most spawning occurs between RM 4.3 and 8.8. Spawning occurs in the lower 3.5 miles of Cottage Lake Creek, a tributary to Bear Creek. In Little Bear Creek, there is 3.8 miles of spawning habitat. No Chinook spawning occurs in the Sammamish River mainstem due to a lack of suitable habitat in the low-gradient, heavily silted channel.

Juvenile Chinook trapping occurs in both the Cedar River and Bear Creek (Kiyohara 2013). From 1998 – 2013, the proportion of juveniles emigrating as fry averaged 79% in the Cedar River but ranged from 34 – 98%. Conversely, fry emigration in Bear Creek averaged 19% and ranged from 4-56%. The remainder of emigrants were parr in both systems as no yearlings were encountered.

2.2.1.4. Status of Critical Habitat for Puget Sound Chinook Salmon

Critical habitat for the Puget Sound Chinook ESU was designated on September 2, 2005, and includes localized 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 extending from extreme high water out to a depth of 30 meters and adjacent to watersheds occupied by the 22 extant natural populations because of their importance to rearing and migration for Chinook salmon and their prey, but does not otherwise include offshore marine areas. There are 61 watersheds within the range of this ESU. Twelve watersheds received a low rating, nine received a medium rating, and 40 received a high rating of conservation value to the ESU (NMFS 2005a). Nineteen nearshore marine areas also received a rating of high conservation value. Of the 4,597 miles of stream and nearshore habitat eligible for designation, 3,852 miles are designated critical habitat (NMFS 2005b)

NMFS determines the range-wide status of critical habitat by examining the condition of its primary constituent elements (PCEs) 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 general categories of: (1) water quantity, quality, and forage to support spawning, rearing, individual growth, and maturation; (2) areas free of obstruction and excessive predation; and (3) the type and amount of structure and rugosity that supports juvenile growth and mobility.

Major management activities affecting PCEs are forestry, grazing, agriculture, channel/bank modifications, road building/maintenance, urbanization, sand and gravel mining, dams, irrigation impoundments and withdrawals, river, estuary and ocean traffic, wetland loss, and forage fish/species harvest. NMFS has completed several section 7 consultations on large scale habitat projects affecting listed species in Puget Sound. Among these are the Washington State Forest Practices Habitat Conservation Plan (NMFS 2006a), and consultations on Washington State Water Quality Standards (NMFS 2008a), the National Flood Insurance Program (NMFS 2008b), the Washington State Department of Transportation Preservation, Improvement and Maintenance Activities (NMFS 2013b), and the Elwha River Fish Restoration Plan (Ward et al. 2008). These documents provide a more detailed overview of the status of critical habitat in Puget Sound and are incorporated by reference here.

2.2.1.5. Life History of Steelhead

Oncorhynchus mykiss has an anadromous form, commonly referred to as steelhead. Steelhead differ from other Pacific salmon in that they can be anadromous or freshwater residents and can yield offspring of the alternate life history form. *O. mykiss* may spawn more than once during their life span (iteroparous) whereas the Pacific salmon species generally spawn once and die (semelparous). Steelhead can be divided into two basic reproductive ecotypes, based on the state of sexual maturity at the time of river entry and duration of spawning migration (Quinn 2005). Summer-run steelhead enter freshwater at an early stage of maturation beginning in the late spring, migrate to headwater areas and hold until spawning in the winter and following spring. Winter steelhead typically enter freshwater at an advanced stage of maturation later in the year and spawn in the winter and spring (Busby et al. 1996; Hard et al. 2007).

2.2.1.6. Puget Sound Steelhead

The Puget Sound steelhead distinct population segment (DPS) includes more than 50 stocks of summer- and winter-run fish, the latter being the most widespread and numerous (WDFW 2002). 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 (71 FR 15666; March 29 2006). Puget Sound steelhead are dominated by the winter life history ecotype 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) . Temporal overlap exists in spawn timing between the two life history ecotypes, 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 (Withler 1966; Behnke and American Fisheries Society 1992; Busby et al. 1996).

The Puget Sound Steelhead DPS was listed as threatened on May 11, 2007 (72 FR 26722). The DPS includes all naturally spawned anadromous winter- and summer-run 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). Also included as part of the ESA-listed DPS are six hatchery-origin stocks derived from local natural steelhead populations and produced for conservation purposes (79 FR 20802, April 14, 2014). 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). The draft 2020 NWFSC biological status review((NMFS 2020d) states that a third of the 32 Puget Sound steelhead populations continue to lack monitoring and abundance data, and in most cases it is likely that abundances are very low.

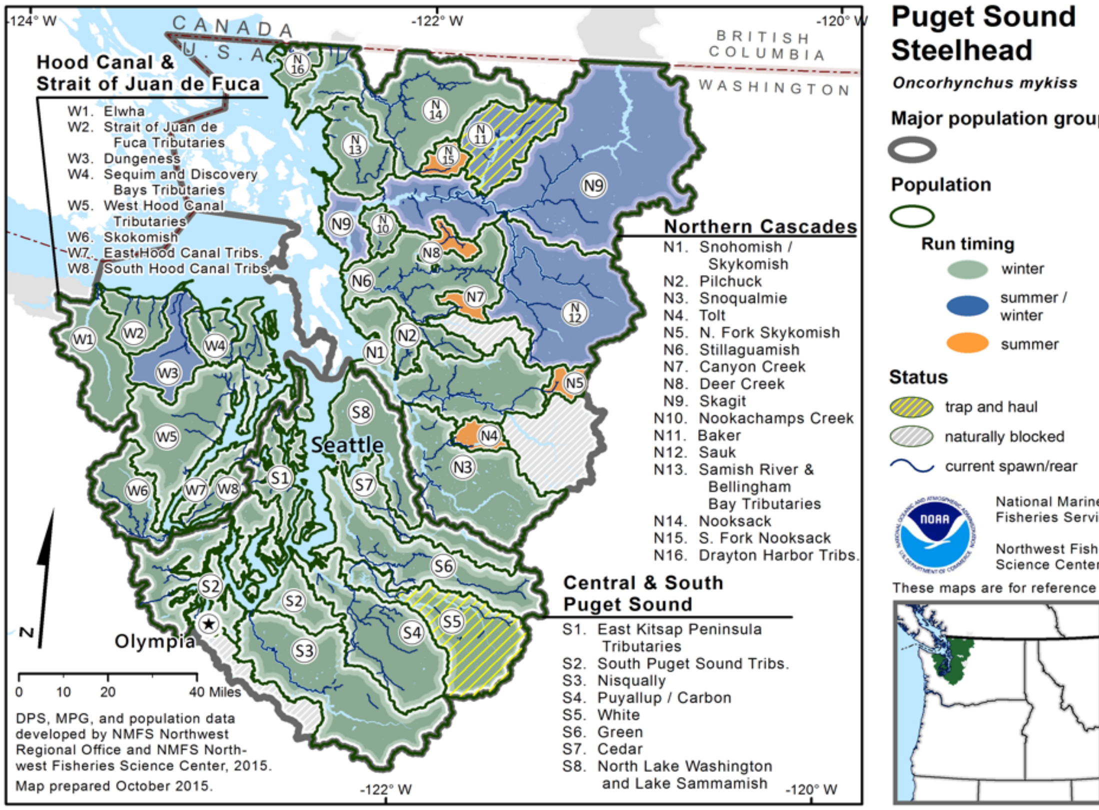

Figure 4. Map of the Puget Sound Steelhead DPS's spawning and rearing areas, identifying 32 demographically independent populations (DIPs) within 3 major population groups (MPGs). The 3 steelhead MPGs are Northern Cascades, Central & South Puget Sound, and Hood Canal & Strait of Juan de Fuca. Source (NMFS 2020b).

Abundance and Productivity

Since publication of the NWFSC report in 2015, and drafting of the 2020 NWFSC biological status review, there have been reductions in hatchery programs founded from non-listed and out-of-DPS stocks (i.e., Skamania). In addition, the fraction of out-of-DPS hatchery steelhead spawning naturally are low for many rivers (NWFSC 2015). The fraction of natural-origin steelhead spawners was 0.9 or greater for the 2005-2009 and 2010-2014 time periods for all populations where data was available except the Snoqualmie and Stillaguamish Rivers. For 17 of 22 DIPs across the DPS, the five-year average for the fraction of natural-origin steelhead spawners exceeded 0.75 from 2005 to 2009; this average was near 1.0 for 8 populations, where data were available, from 2010 to 2014 (NWFSC 2015). However, the fraction of natural-origin steelhead spawners could not be estimated for a substantial number of DIPs during the 2010 to 2014 period, or for the most recent 2015 – 2019 timeframe (NWFSC 2015). In some river systems, such as the Green River, Snohomish/Skykomish Rivers, and the Stillaguamish Rivers, these estimates were higher than some guidelines recommend (e.g., no more than 5% hatchery-origin spawners on spawning grounds for isolated hatchery programs (HSRG 2009) over the 2005- 2009 and 2010 – 2014 timeframes. The draft 2020 NWFSC biological status review

(NWFSC 2020) states that a third of the 32 Puget Sound steelhead populations continue to lack monitoring and abundance data, and in most cases it is likely that abundances are very low. More information on Puget Sound steelhead spatial structure and diversity can be found in NMFS's PSSTRT viability report and NMFS's status review update on salmon and steelhead (NWFSC 2015; 2020).

However, since 2015, fifteen of the 21 populations indicate small to substantive increases in abundance (Table 11). However, most steelhead populations remain small. From 2014 to 2019, nine of the 21 steelhead populations had fewer than 250 natural spawners annually, and 12 of the 21 steelhead populations had 500 or fewer natural spawners (Table 11).

Table 11. Five-year geometric mean of raw natural spawner counts for Puget Sound steelhead. This is the raw total spawner count times the fraction natural estimate, if available. In parentheses, the 5-year geometric mean of raw total spawner counts is shown. A value only in parentheses means that a total spawner count was available but none or only one estimate of natural spawners was available. 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 (NWFSC 2015).

MPG	Run	Population	1990-1994	1995-1999	2000-2004	2005-2009	2010-2014	2015-2019	% Change
Northern Cascades	Winter	Nooksack River	--	--	--	--	1745 (1745)	1906 (1906)	9(9)
		Pilchuck River	1225 (1225)	1465 (1465)	604 (604)	597 (597)	626 (626)	638 (638)	2 (2)
		Samish River/Bellingham Bay	316 (316)	717 (717)	852 (852)	535 (535)	748 (748)	1305 (1305)	74 (74)
		Skagit River	7202 (7202)	7656 (7656)	5419 (5419)	4677 (4677)	6391 (6391)	7181 (7181)	12 (12)
		Snohomish/Skykomish River	3629 (3629)	3687 (3687)	1718 (1718)	2942 (2942)	975 (975)	690 (690)	-29 (-29)
		Snoqualmie River	1831 (1831)	2056 (2056)	1020 (1020)	1250 (1250)	706 (706)	500 (500)	-29 (-29)
		Stillaguamish River	1078 (1078)	1166 (1166)	550 (550)	327 (327)	386 (386)	487 (487)	26 (26)
	Summer	Tolt River							
Central/ South PS	Winter	Cedar River	241 (241)	295 (295)	37 (37)	12 (12)	4 (4)	6 (6)	50 (50)
		Green River	2062 (2062)	2585 (2585)	1885 (1885)	1045 (1045)	662 (662)	1282 (1282)	94 (94)
		Nisqually River	1200 (1200)	754 (754)	409 (409)	446 (446)	477 (477)	1368 (1368)	187 (187)
		N. Lk WA/Lk Sammamish		298 (298)	37 (37)	12 (12)	--		--
		Puyallup River/Carbon River	199 (199)	196 (196)	93 (93)	72 (72)	85 (85)	201 (201)	136 (136)
		White River	169 (169)	183 (183)	147 (147)	57 (57)	79 (79)	182 (182)	130 (130)

Hood Canal/ SJF	Winter	Dungeness River	356 (356)				517 (517)	408 (408)	-21 (-21)
		East Hood Canal Tribs.	27 (27)	21 (21)	25 (25)	37 (37)	60 (60)	93 (93)	55 (55)
		Elwha River					680 (680)	1241 (1241)	82 (82)
		Sequim/Discovery							

Steelhead productivity has been variable for most populations since the mid-1980s (Figure 4). Since around 2000, productivity has fluctuated around replacement for Puget Sound steelhead populations, but the majority have predominantly been below replacement (NWFSC 2015). Some steelhead populations have shown signs of productivity that has been above replacement in the most recent years for which data are available (2015-2019) (Figure 4). Steelhead populations with productivity estimates above replacement include the Samish River, Nooksack River, and Skagit River winter-run in the Northern Cascades MPG, the Nisqually River, White River, Puyallup River, Green River, and Cedar River winter-run in the Central and South Puget Sound MPG, and the Elwha River, East, West, and South Hood Canal Tributaries, and Skokomish River winter-run steelhead populations in the Hood Canal and Strait of Juan de Fuca MPG.

Limiting Factors

Factors limiting steelhead recovery:

- In addition to being a factor that contributed to the present decline of Puget Sound steelhead populations, the continued destruction and modification of steelhead habitat is the principal factor limiting the viability of the Puget Sound steelhead DPS into the foreseeable future. This includes agriculture, residential, commercial and industrial development (including impervious surface runoff), timber management activities, water withdrawals, and altered flows.
- Fish passage barriers at road crossings and dams.
- Reduced spatial structure for steelhead in the DPS.
- Reduced habitat quality through changes in river hydrology and temperature profile, which are expected to increase with continuing climate change.
- Reduced downstream gravel recruitment, and reduced movement of large woody debris.
- In the lower reaches of many rivers and their tributaries in Puget Sound, urbanization has caused increased flood frequency and peak flows during storms, and reduced groundwater-driven summer flows. Altered stream hydrology has resulted in gravel scour, bank erosion, and sediment deposition.
- Dikes, hardening of banks with riprap, and channelization, which have reduced river braiding and sinuosity, have increased the likelihood of gravel scour and dislocation of rearing juveniles.
- Widespread declines in adult abundance (total run size), despite significant reductions in harvest over the last 25 years. Harvest is not considered a significant limiting factor for PS steelhead due to low harvest rates,
- Threats to genetic diversity and of ecological interactions posed by use of two hatchery steelhead stocks (Chambers Creek and Skamania) inconsistent with wild stock recovery throughout the DPS. However, the risk to the species' persistence that may be attributable to hatchery-related effects has declined since the last status review, based on

hatchery risk reduction measures that have been implemented. Improvements in hatchery operations associated with on-going ESA review and determination processes are expected to reduce hatchery-related risks. Further, hatchery releases of steelhead founded from non-native or out of DPS stocks have declined, and are expected to decrease further or cease as a term of recent 4(d) authorizations.

- Declining diversity in the DPS, including the uncertain, but likely weak, status of summer run fish in the DPS.
- High rates of juvenile mortality in estuarine and marine waters of Puget Sound, attributed to marine mammal predation, parasite prevalence, and contaminant loads.
- Concerns regarding existing regulatory mechanisms, including: lack of documentation or analysis of the effectiveness of land-use regulatory mechanisms and land-use management plans, lack of reporting and enforcement for some regulatory programs, certain Federal, state, and local land and water use decisions continue to occur without the benefit of ESA review. State and local decisions have no Federal nexus to trigger the ESA Section 7 consultation requirement, and thus certain permitting actions allow direct and indirect species take and/or adverse habitat effects.

2.2.1.7. Status of the Critical Habitat for Puget Sound Steelhead

Critical habitat has been designated for Puget Sound steelhead DPS (81 FR 9252, February 24, 2016). The 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, Duwamish, Puyallup, Nisqually, Deschutes, Skokomish, Hood Canal, Kitsap, and Dungeness/Elwha. The designation does not include specific areas in the nearshore zone in Puget Sound, nor 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). .

Puget Sound steelhead also occupy marine waters in Puget Sound and vast areas of the Pacific Ocean where they forage during their juvenile and subadult life phases before returning to spawn in their natal streams (NMFS 2012b). The NMFS (NMFS 2012a) could not identify “specific areas” within the marine and ocean range that meet the definition of critical habitat. Instead, NMFS considered the adjacent marine areas in Puget Sound when designating steelhead freshwater and estuarine critical habitat.

The Puget Sound Critical Habitat Analytical Review Team found that habitat utilization by steelhead in a number of Puget Sound areas has been substantially affected by a variety of factors (this and following from NMFS 2013a) including: dams and other manmade barriers, poor forestry practices, urbanization, loss of wetland and riparian habitat, and reduced river braiding and sinuosity. 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 has completed several section 7 consultations on large scale habitat projects affecting listed species in Puget Sound, as discussed above in section 2.2.1.4. Among these are the Washington State Forest Practices Habitat Conservation Plan, and consultations on Washington State Water Quality Standards, the National Flood Plain Insurance Program, the Washington State Department of Transportation Preservation, Improvement and Maintenance Activities, and the Elwha River Fish Restoration Plan. In 2012, the Puget Sound Action Plan was also developed. These documents provide a more detailed overview of the status of critical habitat in Puget Sound and are incorporated by reference here.

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 resulting from this analysis includes the places within or near the Lake Washington watershed where salmon and coho originating from the proposed hatchery programs would migrate and spawn naturally. Therefore, the action area also includes the marine waters of the Salish Sea to Cape Flattery off the Washington Coast in the Pacific Ocean (Figure 1).

2.4. Environmental Baseline

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

2.4.1. Habitat

As described in sections 2.2.1.4 and 2.2.1.7, over the last several years, NMFS has completed several section 7 consultations on large-scale habitat projects affecting listed species in the action area. Among these are the Washington State Forest Practices Habitat Conservation Plan (NMFS 2006a), and consultations on Washington State Water Quality Standards (NMFS 2008a), the National Flood Insurance Program (NMFS 2008b), and the Washington State Department of Transportation Preservation, Improvement and Maintenance Activities (NMFS 2013b). These documents provide a more detailed overview of the status of critical habitat in Puget Sound and are incorporated by reference here. These documents considered the effects of the proposed actions that would occur up to the next 50 years on the ESA-listed salmon and steelhead species in the action area and, more comprehensively, in the Puget Sound basin. The portions of those documents that deal with effects in the action area (described in Section 2.4) are hereby incorporated by reference.

Lakes and Major Rivers

Lake Washington watershed contains two river systems: Sammamish to the north and Cedar River at the southern end. There are also three large lakes: Lake Union, Lake Washington, and Sammamish Lake, which drain directly to Puget Sound through the Lake Washington Ship Canal and Hiram M. Chittenden Locks (Kerwin, 2001), Historically, Lake Washington connected to Puget Sound via the Black River, which joined with the White River (now Green River) to form the Duwamish River before reaching Elliott Bay (Council 2017). At that time, Cedar River was not a tributary to Lake Washington and flowed into the Black River. During Cedar River flood events, the upper Black River reversed its flow, and Cedar River would discharge into Lake Washington (Chrzastowski 1983).

The first major alteration of the Cedar River and Lake Washington watershed was the construction of a permanent barrier (Landsburg Dam), which prohibited access to the upper Cedar River by anadromous species in 1900 (Seattle Public Utilities 2005). The diversion of the lower Cedar River in 1912 redirected the river from the Black River and connected to Lake Washington. In 1911, construction began on a dam and locks system at Ballard, creating a ship canal from Lake Washington to Puget Sound. As a result, lake surface dropped a total of 8.8 feet in elevation and permanently disconnected the Black River outlet to the Duwamish (Larson 1975; Chrzastowski 1983; Council 2017).

The Puget Sound region (especially King, Pierce, and Snohomish Counties) experienced a dramatic increase in human population in the early twentieth century (Kerwin 2001). In subsequent decades, increased urbanization transitioned the surrounding farmland into residential, commercial, and industrial uses (Kerwin, 2001), which affected habitat diversity, quantity, and quality within the watershed.

The Lake Washington watershed drains a catchment of 1,572 km^2. The eastern portion of the watershed includes part of the Cascade Range. Cedar River originates high in the Cascade range, and receives runoff in spring or summer from winter snowpack. In the lower Cedar River reaches, a combination of industrial, commercial, and residential use, transitioning into agricultural and forestry as one moves upstream outside of urban growth boundaries. In the upper Cedar River, the predominant land use is transitioning from commercial forestry to preservation of forests inside the City of Seattle municipal watershed.

Issaquah River flows into Sammamish Lake before entering Sammamish River and connecting with Lake Washington. Issaquah River lies at the base of Cascade Range and summer baseflow is sustained by groundwater (Kerwin 2001). The tributary is occupied by primarily residential, commercial and industrial and generally have high levels of impervious surfaces, altered hydrologic regimes, loss of floodplain connectivity, poor riparian conditions, and water quality problems. The eastern region of the watershed experiences relatively greater annual precipitation than the western portion of the watershed (e.g., Puget Sound Lowland), although precipitation varies widely across the region (Kerwin 2001).

Nearshore

The majority of the mainland nearshore is incorporated into the cities of Seattle, Burien, SeaTac, Normandy Park, Des Moines, and Federal Way. Extensive development and shoreline modification (e.g., shoreline armoring) have resulted in the loss and degradation of nearshore habitats (Kerwin 2001). This loss is mainly caused by disconnection of nearshore habitat forming processes (e.g., loss of sediment sources, marine riparian vegetation). The small streams entering the nearshore area have been adversely affected by urbanization. These streams suffer from a lack of riparian forest, extensive infestation of non-native vegetation, excessive sedimentation, high storm flows, and serious water quality problems. Shoreline armoring has resulted in filled in shallow water habitats, loss of riparian vegetation, and isolation of nearshore habitat from sediment sources. Collectively, the effects of shoreline armoring have reduced the quantity and quality of juvenile rearing habitat and reduced important prey items for anadromous salmonids including vertebrate and invertebrate species utilized by juveniles and forage fish (e.g., herring, sandlance, and surf smelt) utilized by subadult and adult salmonids (Kerwin 2001). Piers and other man-made structures within Elliott Bay have reduced the productivity of nearshore habitat and may also affect salmonid migration patterns.

Marine

Puget Sound, a fjord system of submerged glacier valleys formed during a previous ice age, is an estuary located in northwest Washington State and covers an area of about 900 square miles, including 2,500 miles) of shoreline. Puget Sound can be subdivided into five interconnected basins separated by shallow sills: (1) the San Juan/Strait of Juan de Fuca Basin (also referred to as "North Puget Sound"), (2) Main Basin, (3) Whidbey Basin, (4) South Puget Sound, and (5) Hood Canal. Each basin differs in features such as temperature regimes, water residence and circulation, biological conditions, depth profiles and contours, species, and habitats (Drake et al. 2010).

The discussion of marine habitat in Puget Sound that follows is summarized from information contained in the Shared Strategy for Puget Sound Chinook Salmon Recovery Plan (SSPS 2007) unless otherwise noted. This snapshot of habitat issues in Puget Sound highlights some of the challenges for ESA-listed species:

- 33% of Puget Sound Shorelines have been modified with bulkheads or other armoring
- 73% of the wetlands in major deltas of Puget Sound rivers have been lost in the last 100 years
- In 1854, prior to European settlement, the area downstream of what is now RM 5.5 on the Duwamish River was the Duwamish estuary: 1,450 acres of shallows and flats, 1,170 acres of tidal marshes and 1,230 acres of tidal swamps
- 290 "pocket estuaries" formed by small independent streams and drainages have been identified throughout Puget Sound; 75 are stressed by urbanization
- 40+ aquatic nuisance species currently infest Puget Sound
- 972 municipal and industrial wastewater discharges into the Puget Sound Basin are permitted by the Washington Department of Ecology

- 180 permit holders had specific permission to discharge metals, including mercury and copper
- Over 1 million pounds of chemicals were discharged into Puget Sound in 2000 by the 20 industrial facilities that reported their releases to the Environmental Protection Agency
- An estimated 500,000 on-site sewage systems are estimated to occur in the Puget Sound basin
- 16 major (> 10,000 gallons) spills of oil and hazardous materials occurred in Puget Sound between 1985 and 2001
- 191 smaller spills occurred from 1993 to 2001, releasing a total of more than 70,000 gallons
- More than 2,800 acres of Puget Sound's bottom sediments are contaminated to the extent that cleanup is warranted

These specific examples can be summarized by seven major stressors in the marine environment of Puget Sound: (1) Loss and/or simplification of deltas and delta wetlands; (2) Alteration of flows through major rivers; (3) Modification of shorelines by armoring, overwater structures and loss of riparian vegetation; (4) Contamination of nearshore and marine resources; (5) Alteration of biological populations and communities; (6) Transformation of land cover and hydrologic function of small marine discharges via urbanization; and (7) Transformation of habitat types and features via colonization by invasive plants.

Restoration/Mitigation

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

The federally approved Shared Strategy for Puget Sound Recovery Plan for Puget Sound Chinook Salmon, Volume II of the plan (SSPS 2007), Cedar River Habitat Conservation Plan (HCP), and Landsburg Mitigation Agreement (LMA) describe, in detail, on-going and proposed state, tribal, and local government restoration and recovery activities for listed Chinook salmon in the Lake Washington watershed. The WRIA 8 Salmon Habitat Plan was prepared by the WRIA 8 Steering Committee, which updates the recovery work plan annually through 3-year work plan updates. While the WRIA 8 Plan is based on three Chinook populations, the NOAA Fisheries Puget Sound Technical Recovery Team (PSTRT) identifies two: the Cedar River Chinook and Sammamish River Chinook (which includes North Lake Washington and Issaquah sub-populations). Lake Washington habitat restoration activities are also guided by the (NWIFC 2020) report, which examines key indicators of habitat quality and quantity within the Muckleshoot Tribes' usual and accustomed fishing area.

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

Recent examples of habitat restoration and salmon recovery projects funded through the PCSRF in the action area are accessible online at[1]:
https://secure.rco.wa.gov/PRISM/search/ProjectSearch.aspx).

- Removal of ~3000 feet of levee/revetment and approximately 180,000 cubic yards of fill in the floodplain, planting 28 acres, and constructing ~ 4875 feet of pilot channel.
- Reduction of confinement and connecting the Cavanaugh Pond and Ricardi Natural Areas and supporting 52 acres of floodplain restoration on the left bank of the Cedar River between River Mile 6.5 and 7.5.
- Reconnect a 1,080 foot relic side channel and floodplain to the Sammamish River providing accessible off-channel rearing habitat for Chinook and Coho salmon.
- Six acres of riparian and wetland floodplain would be enhanced through control of reed canary grass and blackberry and 2.6 acres of riparian and wetland planting to enhance native habitat.
- Installing thirty five log structures, five pools, and two box culverts to facilitate flows into and out of the side channel.
- Enhancing six acres of riparian and wetland floodplain through control of reed canary grass and blackberry and 2.6 acres of riparian and wetland planting to enhance native habitat.
- Adding large wood to 800 feet of channel in the headwaters of Willow Creek,
- continued monitoring and removal of knotweed infestations to 20% of the original area of infestation in Cedar River.
- Conversion of 0.3 acres of lawn to riparian habitat with 100 new native trees and 500 native shrubs, widening of the existing channel cross-section to reduce bank erosion, improve flood capacity, and create space for a seasonal inundated plant community, and installation of large wood to create fish habitat, reduce erosion, and protect existing infrastructure in Bear Creek, Redmond.
- Bed-control structures that were composed of large woody debris (LWD) and boulders were placed within Maplewood Creek to improve fish passage.

[1] Search terms for PRISM search were: Selection Criteria: Project Type: Enhancement, Monitoring, Research, Restoration; Geographic Area: WRIA: Cedar-Sammamish; Theme: Salmon Projects - Monitoring and Research Projects, Salmon Projects - Salmon Capacity Projects, Salmon Projects - Salmon Protection Projects, Salmon Projects - Salmon Restoration Projects, Wildlife/Habitat Projects - Wildlife/Habitat Projects;

2.4.2. Dams

The Landsburg Diversion Dam is a run-of-the-river dam that was built in early 1900, to serve as the intake point for the City of Seattle's municipal water supply system. The dam is located on the Cedar River at river mile 21.8, and has excluded anadromous fish from exploiting 17 stream miles of habitat between Landsburg and the natural migration barrier formed by Lower Cedar Falls. In 2000, the city of Seattle formed a 50-year Habitat Conservation Plan (HCP) for the Cedar River. The HCP describes habitat protection and restoration measures for Cedar River, and include descriptions of protective land management practices, instream flow management, and mitigation measures for barriers to fish migration (City of Seattle 2000). As part of the HCP, Seattle Public Utility (SPU) constructed a fish ladder and sorting facility that provided access for native fishes to upstream habitat. This reopened access to spawning and rearing habitat.

SPU typically operates the ladder and sorting facility in sorting mode from September through December to prevent sockeye from passing above Landsburg Dam and operates in a passive mode throughout the remainder of the year (ESA section 10(a)(1)(B) number1235). While in sorting mode, the sockeye salmon are separated from Chinook or coho. The Chinook and coho are crowded into the bypass channel and returned to the Cedar River above the dam. The sockeye are moved to a fish truck and either returned to the Cedar River downstream or moved to the Cedar River Hatchery for use as broodstock (Table 12).When the fish ladder is operated in passive mode, all fish are allowed to bypass the sorting facility and move unhindered into the river above the dam.

Table 12. Counts of Sockeye, Chinook, and Coho at Landsburg Dam. ***Source: MIT. personal communication*****.**

Year	Fish passed above Landsburg		Fish released downstream or taken to Cedar River Hatchery (only Sockeye)
	Chinook	Coho	
2003	79	47	1001
2004	51	99	876
2005	69	170	1238
2006	182	190	2414
2007	397	142	831
2008	146	366	59
2009	138	679	236
2010	169	*	3706
2011	211	*	915
2012	278	1085	1359
2013	262	*	1327
2014	199	*	634
Totals	2181	2778	14596

2.4.3. 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. 2008a; Martins et al. 2012; Wainwright and Weitkamp 2013). While all habitats used by Pacific salmon will be affected, the impacts and certainty of the change vary by habitat type. Some impacts (e.g., increasing temperature) affect salmon at all life stages in all habitats, while others are habitat-specific (e.g., stream flow variation in freshwater). The complex life cycles of anadromous fishes including salmon rely on productive freshwater, estuarine, and marine habitats for growth and survival, making them particularly vulnerable to environmental variation (Morrison et al. 2016). Ultimately, the specific nature, level, and rate of change and the synergy between interconnected terrestrial/freshwater, estuarine, nearshore, and ocean environments will determine the effect of climate change on salmon and steelhead across the Pacific Northwest. The primary effects of climate change on Pacific Northwest salmon and steelhead are:

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

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

These changes will not be spatially homogeneous across the entire Pacific Northwest. Low-lying areas are likely to be more affected. Climate change may have long-term effects that include, but are not limited to, depletion of cold water habitat, variation in quality and quantity of tributary rearing habitat, alterations to migration patterns, accelerated embryo development, premature. 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).

2.4.4. Fisheries

2.4.4. Fisheries

2.4.4.1. Impacts on Chinook Salmon

In the past, fisheries in Puget Sound were generally not managed in a manner appropriate for the conservation of naturally spawning Chinook salmon populations. Fisheries exploitation rates were in most cases too high—especially in light of the declining pre-harvest productivity of natural Chinook salmon stocks. Over the past several decades, the co-managers implemented strategies to manage fisheries to reduce harvest impacts and to implement harvest objectives that are more consistent with the underlying productivity of the natural populations.

Forty-eight percent of the harvest of Lake Washington Chinook salmon management units occurs in salmon fisheries outside the Action Area, primarily in Canadian waters. The effects of these Northern fisheries on Puget Sound Chinook were assessed in previous biological opinions. Chinook salmon stocks are artificially propagated through 41 programs in Puget Sound (completed section 7 consultations are summarized in Table 16). Currently, the majority of Chinook salmon hatchery programs produced 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 (no date), and North Fork Nooksack Rivers, and for summer Chinook salmon on the North Fork Stillaguamish (NMFS 2019a) and Elwha Rivers. Supplementation or re-introduction programs are in operation for early Chinook in the South Fork Nooksack River, fall Chinook in the South Fork Stillaguamish River (NMFS 2019a), and spring and late-fall Chinook in the Skokomish River Table 15.

In Central/South Sound, except for the Sammamish population, average natural-origin escapements since 1999 are well above their critical thresholds. Growth rates for recruits and escapement are positive for the Cedar and Sammamish Rivers (Table 13). As with most populations in other Puget Sound regions, the growth rates for escapement are higher than growth rates for recruitment. The fact that growth rates for escapement (i.e., fish through the fishery) are greater than growth rates for return (i.e., abundance before fishing) indicates some stabilizing influence on escapement from past reductions in fishing-related mortality. However, the Sammamish fall Chinook population is classified as Tier 3 in terms of its role of recovery for the ESU.

Natural-origin spawning escapements in 2019 are not expected to be above the critical threshold for the Sammamish River but are expected to be above the rebuilding threshold for Cedar River (Table 13). The additional contribution of hatchery spawners to natural escapement for most of these populations should mitigate demographic risk.

Exploitation rates for most of the Puget Sound Chinook management units have been reduced substantially since the late 1990s compared to years prior to listing (average reduction = -33%, range = -67 to +30%)(NMFS 2020a).

Table 13. Long-term trends in abundance and productivity for Puget Sound Chinook populations. FRAM adult equivalent exploitation rates in 2019 ocean and Puget Sound Fisheries and escapements expected after these fisheries occur for Puget Sound management units. ***Source Harvest management plan and the other sources embedded within that document***

Population	Natural Escapement Trend (1990 – 2017)[1]		Natural Origin Growth Rate (1990-2015)[2]		2019		
	NMFS		Recruitment (Recruits)	Escapement (Spawners)	NOR	Critical	Rebuilding
Cedar River	1.05	Increasing	1.01	1.04	844	200	282
Sammamish River[3] (late)	1.01	Stable	1.02	1.04	95	200	1,250
Duwamish-Green R. (late)	0.97	Stable	0.94	0.97	2,161	400	1,700
White River[4] (early)	1.10	Increasing	1.02	1.05	434	200	488
Puyallup River (late)	0.98	Declining	0.92	0.94	1,115	200	797
Nisqually River (late)	1.05	Increasing	0.93	1.00	550	200	1,200

[1] Escapement Trend is calculated based on all spawners (i.e., including both natural origin spawners and hatchery-origin fish spawning naturally) to assess the total number of spawners passed through the fishery to the spawning ground. Directions of trends defined by statistical tests.

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

[3] 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.

2.4.4.2. Impacts on Steelhead

Harvest rates on natural-origin steelhead vary widely among watersheds, but have declined since the 1970s and 1980s and are now stable and generally less than 5% (NMFS 2020a) discussed further in Environmental Baseline section 2.4.1). The 2015 NWFSC status review update concluded that current harvest rates on natural origin steelhead are unlikely to substantially reduce spawner abundance for most steelhead populations in Puget Sound (NWFSC 2015).

Available data on escapement of summer, winter, and summer/winter steelhead populations in Puget Sound are limited. NMFS used the available data for eight Puget Sound winter and summer/winter steelhead populations (Skagit, Snohomish, Green, Puyallup, and Nisqually) to calculate terminal harvest rates on natural-origin steelhead (NMFS 2020a). From the late 1970s to early 1990s, harvest rates on natural-origin steelhead averaged between 10% and 40%, with some populations in central and south Puget Sound (NWFSC 2015; WDFW and PSTIT 2016; 2017; 2018; 2019; 2020; 2021). Harvest rates on natural-origin steelhead vary widely among watersheds, but have declined since the 1970s and 1980s, and are now stable at generally less than 5% (Figure 5). North Lake Washington and Sammamish tributaries have not been monitored since 2000, and, due to small numbers of steelhead seen at the Chittenden Locks and estimated in the Cedar River, it is unlikely that there are currently many steelhead in these tributaries (SCORE database).

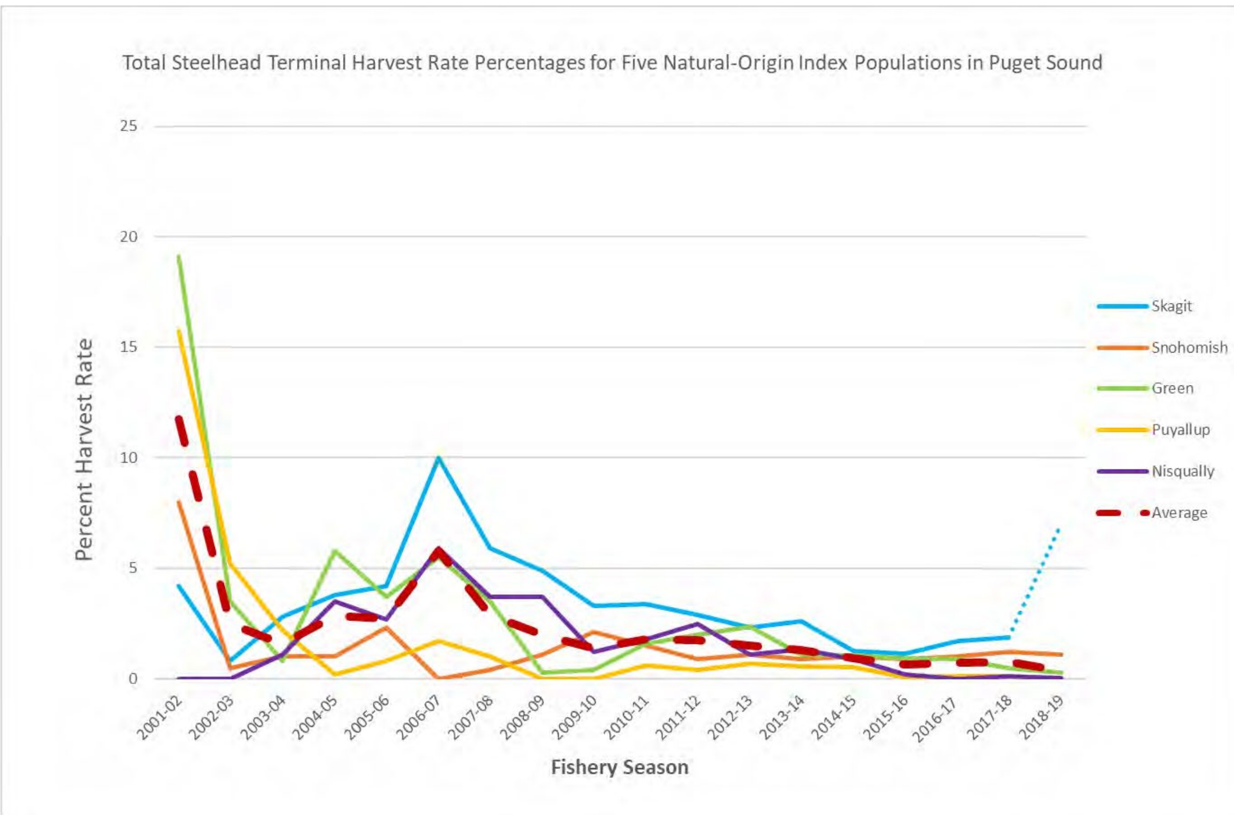

Figure 5: Total Steelhead terminal harvest rate percentage for five natural-origin index populations in Puget Sound

In the 5-year status review update for Pacific Northwest Salmon and Steelhead listed under the ESA (NWFSC 2015). Since 2015, fifteen of the 21 populations indicate small to substantive increases in abundance. However, most steelhead populations remain small. From 2014 to 2019, nine of the 21 steelhead populations had fewer than 250 natural spawners annually, and 12 of the 21 steelhead populations had 500 or fewer natural spawners ((NMFS 2020b)(NMFS

2020b)(NMFS 2020b)(NMFS 2020b)(NMFS 2020a)(NMFS 2020b)(NMFS 2020b)(NMFS 2020a)(NMFS 2020a)(NMFS 2020a)(NMFS 2020a)(NMFS 2020b)(NMFS 2020a)(NMFS 2020b)(NMFS 2020a)(NMFS 2020b)(NMFS 2020b)(NMFS 2020b)(NMFS 2020b)(NMFS 2020b)(NMFS 2020b)(NMFS 2020b)(NMFS 2020b)(NMFS 2020b)(NMFS 2020a)(NMFS 2020b)(NMFS 2020a)(NMFS 2020a)(NMFS 2020b)(NMFS 2020b)(NMFS 2020a)(NMFS 2020a)(NMFS 2020a)(NMFS 2020a)(NMFS 2020a)(NMFS 2020a)(NMFS 2020a)(NMFS 2020a)(NMFS 2020a)(NMFS 2020a)(NMFS 2020a)(NMFS 2020a)NMFS 2021). The steelhead population in Lake Washington basin has been decreasing over the past decade and the 5-year geometric mean is <10 (Table 14).

Table 14: 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 2015).

Major population group	Demographically Independent Population	Recent Abundance (2015 – 2019)	Recovery Target	
			High Productivity	Low Productivity
Central and South Sound	Cedar River	<10[1]	1,200	4,000
	North Lake Washington Tributaries	NA	4,800	16,000

Data Source: Table recreated from (NMFS 2020a)Table 8, which used data from NWFSC 2015.

[1] Abundance is only a partial population estimate

Table 15: Total escapement of Lake Washington winter steelhead natural spawners, 2010 – 2019 co-manager data (WDFW and Muckleshoot Indian Tribe 2020a).

Year	Escapement[1]
2010	2
2011	4
2012	0
2013	8
2014	0
2015	6
2016	10
2017	0
2018	4
2019	0

[1] Data are escapement estimates based on redd surveys conducted in the Cedar River mainstem index area, located between RM 0.0 and the Landsburg Road SE crossing at RM 21. These estimates do not include fish that migrate above Landsburg Dam to spawn. Steelhead have had access to spawning areas upstream from Landsburg since 1993.

2.4.5. 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, fixing the factors limiting viability is essential for long-term viability.

Hatchery production 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 (NMFS 2015). 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).

The current abundance of Lake Washington natural-origin Chinook salmon is substantially reduced from historical levels—escapements from 1999 through 2019 are depicted below in Figure 6 and the number of adult Chinook salmon passed upstream of the Issaquah Creek Hatchery weir are depicted in Figure 7. Prior to 2007, the number of Chinook salmon passed upstream of the weir averaged 3,220 (RY 1996-2006), whereas from 2007 through 2018 the number of Chinook salmon passed upstream averaged 781. Natural-origin Chinook return to three discrete areas: Bear Creek and tributaries, Issaquah Creek and East Fork Issaquah Creek, and Issaquah Creek Hatchery. Based on 5 years of data (RY 2014-2018), the total number of natural-origin Chinook averaged 130 adults with the fish being distributed as follows: Bear Creek (36.9%), Issaquah Creek below Hatchery with (26.2%), and Issaquah Creek Hatchery Trap (36.9%). These averages and distributions are used in section 2.5.2.2.1 to develop future projections of pHOS and PNI for the Sammamish Basin Chinook salmon population.

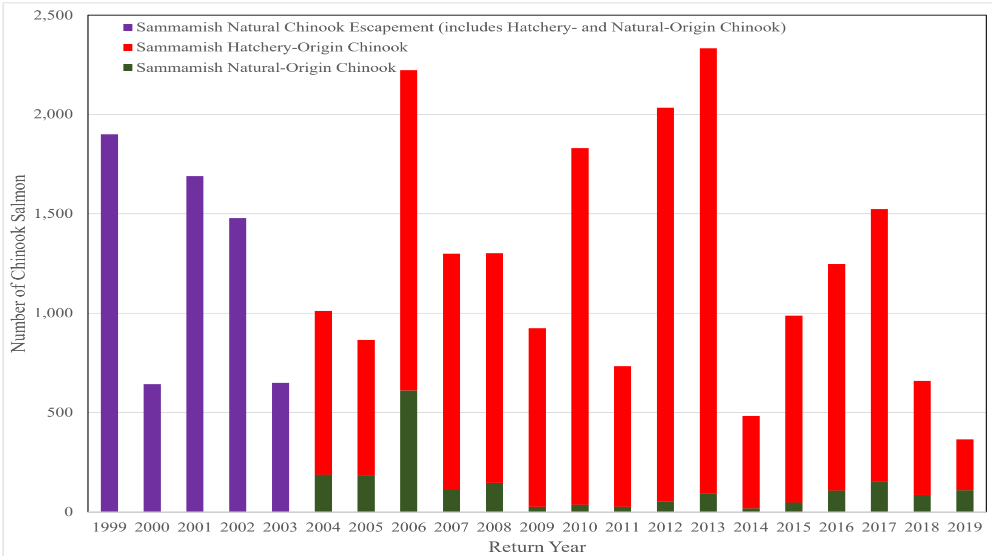

Figure 6: Estimated annual natural Chinook salmon escapement abundances in the Sammamish Basin for 1999 through 2019. Natural- and hatchery-origin breakouts are included for years where data are available. Escapement estimates do not include escapement of hatchery- or natural-origin Chinook salmon to the Issaquah Creek Hatchery or Chinook salmon passed upstream of the Issaquah Creek Hatchery weir. Source: WDFW Score database; WDFW and Muckleshoot Indian Tribe, unpublished escapement data 2020.

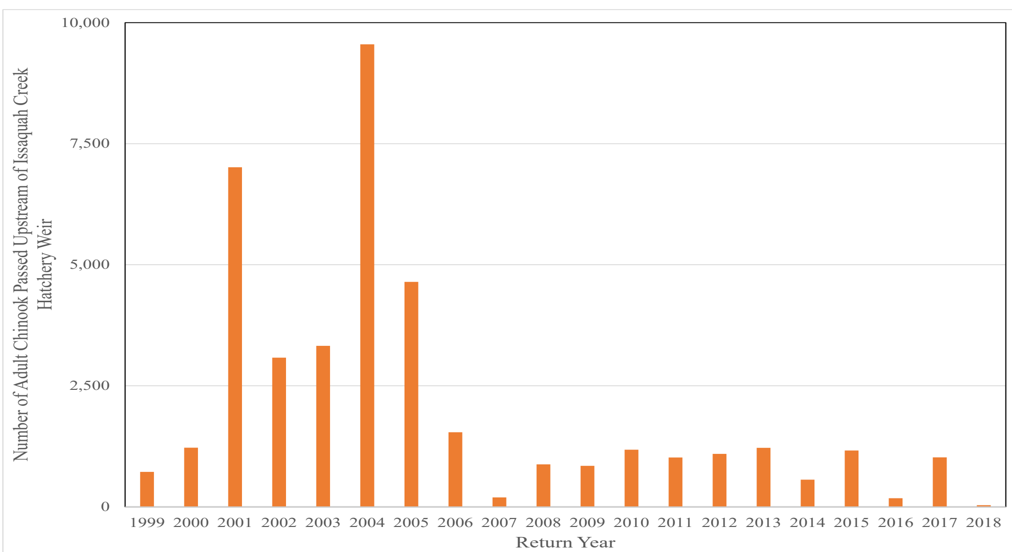

Figure 7: Number of adult Chinook salmon passed/escaped upstream of the Issaquah Creek Hatchery weir. Source: WDFW and Muckleshoot Indian Tribe unpublished data 2020.

Chinook salmon stocks are artificially propagated through 41 programs in Puget Sound (completed section 7 consultations are summarized in (Table 16). Currently, the majority 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. Supplementation or re-introduction programs are in operation for early Chinook in the South Fork Nooksack River, fall Chinook in the South Fork Stillaguamish River (NMFS 2019b), and spring and late-fall Chinook in the Skokomish River.

Table 16. 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 2015b; 2015a)
Elwha	Lower Elwha Hatchery Native Steelhead	December 15, 2014	(NMFS 2014)
	Lower Elwha Hatchery Elwha Coho		
	Elwha Channel Hatchery Chinook		
	Lower Elwha Hatchery Elwha Chum		
	Lower Elwha Hatchery Pink		
Dungeness	Dungeness River Hatchery Spring Chinook	May 31, 2016	(NMFS 2016e)
	Dungeness River Hatchery Coho		
	Dungeness River Hatchery Fall Pink		
Early Winter steelhead #1	Kendall Creek Winter Steelhead	April 15, 2016	(NMFS 2016b)
	Dungeness River Early Winter Steelhead		
	Whitehorse Ponds Winter Steelhead		
Early Winter Steelhead #2	Snohomish/Skykomish Winter Steelhead	April 15, 2016	(NMFS 2016c)
	Snohomish/Tokul Creek Winter Steelhead		
Stillaguamish	Stillaguamish Fall Chinook Natural Stock Restoration	June 20, 2019	(NMFS 2019b)
	Stillaguamish Summer Chinook Natural Stock Restoration		
	Stillaguamish Late Coho		
	Stillaguamish Fall Chum		
Snohomish	Tulalip Hatchery Chinook Sub-yearling	September 27, 2017	(NMFS 2017b)
	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 2016a)
	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 2019c)
	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		

There are currently 13 hatchery programs in Puget Sound that propagate steelhead (completed section 7 consultations are summarized in Table 16). Currently, there are five steelhead supplementation programs operating for natural-origin winter run steelhead conservation purposes in Nookscak (NMFS 2016b), Dungeness (NMFS 2016b), Stilaguamish (NMFS 2016b), and two populations in the Snohomish (NMFS 2016c). Fish produced through the five conservation programs are designated as part of the listed Puget Sound Steelhead DPS, and are protected with their associated natural-origin counterparts from take (79 FR 20802, April 14, 2014). Three other harvest augmentation programs propagate non-listed early summer-run steelhead (ESS) derived from Columbia River, Skamania stock, Hood Canal. The EWS and ESS stocks reared and released as smolts through the eight programs are considered more than moderately diverged from any natural-origin steelhead stocks in the region and were therefore excluded from the Puget Sound Steelhead DPS.

Currently, hatcheries in the Lake Washington watershed are operated mainly to produce fish for harvest, as mitigation for reductions in natural salmon production and productivity resulting from degradation and loss of natural salmon habitat. Effects of the on-going operation for the hatchery programs are discussed in detail in Section 2.5.2.

Issaquah Fall Chinook Program

The first recorded plants of juvenile Chinook into the Lake Washington basin occurred in 1901, and intermittent plants continued for decades. The donor stock originated from native Green River fall Chinook salmon adults trapped in the mainstem river at the outlet of Soos Creek beginning in 1902 (Becker, 1967). Although some additional stocks (e.g., Columbia river-origin Chinook in the 1920s) were occasionally imported in the early days of the hatchery operation, contribution of these out-of-basin stocks was not significant (Marshall et al. 1995). In 1937 Green River Chinook transfers were used to found production at the Issaquah Hatchery (WDF 1939). The program has been self-sustaining since 1992, when transfers of Green River hatchery lineage fall Chinook from other regional hatcheries were prohibited under WDFW's Fish Transfer Policy (WDFW 2003l; WDFW 1992, NMFS/SHIEER 2004). Chinook were not consistently mass-marked at the facility until 2000. Prior to consistent mass-marking the level of natural-origin fish incorporated into the hatchery brood stock was unknown. The Chinook production at Issaquah Hatchery is currently managed as an integrated program, which requires annual inclusion of natural-origin fish into hatchery broodstock at a level of 10-20 % of program goals following recommendations of the Hatchery Scientific Review Group (HSRG).

The Willow Creek Hatchery was built in early 1985. The hatchery originally propagated Chinook, using fish from Soos Creek Hatchery on the Duwamish-Green River (WDF 1939), and was discontinued in 1992.

Issaquah Coho Hatchery Program

Since its inception in 1936, the Issaquah Hatchery coho program has relied on two sources: locally-collected adults, and fish transplants from Soos Creek Hatchery (Green River). The program has been self-sustaining since 1992 (with the exception of 2010, when 540,020 were transferred from the Wallace River Hatchery integrated coho program to make up for a shortfall) (See section 9.1.1). The coho net pen project was initiated in 1978. Coho were originally supplied from Marblemount Hatchery (Skagit River stock); as of 2003, coho releases are from Issaquah Hatchery. Issaquah Creek coho stock was selected to reduce the potential impacts of adult strays into local watersheds. Production of coho at the Willow Creek Hatchery facility was initiated in 1992 using fish from Issaquah Hatchery.

UW Chinook Hatchery

Historically, broodstock were derived from fish returning to Soos Creek Hatchery on the Green River from 1949 until adequate numbers of return were accomplished in 1955. Thereafter, the stock was self-sustaining with the exception of years in which Chinook returns were low. In a low return year (1961), eggs from Soos Creek Hatchery and Issaquah Hatchery were transferred to the UW ARF Hatchery (Fish Transfer Records, University of Washington). The fish were initially selected for early return (return in three years as opposed to four), early migration, and high fecundity, but the conscious selection program was discontinued in the mid-60s. Past selection protocols and potentially rearing conditions at the UW ARF Hatchery had led to observations of phenotypic differences between hatchery stocks and natural stocks in the target area.

UW Coho Hatchery

Starting in the 1950's, the UW ARF hatchery produced coho and Chinook runs for research purposes. Sources of coho broodstock were a mixture of coho stocks with a priority given to returning UW ARF hatchery stock. Issaquah Hatchery stock strays that entered the trap were also used as broodstock.

Cedar River Sockeye Program

As mitigation for the removal of water and restriction of access of sockeye in the Cedar River above Landsburg Dam, and in agreement with Landsburg Mitigation Agreement, a hatchery program for sockeye fry supplementation began in 1991. The sockeye population within Lake Washington and Cedar River were introduced from various sources beginning in 1917. Subsequent introductions occurred in 1935 from Baker Lake, and in 1944, 1950, and 1954 from Cultus Lake. The Issaquah Hatchery started as a sockeye hatchery in 1937 and continued through at least 1962. A self-sustaining population of natural spawning sockeye in Cedar River has existed without further introductions since 1955 (woodly 1966, Royal and Seymour 1940)

A supplementation program in the Cedar River began in 1991, in response to declining sockeye within Cedar River and to mitigate for habitat loss associated with the Landsburg Dam and to augment natural spawning on the Cedar River (HCP and LMA references). An interim hatchery was built with the capacity to produce 18.7 million eggs, but the release of unfed fry did not exceed 15,500,000. Broodstock for the hatchery originated from the local spawning population. For the first two years of the program, adult broodstock were captured by gillnet in the lower river at various locations. From 1993 to 2007, WDFW collected broodstock at a temporary trap and weir (RM 6.5). In fall 2008, Seattle Public Utility (SPU) completed a new access road and other amenities to allow for the installation of a floating resistance-board weir and trap (RM 1.7). The permanent hatchery was completed in 2011 and has the capacity to incubate, rear, and release up to 34 million fry.

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

This section describes the effects of the Proposed Action, independent of the Environmental Baseline and Cumulative Effects. The methodology and best scientific information NMFS follows for analyzing hatchery effects is summarized in Appendix A and application of the methodology and analysis of the Proposed Action is in Section 2.5.2. 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).

NMFS' status review update on Puget Sound salmon and steelhead reports that the abundance of Steelhead in Sammamish and Cedar rivers (undetectable and low respectively) and been decreasing since 2006 (LWGI_SalmonSyn123108.pdf). Similarly, interactions reported by co-managers at Cedar River Weir, Issaquah Hatchery Weir, and Ballard Locks (Table 21), and reporting of total escapement of Cedar River winter steelhead natural spawners by co-managers (Table 15) also indicate that the population within the watershed is low. Given these reported occurrences, encounters would be unexpected for many factors and thus there would be no adverse effects for those factors. Therefore we only discuss steelhead effects for factors where effects could be reasonably expected to occur. Additionally, the Willow Creek hatchery coho are released into "WRIA 8 tributaries," these streams are tributaries to Puget Sound, and are not known to contain listed fish. Thus, they were excluded from our analysis of predation and competition in freshwater.

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 2004; 2005c; Jones 2006; NOAA 2008; NMFS 2011b). For Pacific salmon, NMFS evaluates extinction processes and effects of the Proposed Action beginning at the population scale (McElhany et al. 2000). NMFS defines population performance measures in terms of natural-origin fish and four key parameters or attributes; abundance, productivity, spatial structure, and diversity and then relates effects of the Proposed Action at the population scale to the MPG level and ultimately to the survival and recovery of an entire ESU or DPS.

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

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

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

1. The hatchery program does or does not remove fish from the natural population and use them for hatchery broodstock
2. Hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds and encounters with natural-origin and hatchery fish at adult collection facilities

3. Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas, migratory corridor, estuary and ocean
4. 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 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. Analysis of the Effects of the Proposed Action

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

Chinook Salmon Broodstock

NMFS considers the physical process of collecting hatchery broodstock, and the effect of the process on ESA-listed species, under Factor 2. In the proposed action, the Issaquah Hatchery Chinook program would operate as a segregated program without removing fish from the natural population, and as describe in section 1.3.1, would incorporate fish from the natural population when operating as a genetically-linked program (Table 3). Typically, removing fish from the local natural population is viewed as a negative effect for salmon because removing mature natural-origin adults from the spawning grounds can reduce the effective genetic size and N_e of the population, through a reduction in the number of available natural spawners. The Fall Chinook Salmon hatchery program at Issaquah Hatchery will not remove fish from the local natural populations for broodstock while operating as a segregated program. In some cases, hatchery programs also reduce in-river mortality experienced by juveniles the programs rear and release as smolts. The result is a higher survival to the smolt stage for the overall populations, than would have otherwise been measured through natural spawning alone. This would allow some spawning by hatchery-origin returns, the additional contribution of hatchery spawners to natural escapement for this population should mitigate demographic risk. Thus, some genetic material from those natural-origin Chinook salmon spawned in the hatchery is likely to remain in the natural environment. When the program transitions into a genetically-linked program NOR fish would be included in broodstock and spawned in the hatchery, thereby leading to higher egg-to-smolt survival rates than would be experienced in the wild. The net effect is anticipated to be an increase in abundance. Thus, the effects of this factor are considered beneficial to the Sammamish population. The potential adverse effects of naturally spawning hatchery fish are discussed in the following subsection.

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

The proposed hatchery programs pose both genetic and ecological risks. There is some benefit to the species from the integrated and genetically linked programs designed to supplement the ESA-listed Sammamish Chinook salmon population. This supplementation is designed to increase population abundance and productivity by increasing the number of adult returns. Thus, NMFS believes that the net effect of the is factor on listed species is beneficial with respect to the Chinook programs, while the coho programs are likely to have a small negative effect on listed species through ecological effects. The potential of adverse genetic effects on listed Chinook salmon and steelhead populations are discussed in the following subsection.

The coho and sockeye salmon programs do not have any genetic effects on listed Chinook salmon and steelhead populations because these species do not interbreed. However, there is the potential for adverse ecological risks of redd superimposition, spawning site competition, and predation between species. Thus, NMFS believes that the net effect of the Sockeye and Chinook programs on listed species is beneficial, while the coho programs are likely to have a small negative effect on listed species through ecological effects.

2.5.2.2.1. Genetic Effects

For each ESA-listed program, NMFS considers three major areas of genetic effects: within-population diversity, outbreeding effects, and hatchery-influenced selection. However, the coho and Sockeye programs do not incorporate listed fish into broodstock, therefore we will only address genetic effects related to the Fall Chinook population on listed Chinook populations.

NMFS has not adopted Hatchery Scientific Review Group (HSRG) gene flow (i.e., pHOS, pNOB, PNI) recommendations per se. However, at present the HSRG recommendations and the 5% (or 0.05) stray recommendation (from segregated programs) from (Grant 1997) are the only acknowledged quantitative recommendations available, so NMFS considers them a useful screening tool. For a particular program, NMFS may, based on specifics of the program, and environment, consider a pHOS or PNI level to be a lower risk than the HSRG would but, generally, if a program meets HSRG standards, NMFS will typically consider the risk levels to be acceptable.[1]

For integrated programs, genetic effects on the targeted natural-origin population as well as populations, other than the target population, in which program fish return are considered To perform our analysis for the target population, we used a model developed by (Ford 2002) and expanded by (Busack 2015) that considered the best available information for the target population to determine the current and anticipated future PNI of the population based on the applicants' proposed proportion of natural-origin broodstock (pNOB) and the pHOS, as well as pHOS composition, in natural spawning areas. A PNI of > 0.5 indicates that natural selective forces are equivalent or greater than hatchery-influenced selective forces, and for a tier 3 population under NMFS' Population Recovery Approach (NMFS 2010) the long-term goal has not been stated.

For segregated programs, genetic effects are assessed by considering how many fish from each program spawn naturally. Because supplementation of the natural population is not typically an objective for this type of program, the number/proportion of hatchery-origin spawners spawning naturally should ideally be zero, since the hatchery population will often be highly adapted to the hatchery environment. However, this is not a realistic goal, as a practical matter, and if the population is to reach necessary abundance levels. As explained in the appendix, the Hatchery Scientific Review Group (HSRG) has developed guidelines for allowable pHOS levels in natural-origin populations, scaled by the population's conservation importance, recommending a maximum of 5% in "primary" populations, 10% for "contributing" populations, and at a level required to maintain "sustaining" populations (e.g., HSRG 2014). 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.

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[1] The only exception to date is the case of steelhead programs using highly domesticated broodstocks, where NMFS has imposed more stringent guidelines ((e.g.,NMFS 2016c)).

2.5.2.2.1.1. Within-population Diversity and Hatchery-influenced Selection

Fall Chinook salmon program

In terms of conservation of within-population genetic diversity, the Proposed Action is likely a benefit to the Sammamish River Fall Chinook salmon population. The natural-origin population size is considerably less than decades ago and currently the population is below the critical threshold. However, the population has remained in the hundreds annually, likely because of the continued contributions to population abundance from the hatchery program. It is recognized that Hatchery-origin fish can positively affect the status of an ESU by contributing to the abundance of natural populations in the ESU (70 FR 37204, June 28, 2005, at 37215).

A long-standing guideline for conservation of genetic diversity is that although short-term dips to smaller sizes can be sustained without serious loss of genetic diversity, the effective population size should be 500 or more over the long term (Section 5). Assuming a generation time of four years, which is reasonable for Issaquah Fall Chinook salmon, an average of 125 effective spawners/year would be required.

2.5.2.2.1.2. Gene Flow Assessment for the Lake Washington fall Chinook Salmon Population

There are two fall Chinook salmon populations within the Lake Washington Basin: Cedar River and Sammamish River (Ruckelshaus et al. 2006). The potential negative genetic effects from the Issaquah Creek and UW ARF Fall Chinook Salmon programs are considered along with the demographic benefit of increasing abundance. To perform our analysis, we used a model that considered the best available information for the target population to determine the current and anticipated future PNI of the population based on the applicants' proposed proportion of natural origin broodstock (pNOB) and the pHOS in natural spawning areas. A PNI of > 0.5 indicates that natural selective forces are equivalent or greater than hatchery-influenced selective forces.

The targets for a tier 3 population, including the populations in this opinion are not a priority for recovery compared to Tier 1 and 2 population for which we have established PNI targets.

Cedar River pHOS is expected to range between 35% and 46% under average natural-origin abundance and release Scenarios 1 and 2 (Table 17; Haggerty 2021). Sammamish Basin PNI is expected to range from just over 5% to just over 40% under release Scenario 2 when adult natural-origin abundance ranges from 100 to 900. Sammamish Basin PNI is expected to range from 7% to just over 62% under release Scenario 3 when adult natural-origin abundance ranges from 100 to 900.

The number of unmarked fish passed upstream of the Issaquah Creek Hatchery weir is expected to range from 91 (3 million release from Issaquah Creek Hatchery and 100 natural-origin adult Chinook to Sammamish Basin) to 293 (5.5 million release from Issaquah Creek Hatchery and 499 natural-origin adults to Sammamish Basin (Figure 7).

In the future we anticipate pHOS to increase by up to 15 percentage points in the Cedar River. The best available data also suggest that PNI in the Sammamish River is < 0.06. We anticipate that, in the future, PNI would increase up to 0.4 (Table 17). Over the course of the consultation, the co-managers have agreed to some key changes in the fall Chinook program operation that are anticipated to result in a substantially higher PNI value in the Sammamish River, compared to the current value.
These program modifications are:

- Genetically linked integrated and segregated program components, which requires use of integrated program component returns for segregated component broodstock (for details see Section 1.3.1)
- Creation of a natural production emphasis area in Issaquah Creek, where unclipped fall-run Chinook fish are passed above the weir
- 100% marking of integrated component fish with a CWT to enable easy identification as hatchery fish from that program component. When the program is operating as a segregated program (as described in section 1.3), 100% of unmarked adults will be passed upstream. When the program is operating as a genetically-linked program, a minimum of 50% of NOR will be passed upstream.
- Further improved quality control measures to decrease the miss-clip rate to ≤ 1%

However, the reality of the degraded habitat in the Sammamish River, the difficulties of fish passage at Ballard Locks, and the intention to produce more fish to expand the prey base for resident ESA-listed killer whales make achieving this goal extremely difficult, although, through some major modifications to the current fall Chinook salmon program, the population could achieve a much improved PNI (Table 17) when the program transitions to a genetically-linked program. NMFS expects that there will be a period of relatively low PNI in the Sammamish River, similar to past values (< 0.06), before the benefits of these program modifications can begin to be realized. The population is still likely to achieve vast improvements in PNI under the Proposed Action; an increase in PNI from 0.1 currently to ~ 0.4 over the long-term and in the near term, the existence of the hatchery program ensures that fish will still exist in the Sammamish River if natural-origin returns continue to decrease.

Segregated production was evaluated using a range of hatchery releases and hatchery release locations to evaluate the variation of expected effects on the Sammamish River and Cedar River natural-origin fall Chinook salmon populations (Table 17). We assessed several scenarios to capture a range of potential releases from release sites listed in Table 4 full details are available in Haggerty 2021. Scenario 1 included up to 5 million subyearling released at Issaquah Hatchery and 1 million released at UW ARF. Scenario 2 included up to 3 million subyearlings released at both Issaquah Hatchery and UW ARF. The projected pHOS in the Cedar River would increase from current levels by 10 percentage points.

We relied on a number of assumptions to populate the parameters of the model. We used a mixed log-linear straying model (Figure 8 developed by Schaffler (2020) to route Chinook salmon based on past terminal run-sizes (TRS) and adult escapement within three spawning areas: Cedar River, Bear Creek, and Issaquah Creek (below Issaquah Hatchery). The relationship between TRS and straying to the different spawning aggregations is depicted in Figure 8, (Schaffler 2020). We assumed pre-spawn mortality of 18% for natural-origin fish held for broodstock at the Issaquah Hatchery. We also assumed that SAE (smolt-to-adult escapement) values from Issaquah Hatchery would reflect a 5-year average (0.237%) or 10 year average (0.231%) and that SATR values would reflect a 5-year average (0.248) or a 10 year average (0.267). The model assumed SAE value of 0.5023 and SATR value of 0.565 for UW ARF. Further, co-managers agreed to decrease the mis-clip rate at the facility; therefore, we used a miss clip rate of 1% (current miss clip rate is ~2.9%). In addition, these calculations incorporated an additional 10% of juveniles produced on top of the program release goal (Haggerty 2021).

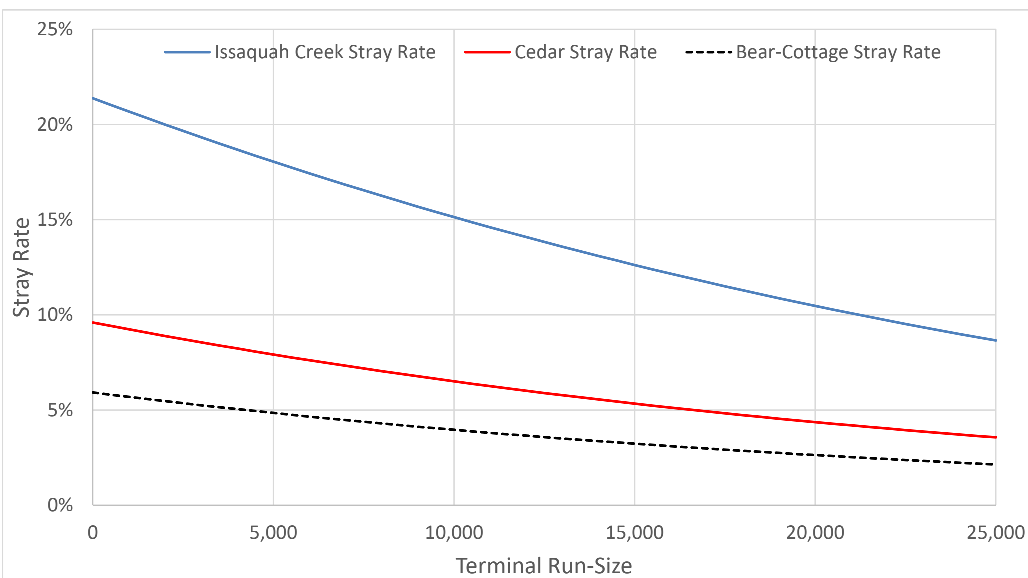

Figure 8: Lake Washington Chinook salmon terminal run-size projected hatchery stray rates to various spawning aggregations (Haggerty 2021).

The most recent 5- and 10-year pHOS in the Cedar River has averaged 30% and 27%, respectively (Table 17). Cedar River pHOS is expected to range between 40% and 46% under average natural-origin abundance and release Scenarios 1 and 2. Sammamish Basin PNI is expected to range from just over 5% to just over 40% under release Scenario 1 when adult natural-origin abundance ranges from 100 to 900. Sammamish Basin PNI is expected to range from 7% to just over 62% under release Scenario 2 when adult natural-origin abundance ranges from 100 to 900 (see Figure 11 and 12 in Haggerty 2021).

Table 17: Current and proposed Proportionate Natural Influence (PNI) for the natural fall Chinook salmon population in Sammamish and Cedar Rivers under various release scenarios. pHOS = proportion of hatchery-origin spawners.

Scenario	pHOS Cedar River (%)	pHOS Sammamish[1] River (%)	PNI[2] Sammamish River		pNOB
			Segregated	Genetically-linked	Genetically-linked
Current[3]	30	87	NA	< 0.06[3]	
1	40-42	45-88	.06 - .09	.22-.42	64-66
2	43-46	39-85	.06-.11	.38-.61	73-66

[1] The ESU population is called Sammamish River and consists of spawning in Bear Creek and Sammamish river watershed (including Issaquah Creek). The pHOS was calculated from Bear Creek spawners.
[2] Calculated as an aggregate, *expanded data is available in (Haggerty 2021)*
[3] Currently, Issaquah Creek fall Chinook program is operating as an integrated program.

2.5.2.2.1.3. Lake Washington Chinook salmon outbreeding genetic effects

The genetic diversity of the Lake Washington Chinook salmon populations could be adversely affected if the proposed hatchery programs incorporated as broodstock Chinook salmon originated from other Puget Sound populations. Inter-mixing the Sammamish or Cedar River stocks with other Puget Sound Chinook salmon populations could decrease genetic differences between, and uniqueness of, the currently distinct, independent population in the ESU. Based on these CWT recoveries and expanded adult Chinook salmon during RYs 2004-2010, Issaquah Hatchery Chinook salmon made up 99.8% of the returning adults to the hatchery and the remaining 0.2% were from hatchery programs that were not in the basin (Table 18). We would expect similar levels of contributions in the future with one exception (Haggerty 2021).

Table 18: Coded-wire tag (CWT) data and estimated adult returns from each production hatchery into each watershed *source: RMIS database*.

Fall Chinook Salmon Hatchery recipient watershed	Observed CWTs	Adjusted Estimated CWTs	M1 Adult Equivalents
Cedar River			
Tulalip Hatchery	1	2	32
Grovers Creek Hatchery	3	7	7
Issaquah Creek Hatchery	8	19	214
Portage Bay Hatchery (UW ARF)	3	7	17

Totals	15	35	270
Sammamish River:			
Gorst Creek Hatchery	1	7	68
Grovers Creek Hatchery	6	12	14
Issaquah Creek Hatchery	116	363	3,959
Portage Bay Hatchery (UW ARF)			3
Totals	123	382	4044
Issaquah Hatchery:			
Tulalip Hatchery	1	1	3
Forks Creek Hatchery	1	1	11
Grovers Creek Hatchery	1	2	2
Issaquah Hatchery	2,421	2,596	28,039
Minter Hatchery	1	1	1
Portage Bay Hatchery (UW-ARF)	4	5	13
Soos Creek Hatchery	1	1	1
Voights Creek Hatchery	2	2	17
Totals	2,432	2,609	28,087

The Fall Chinook salmon program could also pose risk to other Puget Sound Chinook salmon populations if fish from these programs comprise a substantial portion of the natural spawners in those populations or of the broodstock in other programs that influence those populations.

2.5.2.2.2. Ecological Effects

2.5.2.2.2.1. Adult nutrient contribution

The return of hatchery fish likely contributes nutrients to the action area. Decaying carcasses of spawned adult hatchery-origin fish would contribute nutrients that increase productivity in the Lake Washington watershed, providing food resources for naturally produced Chinook salmon. Diminished numbers of salmonids returning to spawn in most Puget Sound watersheds have resulted in nutrient deficiencies compared to historical conditions, affecting salmon and steelhead productivity potential. Adult salmon spawning escapements have substantially declined to a fraction of their historical abundance in many watersheds, raising concerns about a lack of marine-derived nutrients returning back to the systems in the form of salmon carcasses. Historically, salmonids themselves were an important source of nutrients to both riverine and riparian ecosystems (WRIA 2000).

Estimates of naturally spawning hatchery-origin salmon and steelhead are depicted in Table 19. It was estimated that these naturally spawning hatchery-origin salmon would contribute a total of 198.5 kg of phosphorous to the action area annually.

The transport by anadromous fish of nutrients from the marine environment to freshwater is important because temperate freshwater environments like that of the action area are typically low in available nutrients and relatively unproductive (Cederholm et al. 2000). Thus, hatchery-origin fish increase phosphorous concentrations, which likely compensates for some marine-derived nutrients lost from declining numbers of natural-origin fish.

Table 19. Total phosphorous imported by adult returns from the proposed hatchery programs based on the equation (Imports = hatchery adults*mass*phosphorous concentration) in (Scheuerell et al. 2005)

Program	Release Size	SAE (%)[1]	Estimated number of hatchery-origin adults[2]	Adult Weight (Kg)	Phosphorous Concentration	Phosphorous Imported Kg/Y
Fall Chinook	6,000,000	0.261	15,600	5.5	0.0038	18
Coho hatchery	740,000	0.016	14,445[3]	3.2	0.0038	176
Cedar River Sockeye	34,000,000	0.001	34,000	3.0	0.0038	388

[1] Smolt-to-Adult Escapement (SAE) from smolt trap in Cedar River, Sockeye are calculated as a fry-to-adult Escapement. Coho calculated as SAR/Escapement
[2] Calculated by multiplying the release number by the smolt to adult return (SAR) values.
[3] Release size was calculated as the total coho released (763,070) assuming a 3% stray rate, 3K spawners that are passed upstream when they reach the Issaquah weir and another 410,000 fish are released through educational purposes and return to the natural environment.

2.5.2.2.2.2. Spawning ground competition and redd superimposition

Chinook Salmon

Hatchery-origin adult salmon produced through the within-basin hatchery salmon programs that escape to spawn naturally have the potential to adversely affect listed Chinook salmon through competition for spawning sites and redd superimposition. Redd superimposition has been reported to occur in salmonids when spawning habitats become limited, whether by habitat limitations or high spawner abundance and has also has been inferred as a major cause of density-dependent embryo mortality through egg displacement (Fukushima et al. 1998).

The natural origin geometric mean for returns to Cedar river is 659 and Sammamish river is 161 (Table 10). The expected projected hatchery escapement as presented in section 2.5.2.3.1.1 under the modeled scenarios there would be 567 to 717 hatchery origin fish expected in Cedar River. There would be 1327-1753 hatchery origin fish expected in Sammamish/Issaquah Rivers (Haggerty 2021). The total recovery goal for each population is 2000 fish and current abundance plus the projected hatchery escapement is below this target. Thus, it is likely that, during most years, the watershed is under-seeded with naturally spawning Chinook salmon, making competition for spawning sites with and redd superimposition by hatchery Chinook salmon unlikely to occur.

Although Sockeye and Chinook salmon overlap in spawning habitat, the larger sized Chinook spawn in deeper water where water velocity is faster (Kondolf and Wolman 1993). Therefore, effects of competition for spawning sites and/or redd superimposition are expected to be low while the habitat is underseeded. The relationships between Chinook productivity (migrants/spawner) and sockeye spawning escapement for BY 1998 through 2016 as plotted in Figure 9 suggests that the increased numbers of sockeye salmon are not decreasing the number of juvenile Chinook migrants per adult spawner, which could be expected if redd superimposition were to occur. The second and third largest productivity of Chinook were in years when sockeye escapements exceeded 75,000. In the proposed action hatchery origin Sockeye escapement would range 12,000 to 68,000 adults at maximum production. The maximum escapement would fall within the range of values depicted in figure 9 suggesting that based on current and reasonable foreseeable conditions, the density-dependent effects of redd superimposition are unlikely to occur.

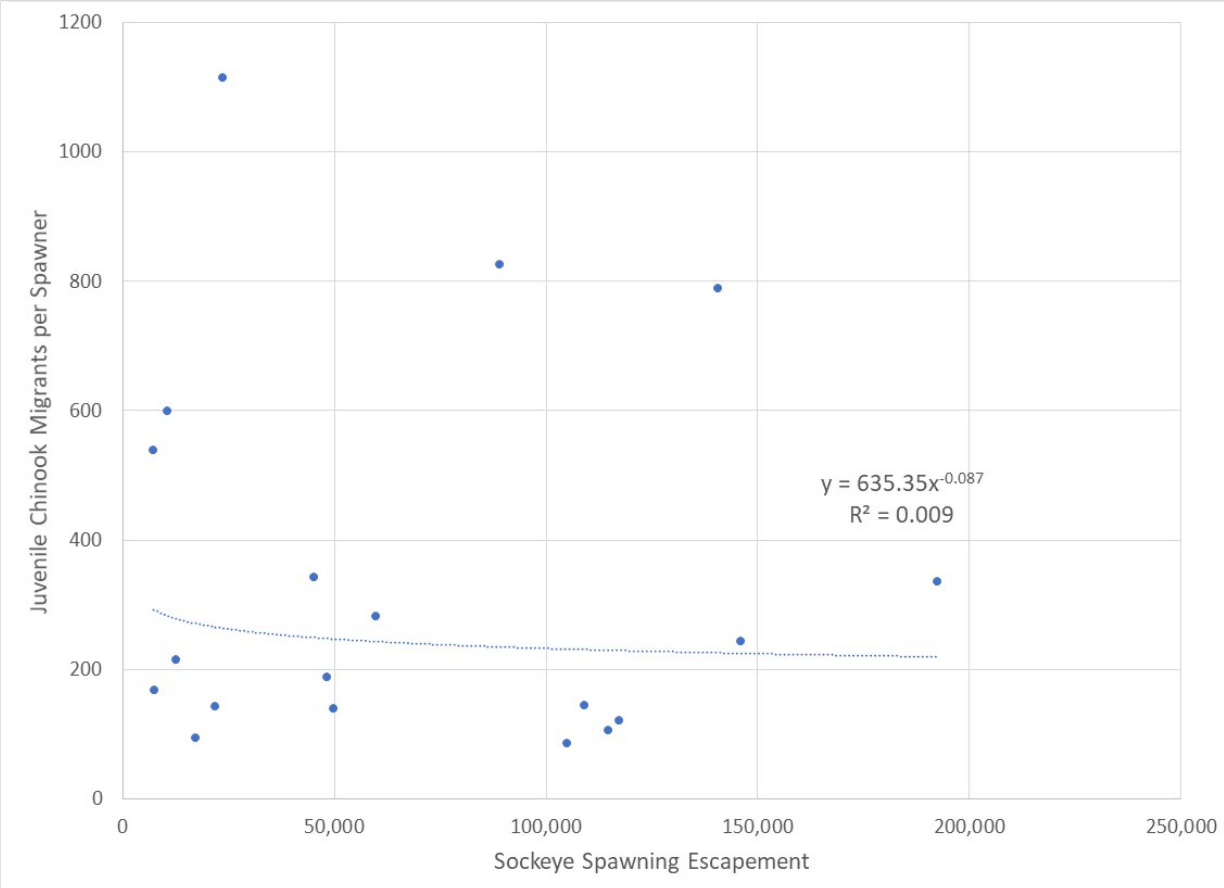

Figure 9: The relationship between Sockeye spawning escapement and juvenile Chinook migrants per spawner for brood years 1998 through 2016. ***Score database***

Coho Salmon

Coho and Chinook have always existed in the watershed together but spawn timing and spawning habitat preference between coho and Chinook salmon differ. Chinook enter the watershed in July – early September and coho return in late September – October (Table 20). Coho tend to spawn in areas of mid-velocity water with small to medium sized gravels and Chinook tend to spawn in the mainstem where water flow is high and larger gravel sizes are present. Natural origin Chinook spend a few days or months in natal streams before entering Lake Washington in the spring, whereas juvenile coho rear in their natal streams for up to 1 year before entering Lake Washington as parr. It is thought that coho generally move through the lake and into Shilshole Bay more quickly than Chinook salmon because of their large size upon entry into Lake Washington, thus reducing the potential for overlap in time and space which would lead to predation. Therefore, effects of competition for spawning sites and/or redd superimposition are expected to be low given the life histories and use of habitat at different life-stages by these species Table 20.

Steelhead

Adult salmon produced by the hatchery programs that escape to spawn naturally do not have the potential to adversely affect listed steelhead through competition for spawning sites and redd superimposition. Natural-origin returns of winter steelhead in Lake Washington watershed have been very low over the past decade and overall the population has been in decline since 2006 (Table 11 Table 12 Table 15). Furthermore, Chinook salmon spawn from mid-September through early-November (Table 20), before the earliest spawning steelhead historically have entered the river as returning adults. Sockeye salmon return to freshwater from mid-June through July and Coho return from late August through early October. Both spawn before Steelhead begin freshwater entry. Thus, there are unlikely to be any competition and redd superimposition effects of hatchery salmon on winter steelhead due to temporal separation. Sufficient surplus fish above the escapement goal of 350,000 sockeye, sport and tribal fishing seasons will be opened.

Table 20. Terminal area or river entry timing (light blue), spawn timing (black) for Lake Washington watershed Chinook, sockeye, and steelhead populations.

Species	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Chinook salmon												
Sockeye												
Winter Steelhead[1]												
Winter Steelhead												
Coho[2]												

[1] Recent declines footnote for steelhead
[2] Arrival based on counts from Ballard Locks by MIT and WDFD Source: https://wdfw.wa.gov/fishing/reports/counts/lake-washington#chinook

2.5.2.2.3. Disease

Adults returning back to hatchery facilities can have pathogens they become infected with upon their return to freshwater or that may have contracted during their juvenile rearing and outmigration. For programs in the Lake Washington watershed, the same pathogens detected in the juveniles were detected in the returning adults, *Flavobacterium psychrophilum, F. columnare, F. branchiophilum*, *Aeromonas salmonicida*, *Ichthyopthirius multifiliis*, *Ichthyobodo* spp., *Gyrodactylus* spp., *Trichodina* spp. were all detected for returning adults collected for broodstock. These pathogens are all native to the Lake Washington watershed and did not result in any disease outbreaks in adults over the past year. Adults are also routinely screened for viral pathogens, such as infectious hematopoietic necrosis virus (IHNV) and infectious pancreatic necrosis virus (IPNV), but none were detected over the last three years. Implementation of co-manager fish health protocols minimize the risk of fish disease pathogen transfer and amplification associated with salmon production through the programs. Based on the endemic state of the pathogens and the lack of outbreaks, risk of disease transmission and amplification from returning adults is low.

2.5.2.2.4. Adult Collection Facilities

The operation of weirs and traps for broodstock collection may result in the capture and handling of both natural- and hatchery-origin Chinook salmon (Table 21). A seasonal weir may also be installed on Bear Creek as backfill when sockeye broodstock collection targets are not met by collection at Cedar River weir and Landsburg Dam, which would involve the capture and handling of sockeye salmon to meet that target. Additional Cedar River locations may be used for sockeye broodstock collection. Generally speaking, weir technology has improved greatly over the previous couple of decades and the technology is now widely and effectively applied throughout the Pacific Northwest (NMFS 2010; NMFS 2011d). Bear Creek weir would be operated in a manner consistent with this current standard application, and would continue to be so operated. Further, the weir is not permanent and would be deployed seasonally to provide backfill when the Sockeye would not meet collection targets described in (Table 2).

Take resulting from collection at either weir would not result in adverse effects on the listed population because 1) the weirs are designed to allow juvenile passage, and natural-origin adults are passed upstream when not required for broodstock 2) weir operation guidelines and monitoring of weirs by the co-managers minimize the delays to and impacts on fish and 3) deployment/use of the weir is to supplement broodstock and therefore would not occur every year.

Table 21. Number of ESA-listed Chinook salmon handled by origin for all program facilities. Maximum incidental mortalities in any given year, if any, are shown in parentheses and exclude those collected and held for broodstock.

Facility	Origin	Chinook Salmon		Steelhead	
		Average; range handled (average incidental mortalities)	Proposed handle (incidental mortality)	Average; range handled (average incidental mortalities)	Proposed Handle (incidental mortality)
Issaquah Creek Hatchery Weir[1]	Natural	154; 49-304 (26)	100% (30%)[2]	0; (0)	10 (1)
	Hatchery	2828; 1794-4213 (498)	12800 (2450)	0; (0)	10 (1)
UW ARF[3]	Natural	1849; 1069-2769 (NA)	200 (5)	N/A	10 (1)
	Hatchery		4000 (80)	N/A	10 (1)
Cedar R. Weir[4]	Natural	25; 3-53 (6)	1570 (31)	0; (0)	10 (1)
	Hatchery	7; 0-31(0)	1000 (20)	0; (0)	10 (1)
Bear Creek Weir[5]	Natural	N/A	76 (2)	N/A	10 (0)
	Hatchery	N/A	531 (11)	N/A	10 (0)
Ballard Locks[6]	Natural	N/A	459 (9)	N/A	10 (1)
	Hatchery	N/A	1680 (34)	N/A	10 (1)

[1] Issaquah Chinook salmon data set from 2010-2018, includes adults and jacks. Proposed increase in hatchery handle and mortality results from increase in size of program.
[2] The Fall Chinook program would handle 100% of the NOR that return to Issaquah weir (the primary sampling location for the Chinook program). Those NORs that are not used in brood during operation of the segregated program or are above brood needs during the operation of the genetically-linked program would be passed upstream to access spawning habitat (section 1.3.1)
[3] No information available on origin (hatchery or natural) or mortality prior to program ending with releases in 2003. Projected handle and mortality based on maximum holding capacity of UW ARF holding pond.
[4] Cedar River Weir data for the average handle and mortality is for the years 2011-2018. Proposed handle is higher than the historical average due to the expectation that implementation of a more effective weir will result in increased handling of Chinook salmon. The projected handle is the maximum number of spawners from 2010-2018. Projected mortality assumes a 2% mortality rate.
[5] Potential new broodstock collection site for sockeye salmon. Projected Chinook handle is the maximum number of natural or hatchery-origin spawners from 2010-2018. Projected Chinook salmon mortality assumes a 2% mortality rate of fish handled.
[6] Potential new broodstock collection site for sockeye and Chinook salmon. Chinook handle based on assumed ability to collect 50% of Issaquah broodstock objective of 3,360 at the Ballard Locks. Projected Chinook salmon mortality is 2% mortality rate of fish handled.

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

Based on the science available to detect the effects of salmon hatchery releases in the ocean, and the releases from these programs relative to the total number of juvenile salmonids detected in the freshwater, estuary, and ocean, NMFS believes it is not possible to detect a measurable effect specific to this proposed action once these releases reach the ocean. Thus, this analysis will only consider effects of juvenile hatchery fish in juvenile freshwater rearing areas. Further, Coho released from the educational program at Willow Creek Hatchery are released into streams that are a tributary to Puget Sound, and are not known to contain listed fish. Thus, they were excluded from our analysis of predation and competition in freshwater. The effects of this factor on all listed species considered in this opinion is negative, as discussed below.

2.5.2.3.1. Competition and predation in rearing areas and the migratory corridor

2.5.2.3.1.1. PCD Risk Model Analysis in Freshwater

Chinook

While competition and predation are important factors to consider, they are events that can rarely, if ever, be observed and directly calculated. However, these behaviors have been established to the point where NMFS can model these potential effects on the species based on known factors that lead to competition or predation occurring. Here, we used the PCD Risk model version 4.0.0 of (Pearsons and Busack 2012), to quantify the potential number of natural-origin Chinook salmon lost to competition and predation from the release of hatchery-origin juveniles (for details see appendix section 5).

For our model runs, we made a number of assumptions for some of the parameter inputs, consistent with all of the other consultations in which we use this model (Table 22; Section 5). We generally assumed a 100% population overlap between hatchery fish and ESA-listed natural-origin Chinook salmon when both populations were present in the habitats at the same time. We acknowledge that a 100% population overlap in microhabitats is likely an overestimation. Within Lake Washington, we varied the level of populations overlap based on entry timing proportions for each populations. We assumed that habitat complexity was low during residence/travel through the streams, rivers, and lakes at only 10% to account for habitat degradation in the Lake Washington watershed.

We used habitat segregation estimates, maximum encounters per day, and dominance mode for most interactions based on (HETT 2014) database for hatchery programs of the same life stage and species (Table 22). However, because sockeye salmon programs are not present in the Upper Columbia River where the HETT team conducted their analyses, we decided to use a user-specified dominance mode when modeling the sockeye salmon program in Lake Washington. Dominance mode 3 assumes an equal likelihood of dominance between hatchery and natural fish when fish are approximately the same size, and a higher likelihood when hatchery fish are larger (70-90%), and a lower likelihood when hatchery fish are smaller (0-30%)(Pearsons and Busack 2012). However, literature suggests that sockeye salmon are less aggressive than other Pacific salmon and steelhead regardless of their size (Hoar 1954; Hutchison and Iwata 1997; Tatara and Berejikian 2012). Thus for the user-specific dominance mode (6) we used values of 0-10% dominance by hatchery sockeye salmon when the hatchery fish were smaller than natural-origin fish, and we used a value of 25% when hatchery sockeye salmon were equal or larger in size compared to natural-origin fish.

The Lake Washington residency of the hatchery sockeye fry is also a unique aspect of the Lake Washington hydroography and the life history of this particular species (WDFW and Muckleshoot Indian Tribe 2019). A great deal of research has been conducted to understand the habitat requirements of juvenile Chinook and sockeye salmon in Lake Washington. Much of this work has been summarized in (U.S. Army Corps of Engineers 2008). This body of research found that Chinook salmon fry reside primarily within the littoral lake zone within the top 1 m of water. Larger juvenile Chinook salmon reside within the littoral zone, but still remain within 4 m of the water surface. In contrast, sockeye salmon fry inhabit the limnetic zone below 20 m in water depth. Sockeye salmon do ascend to shallower waters at night to feed, and may interact with larger Chinook salmon individuals during these night ascensions (Eggers 1978). Thus, we modeled a 90-95% habitat segregation between Chinook salmon and juvenile sockeye salmon. Feeding, growth, and proportions of juvenile Chinook with maximum daily rations from modeling work conducted by Koelher et al. 2006 suggested that under current conditions both naturally produced and hatchery-produced juvenile Chinook salmon were finding ample food in littoral habitats of Lake Washington. Based on the lack of evidence of food availability limiting early growth of juvenile salmonids in Lake Washington, we modified the probability of weight loss from competitive interactions from the default value of 5% to 1%.

Table 22. Parameters in the PCD Risk model that are the same across all programs.

Parameter	Value
Habitat complexity	0.1
Population overlap	varied through space and time
Habitat segregation	0.3 for conspecifics; 0.6 for other species

	And 90-95% for Chinook/sockeye rearing in Lake Washington
Dominance mode	3 Chinook and coho, 6 sockeye
Maximum encounters per day	3
Piscivory rate	0 sockeye; 0.002 Chinook; 0.0189 coho
Predator:prey length ratio for predation	0.33[1]

[1] Daly et al. (2014)

Because of the hydrography of the Lake Washington watershed, we conducted multiple runs of the model to account for the travel of hatchery species through lakes and streams. To do this, we conducted model runs from release site to Lake Washington. We then modeled their potential interactions in Lake Washington, and finally conducted a third model run when fish exited Lake Washington until they reached Puget Sound.

For sockeye salmon, which rear in Lake Washington after release until they outmigrate as smolts the following spring, we conducted multiple model runs in Lake Washington. Immediately after their release as fry and fed fry, we modeled interactions with natural-origin juvenile Chinook salmon for a period of 107 and 45 days during the period of temporal overlap with lake rearing Chinook salmon; Chinook salmon fry spend one to four months during this phase. For the second model run, we assumed sockeye fry grew to a parr and pre-smolt size during their residency in Lake Washington in the absence of Chinook salmon. A third model run was conducted for a 90-day period when pre-smolt sockeye were rearing in Lake Washington at the same time as age-0 Chinook. We ran a fourth model run where we combined yearling hatchery-origin sockeye with age-1+ hatchery-origin sockeye released during previous year.

For coho salmon fry and parr releases, we assumed they resided in streams until emigrating as smolts the following year. Thus, we modeled this similarly to how we modeled overlap with sockeye fry in Lake Washington, 77 and 30 days of overlap with natural-origin Chinook salmon parr (mid-April through June) in the year of release, and 90 days overlap with natural-origin Chinook salmon fry in the year after release.

In contrast to some previous consultations where we ran the model using numbers of natural-origin fish that allowed the hatchery-origin fish to exhaust all interaction possibilities at the end of each day, we had data to inform the actual number and proportion of natural-origin juveniles of each species present in the Lake Washington watershed (Table 23). We believe this more closely mimics the reality of the Lake Washington watershed compared to how we have modeled abundance and proportions of natural-origin fish in previous consultations. For Chinook salmon, this was based on average data from the annual smolt trapping estimate reports for Cedar and Sammamish Rivers that occurred 2014 to 2018 (Lisi 2020). Because coho and Chinook salmon are released later in the spring (April-June) well after fry emergence, we assumed for our year-1 model runs that all natural-origin Chinook were of a parr size when interactions with these species occurred.

The number of natural-origin steelhead in Lake Washington is estimated to be in the single digits if not zero based on redd counts. Resident rainbow trout population abundance is unknown in the

Lake Washington watershed; therefore, it was not possible to meaningfully model effects from hatchery release programs on the steelhead population.

Table 23. Age, size, and occurrence of listed natural-origin salmon and steelhead encountered by juvenile hatchery fish after release.

Chinook Population	Fry	Parr	Total
Cedar River	667,762	27,870	695,632
Sammamish River	46,127	41,951	88,078

Sources: (Lisi 2020)

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 of hatchery juveniles on natural juveniles. For example, the model assumes that if a hatchery fish is piscivorous and stomach capacity allows the fish to consume prey it will be natural-origin prey. The reality is hatchery-origin fish could choose to eat a wide variety of invertebrates, other fish species (e.g., shad, minnows), and other hatchery-origin fish in addition to natural-origin smolts. However, we believe that with this model we are estimating, to the best of our ability, a worst-case estimate for the effects on ESA-listed natural-origin juveniles Chinook salmon.

The maximum numbers of juvenile fish lost for each species are shown in Table 24. This table also includes the potential increase of Chinook salmon from Issaquah Hatchery from three to six million (with a 10% overage), and the release of sockeye salmon at larger life stages. We then convert the number of juveniles lost to adult equivalents, using smolt-to-adult escapement (SAE) rates of 0.163% and 0.153% for Sammamish and Cedar River juvenile Chinook salmon.

In doing so, we estimate that the equivalent of up to 14 Chinook salmon, or about 1.4% of the basin-wide Chinook salmon, run. Juvenile mortalities were accounted for at the population level based on release site and location along the migration routes for each hatchery release (Table 23). This leads to an estimated 5% loss of Chinook salmon adult equivalents from the Sammamish population, and a 0.8% loss from the Cedar.

Table 24. Maximum numbers and percent of juvenile natural-origin salmon and steelhead lost annually to competition and predation with hatchery-origin fish released from the Proposed Action.

Hatchery Species	**Cedar River**		**Sammamish River**	
	Predation	**Delayed Mortality**	**Predation**	**Delayed Mortality**
Fall Chinook salmon (up to 6 million)	0	1030	0	1366
Coho salmon	858	228	1333	1458
Sockeye salmon	0	2432	0	301
Total Juveniles Lost	4548		4458	
Adult Equivalents[1]	7.4		7.3	

Fish that are not physiologically ready to migrate are not explicitly accounted for in our model at this time. Literature suggests that Chinook salmon subyearlings need to be at least 65 mm to tolerate the transition to saltwater (Kerwin 1999; Campbell et al. 2017). Fish that do not emigrate have the potential to compete with and prey on natural-origin fish for a longer period of time relative to fish actively outmigrating, and could impart some genetic effects when they spawn naturally. To address this potential effect, NMFS recommends that, of the subset of fish measured prior to release, the proportion below a size that are unlikely to immediately emigrate be reported. For sockeye salmon, no metric is proposed as these fish are released as fry, and their life history is to emigrate to the lakes soon after hatchery release, and rear in the lakes for up to one year.

Steelhead

Steelhead are not propagated as part of the proposed action, therefore there are no adult hatchery steelhead directly released into the watershed to compete or prey on the threatened natural-origin steelhead populations in the action area. Further, the geometric mean for natural origin steelhead in Sammamish River is undetectable and the geometric mean is low in Cedar River (discussed in section 2.2), and both populations have been declining overall since 2006. The PCDRisk model would not provide meaningful interpretation of interactions given a population size in this range. Thus, we qualitatively discuss effects of Fall Chinook, and Coho Salmon releases on natural origin Steelhead in this section. Additionally, there are no releases of Fall Chinook and coho in Cedar River, therefore we discuss the effects of predation and competition by Fall Chinook and coho salmon on the Steelhead population where they would be likely to co-occur in Lake Washington and the Ship canal. Overall, NMFS expects the risk of adverse interactions between hatchery-origin fish released from the programs and natural-origin Steelhead to be negligible, as discussed below.

Although newly released hatchery-origin yearling Coho salmon may prey on juvenile steelhead and other juvenile salmon in the freshwater and marine environments (Hargreaves and

LeBrasseur 1985; Hawkins and Tipping 1999; Pearsons and Fritts 1999) yearling coho would be released as smolts. Releasing fish as smolts is done as a measure to foster rapid emigration seaward and clearance from watershed areas where they may interact with natural-origin steelhead. Sockeye fry that are released into Cedar river are unlikely to have substantial adverse ecological effects on listed juvenile natural-origin fish because of their small size relative to natural origin steelhead, and late release timing that minimizes spatial and temporal overlap with natural-origin steelhead. The Sockeye salmon fry enter Lake Washington from the Cedar River between mid-January and mid-May (Seiler et al. 2004b) and then move offshore to rear. Overall, Steelhead smolts enter the lake in May and are thought to outmigrate quickly; limiting the temporal overlap between juvenile Steelhead and Sockeye in the lake.

Measures are applied to limit the risk of adverse capture, handling, and release effects on steelhead through application of appropriate protocols described in the Proposed Action (section 1.3). The earlier spawn timing for Chinook and coho salmon relative to steelhead makes adult fish interactions and substantial competitive or redd superimposition effects in listed steelhead spawning areas unlikely.

2.5.2.3.2. Competition and predation in the estuary and ocean

2.5.2.3.2.1. Spatial and Temporal Overlap

The overlap among the life stages of juvenile salmon are depicted in Table 25 below.

Table 25. Periodicity of juvenile salmon and steelhead entry (blue shading) and residence time (black shading) in Puget Sound estuaries.

Species	Life Stage/ history	Dec	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov
Chinook salmon	Fry												
	Parr												
	Yearling												
Sockeye	Yearling												
Steelhead	Yearling												
Coho[1]	Yearling												

[1] In the Lake Washington watershed, juvenile coho rear in their natal streams for up to 1 year before entering Lake Washington

Chinook Salmon

In Puget Sound, Fresh (2006) suggests that juvenile Chinook salmon could be aggregated into four general life history strategies, referred to as *migrant fry*, *delta fry migrants*, *parr migrants*, and *yearlings*, based upon when the fish leave freshwater and their size at this time. Most Chinook salmon from Puget Sound tributaries are "ocean-type," and arrive in estuaries as fry (< 50 mm fork length), entering natal deltas between December and April (Simenstad et al. 1982; Duffy 2003; Brennan et al. 2004; Duffy et al. 2005; Duffy 2009; Beamer et al. 2010). Some of these ocean-type juveniles pass quickly through the natal delta and enter Puget Sound (the migrant strategy), spending only days in natal deltas. Other fry remain in natal deltas for extended periods of up to 120 days (the delta strategy), where they make extensive use of small, dendritic tidal channels (channels that end in the upper end of the marsh) and sloughs in tidal wetlands (Fresh 2006).

During the late spring, fish associated with two other life history strategies (parr and yearling migrants) leave freshwater and migrate downstream to the estuary. Most Chinook salmon parr and yearlings arrive in the delta from mid-April to mid-June (Anderson and Topping 2018). Residence time and migration timing from the natal delta into Puget Sound habitats are a function of a number of factors. In general, with the exception of the migrant fry strategy, larger fish at the time of estuary entry tend to spend less time within an estuary than smaller fish. Environmental conditions, especially increasing water temperatures, may also be an important determinant of when juvenile Chinook salmon leave delta habitats (Fresh 2006).

Duffy et al. (Duffy et al. 2005) found that wild ocean-type Chinook salmon out-migrate to Puget Sound waters from March to July. The authors also found that hatchery Chinook salmon occupy nearshore Puget Sound waters soon after release and in pulses from May to June. Juvenile Chinook salmon abundance in shoreline areas of Puget Sound typically peaks in June and July, although some are still present in shoreline habitats through at least October.

Evidence indicates that all Chinook salmon populations in the ESU may rear throughout the Salish Sea for varying periods of time (Duffy 2003; Fresh 2006). Juvenile Chinook salmon may rear in Puget Sound for one to seven weeks, but certain stocks may become resident in the Salish Sea and remain there until maturity (commonly called "blackmouth"; Simenstad et al. 1982). Recent studies indicate that, upon release, substantial fractions (approximately 30%) of most hatchery stocks of Chinook salmon adopt the blackmouth life history strategy (O'Neill and West 2009; Chamberlin et al. 2011).

Sockeye Salmon

Sockeye salmon usually enter marine waters in the spring, from late April to early June as smolts, but there are some populations that enter salt water as fry (Thorpe 1994). For some populations, fish may reside in estuaries, where they feed on copepods, insects, amphipods, euphausids, and fish larvae (Burgner 1991). In general, most sockeye have moved out of the estuaries by late summer into the ocean (Burgner 1991; Thorpe 1994).

Steelhead

Evidence indicates that because steelhead attain a relatively large size in freshwater prior to smoltification (approximately 150–220 mm (Ward et al. 1989), migrants may move rapidly through estuaries (Quinn 2005) or use deeper water habitat offshore (Moore et al. 2010). (Beamish et al. 2003) reported that juvenile steelhead entering the Salish Sea generally migrate offshore into oceanic waters of the Gulf of Alaska, and are rarely found close to shore (Pearcy and Masuda 1982; Hartt and Dell 1986). In a telemetry study of steelhead migration behavior and survival in Hood Canal and Puget Sound, (Moore et al. 2010) reported that steelhead did not favor migration along shorelines. The authors suggested that Hood Canal provides rearing habitat for steelhead and does not function simply as a migratory corridor, with residence times averaging around 15-17 days.

Once juvenile steelhead enter coastal waters, they move quickly offshore to oceanic feeding grounds (Burgner et al. 1992; Daly et al. 2014). Puget Sound steelhead appear to migrate quickly through estuaries (Moore et al. 2010). In oceanic waters off Washington State, Daly et al. (2014) determined that juvenile steelhead moved quickly offshore from near-coastal habitats and were associated with shelf waters for only a short period after their migration from freshwater.

Coho Salmon

Coho salmon do not reside for long in estuaries and generally enter ocean waters in the spring (late April through early June) (Thorpe 1994). Simenstad et al. (1982) found that a small proportion (3-5%) of juvenile coho salmon may remain in the estuaries of Puget Sound and feed on decapod larvae, amphipods, euphausids, and fish larvae, but the overall majority move through the estuary to the ocean.

2.5.2.3.2.2. Competition

The early estuarine and nearshore marine life stage, when natural-origin fish have recently entered the estuary and populations are concentrated in a relatively small area, is a critical life history period. Mortality was found to be greater during the first few weeks of steelhead marine residence, but decreased substantially after the migrating steelhead enter the Pacific Ocean (Moore et al. 2010; Goetz et al. 2015; Moore et al. 2015). Some researchers have hypothesized that there may be short-term instances where food is in short supply, and growth and survival declines as a result (Rensel et al. 1984; Duffy 2003; Pearcy and McKinnell 2007). As juvenile salmon released from the proposed programs arrive in Puget Sound estuaries, they may compete with other salmon and steelhead in areas where they co-occur, if shared resources are limiting. Studies suggest that marine survival rates for salmon can be density dependent, and thus possibly a reflection of the amount of food available (Rensel et al. 1984; Brodeur 1991; Holt et al. 2008). Fresh (1997) summarized information concerning competition in marine habitats and concluded that food is the most limiting resource in marine habitats. The degree to which food is limiting depends upon the density of prey species and food production.

All of the hatchery-origin Chinook salmon released from hatcheries being evaluated in this Opinion are subyearlings released from April to June. These fish will most likely reach marine waters within weeks, and potentially interact with natural-origin fish that will be rearing in estuarine waters at the same time. Davis et al. (2018) examined size-class and origin-level differences throughout a gradient of delta habitat types. Wild (unmarked) and hatchery juveniles exhibited distinct habitat use patterns whereby unmarked fish were captured more frequently in tidally influenced freshwater and mesohaline emergent marsh areas, while hatchery fish were caught more often in the nearshore intertidal zone.

Consequently, hatchery fish were less likely to consume the energy-dense terrestrial insects that were more common in freshwater and brackish marshes (Davis et al. 2018). The authors measured stable isotope signatures from muscle and liver tissues, the results corroborated this finding, supporting that unmarked juveniles had derived 24–31% of their diets from terrestrially sourced prey, while terrestrial insects only made up 2–8% of hatchery fish diets. This may explain why unmarked fish were in better condition than hatchery fish (also see Daly et al. 2012; Daly et al. 2014) and had stomach contents that were 15% more energy-rich than those of hatchery fish. Davis et al. (2018) did not observe strong evidence for trophic overlap in juvenile Chinook salmon of different rearing origins, but their results suggest that hatchery-origin juveniles could be more sensitive to diet-mediated effects on growth and survival.

Interactions and effects likely diminish as hatchery- and natural-origin fish disperse into the main body of the Salish Sea and into the Pacific Ocean. Assessment of the effects of hatchery fish on natural-origin steelhead and Chinook salmon in the Salish Sea is problematic because there is a lack of basic information about what shoreline habitats are preferred by steelhead and Chinook salmon, their duration of habitat use, and their importance (Fresh 2006; Moore et al. 2010). Researchers have looked for evidence that marine area carrying capacity can limit salmonid survival (Beamish et al. 1997; HSRG 2004a). Some evidence suggests density-dependence in the abundance of returning adult salmonids (Emlen et al. 1990; Lichatowich et al. 1993; Bradford 1995), and/or is associated with cyclic ocean productivity (Nickelson et al. 1986; Beamish and Bouillon 1993; Beamish et al. 1997). (Naish et al. 2008b) could find no systematic, controlled study of the effects of density on natural-origin salmon, or of interactions between natural- and hatchery-origin salmon, nor on the duration of estuarine residence and survival of salmon. The Salish Sea marine ecosystem was until recently believed to be stable, internally regulated and largely deterministic. The current view is that Puget Sound is dynamic, with much environmental stochasticity and ecological uncertainty (Mahnken et al. 1998; Francis 2002a).

From the scientific literature reviewed above, the influence of density-dependent interactions on growth and survival is likely small compared with the effects of large scale and regional environmental conditions. While there is evidence that hatchery production of pink and chum salmon in Alaska, Japan, and Russia, can affect natural-origin salmon survival and productivity in the Northeast Pacific Ocean (Ruggerone et al. 2010), the degree of impact is not yet understood or predictable. Large-scale hatchery production may exacerbate density dependent effects when ocean productivity is low. Puget Sound-origin salmonid survival may be intermittently limited by competition with almost entirely natural-origin odd-year pink salmon originating from Salish Sea watersheds (Ruggerone and Goetz 2004), particularly when ocean productivity is low (Nickelson et al. 1986; Beamish and Bouillon 1993; Beamish et al. 1997; Mahnken et al. 1998). However, in studies of post-release migration and survival for natural and hatchery-origin steelhead smolts in Hood Canal and Central Puget Sound, predation by birds, marine mammals, and perhaps, other fish appears to be the primary factor limiting abundance of smolts reaching ocean rearing areas, not competition (Moore et al. 2010).

Green River hatchery-origin smolts migrating in marine waters exhibited an early offshore movement and a strong northward and westward seaward-bound orientation. Moore et al. (2015) found that natural-origin steelhead emigrating in early-April and late-May had a higher probability of survival than those migrating in early-and mid-May. The authors hypothesized that lower survival in the first half of May was related to consistent hatchery releases of coho and steelhead during the first week of May. However, their findings conflict with results from the Skagit River, which indicate that hatchery-origin fish had higher freshwater and early-marine survival rates than natural-origin steelhead, making it difficult to speculate how hatchery-releases, which survived at a higher rate, could reduce the survival rate of natural-origin fish. Thus, competition from hatchery-origin steelhead in Puget Sound appears to be short in duration because steelhead are actively migrating offshore and seaward into areas where the fish may disperse more widely and where food resources are more plentiful.

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

2.5.2.3.2.3. Residualism

A proportion of the smolts released from a hatchery may not migrate to the ocean but rather reside for a period of time in the vicinity of the release point. These non-migratory smolts (residuals) may directly compete for food and space with natural-origin juvenile salmonids of similar age. Although this behavior has been studied and observed, most frequently in the case of hatchery steelhead, residualism has been reported as a potential issue for hatchery coho and Chinook salmon as well. Adverse impacts of residual hatchery Chinook and coho salmon on natural-origin salmonids can occur, especially given that the number of smolts per release is generally higher; however, the issue of residualism for these species has not been as widely investigated compared to steelhead. Implementation of co-manager protocols for tracking the smolt transition among the yearling release groups as described in the proposed action, would minimize the risk of residualism occurring by coho yearlings.

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

2.5.2.3.2.4. Predation

Newly released hatchery-origin yearling salmon may prey on juvenile salmon and steelhead in the freshwater and marine environments (Hargreaves and LeBrasseur 1986; Hawkins and Tipping 1999; Pearsons and Fritts 1999). Chinook salmon, after entering the marine environment, generally prey upon fish one-half their length or less and consume, on average, fish prey that is less than one-fifth of their length (Brodeur 1991). During early marine life, predation on Chinook salmon will likely be highest in situations where large, yearling-sized hatchery fish encounter fry (Rensel et al. 1984). For example, (Beauchamp and Duffy 2011) estimated that older Chinook salmon (>300 mm FL; blackmouth) during June-August could potentially consume 6 to 59% of age-0 juvenile Chinook salmon recruiting into marine waters in the Puget Sound. The estimate depends on whether a very conservative estimate (6% Chinook in diet) or reasoned assumptions (20% Chinook in diet in May and June then allowed to decline daily via linear interpolation) were used.

Conversely, for the non-blackmouth life histories, results from Seiler et al. (2004a) suggest that the individual sizes of Chinook salmon successfully transitioning to the marine environment are too large for predation by co-occurring hatchery-origin fish. Likely reasons for apparent low predation rates on Chinook salmon juveniles by larger Chinook salmon are described by Cardwell and Fresh (1979): (1) due to rapid growth, natural Chinook salmon are not as accessible and are better able to elude predators; (2) because Chinook salmon have dispersed, they are present in low densities relative to other fish; and (3) there has either been learning or selection for some predator avoidance.

2.5.2.3.2.5. Summary

Based on the information available at this time, it is apparent that some overlap in time and space occurs between species and between hatchery- and natural-origin fish of the same species in the estuaries of Puget Sound. Effects may be more pronounced in nearshore marine waters adjacent to river mouths where salmon may initially be concentrated. Interactions and effects likely diminish as the fish disperse into the main body of Puget Sound and into the Pacific Ocean because overlap in resource use, and direct contact become less likely. However, whether this leads to either inter-or intra-specific competition and predation is less certain. In years of poor food productivity, releases of millions of hatchery fish may negatively affect natural-origin juveniles in the marine environment. However, because of the variable nature of food productivity, it is difficult to quantitatively account for interactions of hatchery fish on natural-origin fish in the estuary and marine environments, but a qualitative account of potential interactions can be made based on the knowledge we do have. This exercise suggests that the highest number of consistent potential interactions occur between natural- and hatchery-origin fish of the same species (Table 26).

Table 26. Likelihood and rationale for competitive interactions between juvenile salmon and steelhead species.

Natural Species	Proposed Action Hatchery Species		
	Sockeye	Subyearling Chinook	Coho
Yearling Chinook	High: same habitat, timing and body size	Low: different habitat and timing	Low: different habitat, timing, body size

Subyearling Chinook	Low: different habitat and timing	High: same habitat, timing and body size	Medium: different habitat and body size, same timing
Sockeye	High: same habitat, timing	Low: different habitat	Low: different habitat
Steelhead	Medium: different habitat and body size, same timing	Low: different timing and body size	Low: different timing and body size

Based on a review of the scientific literature, NMFS's conclusion is that the influence of density-dependent interactions on the growth and survival of salmon and steelhead is likely small compared with the effects of large-scale and regional environmental conditions and, while there is evidence that large-scale hatchery production can affect salmon survival at sea, the degree of effect or level of influence is not yet well understood or predictable. hatchery enhancement of salmon populations could exacerbate density-dependent effects during years of low ocean productivity.

2.5.2.3.3. Naturally-produced progeny competition

Naturally spawning hatchery-origin salmon are likely to be less efficient at reproduction than their natural-origin counterparts (Christie et al. 2014a), but the progeny of such hatchery-origin spawners are likely to 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. Therefore, the only expected effect of this added production is a density-dependent response of decreasing growth and increased competition/predation when habitat capacity is being approached. However, ecological impacts on listed Chinook salmon may increase in the future if the Chinook salmon populations grow.

Because fall Chinook and coho salmon historically coexisted in substantial numbers with steelhead, it follows that there must have been adequate passage and habitat to allow all species to be productive and abundant. It does not follow automatically, however, that the historical situation can be restored under present-day conditions. Habitat and passage conditions have changed considerably over time. Should the situation arise where salmon production is limiting natural production of listed salmon species, recovery planners would have to prioritize species. NMFS expects that the implementation of co-manager protocols for tracking the smolt transition among the yearling release groups prior to release would detect negative impacts before they reach problematic levels.

2.5.2.3.4. Disease

Adults returning back to hatchery facilities can have pathogens they become infected with upon their return to freshwater or that may have contracted during their juvenile rearing and outmigration. For programs in the Lake Washington watershed, the same pathogens detected in the juveniles were detected in the returning adults, *Flavobacterium psychrophilum, F.*

columnare, F. branchiophilum, *Aeromonas salmonicida*, *Ichthyopthirius multifiliis*, *Ichthyobodo* spp., *Gyrodactylus* spp., *Trichodina* spp. were all detected for returning adults collected for broodstock. These pathogens are all native to the Lake Washington watershed and did not result in any disease outbreaks in adults over the past year. Adults are also routinely screened for viral pathogens, such as infectious hematopoietic necrosis virus (IHNV) and infectious pancreatic necrosis virus (IPNV), but none were detected over the last three years. Based on the endemic state of the pathogens and the lack of outbreaks, risk of disease transmission and amplification from returning adults is low.

The risks of pathogen transmission and subsequent disease outbreaks in natural-origin salmon, and amplification of pathogens in the environment are low for the programs included in this proposed action. The reasons for this conclusion are three fold; outbreak frequency is low, the pathogens listed in Table 27 are treatable, and all of the pathogens detected are endemic to the area.

Fish health management protocols defined in the Co-manager's Fish Health Policy are designed so that compliance with these protocols minimizes the likelihood for fish disease amplification and loss within the listed, propagated population, or transmission to listed natural-origin Chinook salmon. This requires on-going monitoring prior to release, and treatment as prescribed to minimize disease outbreaks prior to release. Culling of diseased fish is also considered when necessary to protect listed populations within the release basin. Furthermore, prudent use of pathogen treatments limits the ability of the pathogens to develop resistance (i.e., bacteria to antibiotics), which could lead to no suitable treatment in the future and increased risk of pathogen amplification. Pathogen treatments are administered when the pathogen load is high enough to become a stressor to the fish host. Typical formalin treatments can range from 1 to 3 days, and last up to 2 hours per day. These are administered as a drip into the rearing unit. The bacterial pathogens are treated with an antibiotic that is premixed into the daily feed ration of feed for 5 to 14 days. Thus, the amount of time available over which shedding of pathogens could occur is limited.

There can be a few endemic pathogens detected within juvenile fish for which there is no known treatment or for which treatments with therapeutants may not be completely effective. However, fish health protocols are designed to prevent and control outbreaks with these pathogens. For example, to prevent outbreaks and reduce the amplification of *Renibacterium salmoninarum* in natural environments, hatchery staff may cull fish with high levels of the bacteria (WWTIT and WDFW 2006). These control measures have proven effective in controlling pathogens as indicated by the low number of outbreaks.

Table 27. Occurrence of the detection of pathogens and treatment for each hatchery program in Lake Washington.

Program	Pathogen	Season[1]	Treatment
Issaquah Coho	*Ichthyobodo*	March-Dec 2018, 2019	Formalin
	Aeromonas salmonicida	May-Aug 2017, 2018 2019	Medicated feed
	Flavobacterium columnare	Aug-Sept 2019	Medicated feed

	Trichodina	May 2017	None
Issaquah Fall Chinook	*Ichthyobodo*	Jan-May 2017,2018, 2019	Formalin
	Gyrodactylus	Feb-March 2018	Formalin
	Ichthyophthirius multifilis	Jan-March 2017, 2018, 2019	Formalin + salt
	F. branchiophila	March 2019	Formalin + salt
	F. psychrophilus	April 2019	None
	A. salmonicida	May 2017 2019	None
Cedar River sockeye	*Aeromonas salmonicida*	Sept-Nov 2019 2020 (adults)	salt
	Bacterium salmonicida	Sept-Nov 2019 2020 (adults)	salt
	Chondrococcus columnaris	Sept-Nov 2019 2020 (adults)	salt

[1] The season is when the pathogen is present at the facility, and although they may be present that does not mean that a treatment was administered.

2.5.2.4. Factor 4. Research, monitoring, and evaluation

The programs include RM&E to monitor compliance with this opinion and to reduce risks to ESA-listed Sammamish and Cedar River 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 Lake Washington basin Chinook salmon population. General monitoring and evaluation measures are included in the HGMP; RM&E actions include, but are not limited to:

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

Observing/Harassing

Direct observation is the least disruptive method for determining a species' presence/absence and estimating their relative numbers. Its effects are also generally the shortest-lived and least harmful of the research activities discussed in this section because a cautious observer can effectively obtain data while only slightly disrupting fishes' behavior. Fry and juveniles frightened by the turbulence and sound created by observers are likely to seek temporary refuge in deeper water, or behind/under rocks or vegetation. In extreme cases, some individuals may leave a particular pool or habitat type and then return when observers leave the area. At times, the research involves observing adult fish, which are more sensitive to disturbance. These avoidance behaviors are expected to be in the range of normal predator and disturbance behaviors therefore we do not anticipate actions to result in a decrease in the likelihood of survival and recovery of the listed species.

Capturing/handling

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

The handling expected to occur as part of RM&E programs is the same handling discussed in the analysis of Factor 1, above.

Fin clipping and tagging

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

In addition to fin clipping, CWTs may be used according to the details in table Table 4. Coded-wire tags are made of magnetized, stainless-steel wire and are injected into the nasal cartilage of a salmon and thus cause little direct tissue damage (Bergman et al. 1968; Bordner et al. 1990). A major advantage to using CWTs is that they have a negligible effect on the biological condition or response of tagged salmon (Vander Haegen et al. 2005); however, if the tag is placed too deeply in the snout of a fish, it may kill the fish, reduce its growth, or damage olfactory tissue (Fletcher et al. 1987; Peltz and Miller 1990). This latter effect can create problems for species like salmon because they use olfactory clues to guide their spawning migrations (Morrison and Zajac 1987).

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

For some parts of the proposed studies, listed fish would be observed in-water (e.g., by snorkel surveys, wading surveys, or observation from the banks). However, any avoidance behaviors are expected to be in the range of normal predator and disturbance behaviors. Redds may be visually inspected, but would not be walked on.

The effects of take associated with these activities were analyzed and determined not to result in a decrease in the likelihood of survival and recovery of the listed species, and will have no measurable effects on the listed salmonids' habitat.

2.5.2.5. Factor 5. Operation and maintenance of hatchery facilities

Effects on listed fish from operation and maintenance activities associated with the proposed hatchery programs are negative. The proposed action will require the construction of new facilities; however, the scope of this BiOp does not include any future facility construction or expansion, or any increases in quantities of water withdrawals beyond existing permissible volumes. Construction of a permanent Weir on Cedar River is expected to commence in the future, when construction and installation plans are in consultation with NMFS or other necessary agencies.

Screening and Passage

The facilities at Issaquah, Willow Creek, and Cedar River hatcheries are not anticipated to have any adverse effects on ESA-listed salmon because they are compliant with NMFS screening criteria (Table 7).

The facilities at UW ARF water intake are an infiltration gallery. NMFS engineering staff have investigated the water intake for the facility and have determined that the water intake is an infiltration gallery, and as an existing infiltration gallery of sufficient depth below the bed elevation of the water body to mitigate entrainment concerns. The infiltration gallery is not anticipated to have any adverse effects on ESA-listed salmon because it meets NMFS screening criteria as applicable.

Water Withdrawals

Facilities that withdraw a relatively large proportion of water over a relatively large diversion distance may present risks to the migration and survival of listed salmon.
However, NMFS believes the facilities analyzed in this Proposed Action are not a risk for several reasons: (1) diversion distance is very small < 0.002 km and therefore minimizes the risk of affecting individual fish; (2) water use is non-consumptive; (3) the proportion of water withdrawn is relatively low; and (4) no changes to surface water use have been proposed. These impacts will not measurably change freshwater rearing, freshwater spawning, or migration corridors.

Withdrawal of surface water at maximum permitted levels for fish rearing would reduce the quantity of water available for salmon and steelhead migration and rearing between the hatchery water intake and water discharge points (Table 28). Therefore NMFS expects that the water withdrawals would not lead to any dewatering of spawning habitat or the migration corridor, nor will it cause the interruption or prevention of fish movement.

The net pen in the Port of Edmonds, in central Puget Sound, uses passively supplied marine water, which is not diverted and is non-consumptive, and thus has no effect on salmon (Table 28).

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

No major construction is included as part of the Proposed Action.

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

Table 28. Water source, use, and discharge by salmon hatchery facilities.

Facility	Surface/Spring Water (cfs)	Ground Water (gpm)	Water Diversion Distance (km)	Water Source	Discharge Location
	NA	49	NA	Darigold/west farms foods	Issaquah Creek
	16	NA	0.002		
Issaquah	10	NA	1.19	Issaquah Creek	Issaquah Creek
	10	NA	0.009		
Willow Creek Hatchery	1	NA	0.005	Willow Creek (Deer Creek)	Willow Creek
Edmonds Net Pens[1]	NA	NA	NA	Puget Sound	NA
	5.0	NA	NA	Lake Union (Portage Bay)	
UW ARF	NA	80	NA	Groundwater	Lake Union
	NA	50	NA	Groundwater	
Cedar River Sockeye	NA	1.7	0.54	unnamed spring	
	4.46	NA	0.21	Cedar River	
	1.3	NA	0.26	unnamed stream	
	2.0	NA	0.09	unnamed stream	Cedar River
	NA	2,000	NA	Groundwater	
	0.9	NA	0.44	unnamed stream	

Effluent

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

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

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

Because the same water used for rearing (where survival is high compared to the natural environment) is then discharged into the surrounding habitat and then further diluted once it is combined with the river water, we believe effluent will have a minimal impact on ESA-listed salmonids in the area.

Therapeutic chemicals used to control or eliminate pathogens (i.e., formaldehyde, sodium chloride, iodine, potassium permanganate, hydrogen peroxide, antibiotics), can also be present in hatchery effluent. However, these chemicals are not likely to be problematic for ESA-listed species because they are quickly diluted beyond manufacturer's instructions when added to the total effluent and again after discharge into the recipient water body. Therapeutants are also used periodically, not constantly, during hatchery rearing (see Section 2.5.2.3.4). In addition, many of them break down quickly in the water and/or are not likely to bioaccumulate in the environment. For example, formaldehyde readily biodegrades within 30 to 40 hours in stagnant waters. Similarly, potassium permanganate would be reduced to compounds of low toxicity within minutes. Aquatic organisms are also capable of transforming formaldehyde through various metabolic pathways into non-toxic substances, preventing bioaccumulation in organisms (EPA 2015).

2.5.2.6. Factor 6. Fisheries

There are no fisheries that exist as a direct result of the Proposed Action. The Chinook salmon under propagation are not essential for recovery of the Puget Sound Chinook ESU (PRA Tier 3) The effects of fisheries that may impact fish produced by these programs are described in Section 2.3.3. Therefore, the effects are considered in the Environmental Baseline.

2.5.3. Effects of the Action on Critical Habitat

Existing hatchery facilities have not led to: altered channel morphology and stability; reduced and degraded floodplain connectivity; excessive sediment input; or the loss of habitat diversity. No new facilities or construction are directly proposed as part of the proposed actions considered in this opinion. No hatchery facilities are located in Sammamish river waters where designated critical habitat for listed Chinook salmon would be affected. Critical habitat for listed Steelhead has not been designated in the Lake Washington watershed and therefore there would not be effects on designated critical habitat for this species.

Most facilities that use surface water diversions return that water to a creek a short distance from the diversion point, and use only a small proportion of the total surface water volume (Table 28). Because the uses are non-consumptive, these withdrawals would not affect adult spawning and juvenile rearing critical habitat of ESA-listed Chinook or steelhead. Hatchery diversion screens protect listed juvenile Chinook salmon and steelhead from entrainment and injury, and meet current NMFS screen criteria, or are proposed for retrofitting to meet those criteria as needed (See **Table 7**; section 1.3.8).

Another potential effect on critical habitat is the use of chemicals for cleaning or treating pathogens that are present in the hatchery effluent. Compliance with NPDES permits issued for the programs would help ensure that water quality in downstream areas where listed fish may be present is not degraded. Consistent with effluent discharge permit requirements developed by the Environmental Protection Agency and the Washington Department of Ecology(WDoE) for upland fish hatcheries, water used for fish production at Issaquah and willow creek hatcheries would be adequately treated prior to discharge into downstream areas to ensure that federal and state water quality standards for receiving waters are met and that downstream aquatic life, including salmon and steelhead, will be no more than minimally affected.

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). Future Federal actions that are unrelated to the Proposed Action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA. For the purpose of this analysis, the action area is described in Section 0. Future Federal actions, including the ongoing operation of the hydropower system, hatcheries, fisheries, and land management activities will be reviewed through separate section 7 consultation processes.

The federally approved Shared Strategy for Puget Sound Recovery Plan for Puget Sound Chinook Salmon (NMFS 2006b) describe, 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 Lake Washington 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. Government actions are subject to political, legislative, and fiscal uncertainties.

Non-Federal actions are likely to continue affecting listed species. State, tribal, and local governments have developed plans and initiatives to benefit listed species (Council 2017) . 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 2018c) would likely continue to help lessen the effects of non-Federal land and water use activities on the status of listed fish species. The temporal pace of such decreases would 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 2.3)

Climate Change
Climate change may have some effects on critical habitat as discussed in Section 2.4.3. With continued losses in snowpack and increasing water temperatures, it is possible that increases in the density and residence time of fish using cold-water refugia could result in increases in ecological interactions between hatchery and natural-origin fish of all life stages, with unknown but likely small effects. However, the continued restoration of habitat, should alleviate some of this potential pressure for cold water refugia as well as suitable rearing and spawning habitat. It is also possible the changing flow patterns due to climate change may change the suitable operation periods of water intakes and weirs for the programs. In the short-term, these changes are expected to be small, and infrastructure is likely able to sustain continued operations as described without exacerbating changes.

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, NMFS adds the effects of the proposed action (Section 2.5.2) to the environmental baseline (Section 2.4) and to cumulative effects (Section 2.6) to formulate the agency's opinion as to whether the Proposed Action is likely to: (1) result in appreciable reductions in the likelihood of both survival and recovery of the species in the wild by reducing its numbers, reproduction, or distribution; or (2) appreciably diminish the value of designated or proposed critical habitat as a whole for the conservation of the species (Section 2.2).

In assessing the overall risk of the proposed action on each species, NMFS considers the risks of each factor discussed in Section 2.5.2, 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

Best available information indicates that the Puget Sound Chinook Salmon ESU remains threatened (NWFSC 2015). Spawner abundance is currently depressed, and below the critical threshold for Sammamish Fall Chinook population, but above the rebuilding threshold for the Cedar River fall Chinook population (NMFS 2021). The Sammamish River and Cedar River populations currently do not assume a primary role for recovery of the Puget Sound ESU

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

Effects of the proposed action include effects that occur immediately (handling, monitoring, construction, and operation of facilities), as well as those that will occur over time (genetic and ecological). NMFS will monitor whether decreased productivity, diversity, or abundance of natural-origin fish may necessitate more aggressive adult management, and/or reconsideration of hatchery program size in the future to limit impacts on these VSP parameters in these ESUs.

Broodstock collection requires ongoing annual handling of a portion of the population (juvenile and adult), though handling mortality is low. The broodstock collection is an essential component of the action. The effects of broodstock collection on the Steelhead population would be infrequent and there is potential for years with no interactions, therefore it is unlikely to 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 have been covered previously (NMFS 2017c; 2018b), 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 Sammamish Fall Chinook salmon population are limited by the use of natural-origin broodstock while the natural origin population is below the critical threshold. Even though the population is a tier 3 in recovery scenario and a target PNI value has not been established for tier 3 populations, a PNI > 0.5 is indicative of the dominance of natural selective forces (Section 5.2.1.4.2.1). In years where natural-origin abundance triggers the program to transition into a genetically-linked program, the population could achieve a PNI of 0.4. Because the Sammamish River population is one of 22 populations in the ESU, most populations are above critical thresholds, and the Proposed Action substantially improves the Sammamish population's PNI, the Proposed Action is unlikely to have an adverse effect at the ESU level.

Ecological effects on natural-origin juvenile Chinook salmon associated with hatchery program releases are equivalent to an estimated 5% loss of Chinook salmon adult equivalents from the Sammamish population, and a 0.8% loss from the Cedar. 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 ESU. The ESU is composed of 21 other populations in addition to the Sammamish River, and many of those populations are situated in Basins that have substantially better habitat than the Sammamish River (e.g., Nisqually). In addition, most Chinook salmon populations are above the critical threshold and are on their way to the rebuilding threshold. 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 Lake Washington Steelhead populations would occur incidental to collection of Fall Chinook salmon, Coho salmon or Sockeye for broodstock, and during RM&E activities. The effects of Fall Chinook and Coho broodstock collection on the Steelhead population would be infrequent and there is potential for years with no interactions. The effects of Sockeye broodstock collection would be limited because there is little overlap between the steelhead and Sockeye runs such that the overlap is only during a short window at the early part of the run. Because Steelhead are not a target species, they are 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.

The Central and South Puget Sound 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 group's in the Puget Sound DPS. Although, abundance varies greatly among the populations in the Central and South Puget Sound MPG, the Green, White, Puyallup, and Nisqually populations comprise the majority of steelhead in the MPG. 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 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 Central and South Puget Sound MPG is sustained by contributions from the larger watersheds rather than the contributions from Lake Washington. 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 2.2.1.4, and 2.2.1.6 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.

Withdrawal of surface water at maximum permitted levels for fish rearing could decrease the quantity of water available for salmon and steelhead migration and rearing between hatchery water intake and water discharge points, potentially leading to adverse effects on designated critical habitat. However, such adverse effects on critical habitat are unlikely, because water withdrawal amounts for hatchery fish rearing during the summertime low flow periods, when any effects would be most pronounced, will be much less than the permitted maximum levels. Fish biomass at the hatchery rearing locations, 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 the fish are at their largest size, and flows in the Green River Basin approach their annual maximums. At these times, the water withdrawals would not be a substantial proportion of the streamflow, and so critical habitat would not be adversely modified.

Steelhead and Chinook salmon populations in the Lake Washington watershed may be adversely affected by climate change (see section 2.4). 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 Cedar 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 programs are expected to help attenuate climate change impacts over the short term by providing a refuge for the listed populations from risks affecting critical life stages for naturally produced fish through circumvention of potentially adverse natural spawning, incubation, and rearing conditions.

After reviewing the Proposed Action and conducting the effects analysis, and considering future anticipated effects of climate change, NMFS has determined that the Proposed Action would not diminish the conservation value of this critical habitat for the Snake River Basin steelhead DPS, or the Snake River Fall and Spring/Summer Chinook Salmon and Sockeye Salmon ESUs.

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 the Puget Sound Chinook Salmon ESU and the Puget Sound Steelhead DPS or to destroy or adversely modify designated critical habitat.

2.9. Incidental Take Statement

Section 9 of the ESA and Federal regulation pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by regulation to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. For purposes of this consultation, we interpret "harass" to mean an intentional or negligent action that has the potential to injure an animal or disrupt its normal behaviors to a point where such behaviors are abandoned or significantly altered. Section 7(b)(4) and section 7(o)(2) provide that taking that is incidental to an otherwise lawful agency action is not prohibited under the ESA, if that action is performed in compliance with the terms and conditions of this Incidental Take Statement (ITS).

2.9.1. Amount or Extent of Take

The primary form of take of ESA-listed Chinook salmon and steelhead proposed in this action 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:

- Genetic and ecological effects of hatchery adults on the spawning grounds
- Handling/tagging of adults at adult collection facilities
- Ecological effects of juveniles during emigration
- Ecological and genetic effects of juveniles that do not migrate

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

NMFS expects that while the Fall Chinook program is operating as a segregated program, the total annual number of natural-origin Fall Chinook salmon captured handled, and released during annual Chinook broodstock collection activities will not exceed the values listed in Table 21 columns titled Proposed Handling. Natural origin Fall Chinook encountered at the Issaquah weir, that are not retained for broodstock, will be released unharmed back into the river upstream of Issaquah weir where they would have access to suitable spawning habitat, with an incidental mortality of up to 30%, although not expected to exceed a three year average of more than 20%.

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**

There is take for this factor due to three forms of harm: genetic effects, ecological effects, and adult handling/tagging and incidental mortality at adult collection facilities.

For genetic effects, take occurs through a reduction in genetic diversity, outbreeding depression, and hatchery-influenced selection, which results from hatchery Chinook salmon spawning with natural-origin fish. Additionally, take occurs through ecological effects of intraspecific hatchery adults on the spawning grounds such as competition for spawning sites and redd superimposition. Take due to these two pathways cannot be directly measured because it is not possible to observe gene flow or interbreeding between hatchery and wild fish in a reliable way, or to quantify spawning site competition or redd superimposition. Thus, to ascertain the extent of take, NMFS will rely on a gene flow surrogate that can be measured through the annual evaluation of the proportion of marked and tagged hatchery fish and unmarked and untagged natural-origin fish that are collected in-river for broodstock and spawned, and through the estimation of the composition spawners reported as pHOS or PNI values (depending on program) on an annual basis as follows:

- While the Fall Chinook program is segregated the five year average pHOS shall not exceed 87%
- While the Fall Chinook program is operating as a genetically-linked program PNI would initially begin at or below 0.06 and would be expected to range between 0.22 – 0.61. If annually reported data indicates that the pHOS continues to increase, in conjunction with a decrease in natural-origin returns such that the PNI would drop below 0.06 over a measured five-year rolling average for more than two consecutive brood cycles, ten years, NMFS will need to reevaluate the levels of potential reduction in genetic diversity of the programs to listed populations.
- In Cedar River we expect a pHOS that corresponds with the ranges depicted in (Table 17) but the five year running average for pHOS should not exceed 46%. Natural population fluctuations are expected, as reflected in the composition of hatchery and natural spawners on the spawning grounds annually. Thus, the five-year rolling average is expected to adequately describe the overall effect without being unduly complicated by year-to-year variation. However, if pHOS after one or two years is so high that attainment of expected pHOS value across five years is not a reasonable expectation, or if data indicates that the assumptions of the model are incorrect, co-managers and NMFS will look more closely at the genetic risks to natural Chinook salmon populations.

These thresholds are rationally connected to the take pathway because they measure the extent to which interactions are occurring which could lead to genetic effects. They can reasonably be measured and monitored through the monitoring requirements in the proposed action.

For the ecological effects of redd superimposition and spawning site competition associated with the coho salmon hatchery programs, the take surrogate is the proportion of hatchery fish spawning naturally compared to the baseline numbers in Table 29. The number of hatchery-origin fish on the spawning grounds in Cedar River shall not increase by more than 46% based on a 5-year running average beginning in 2020 (average of 2016-2020). This take surrogate can be reliably measured and monitored through weir collections, CWT recoveries, and hatchery rack returns.

The third take pathway for this factor is the handling/tagging of listed hatchery and natural-origin Chinook salmon and steelhead at adult collection facilities to facilitate broodstock collection, and sampling of fish for monitoring and evaluation. The amount of incidental take of ESA-listed steelhead and fall Chinook salmon expected to occur as a result of the proposed action by this pathway is contained in Table 23 the column titled Proposed Handling. Additional take would occur during collection at Bear Creek weir. The amount of incidental take of ESA-listed steelhead and fall Chinook salmon expected to occur as a result of the proposed action by this pathway is contained in (Table 21).

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

Predation, competition, or pathogen transmission, collectively referred to as ecological interactions, between natural-origin juvenile Chinook salmon and steelhead and hatchery coho and Chinook could result in take of natural-origin Chinook salmon and steelhead. In addition, non-migrating fish could also cause genetic effects when non-migrating fish spawn naturally (residualized Chinook or coho). This type of take is difficult to quantify because it cannot be observed, and, therefore, cannot be directly or reliably measured. However, as described in section 2.5.2.3.1.1, ecological interactions are the direct result of hatchery releases and so anticipated ecological effects can be evaluated using the PCDRisk Model.

Thus, we will rely on a take surrogate, to ascertain the extent of the effects of non-migrating hatchery juveniles. Hatchery releases shall not release more than the planned release targets of six million juveniles from facilities as described in Table 4 of the proposed action.

This surrogate has a rational connection to the amount of take expected from competition and predation, as more of these events will occur as more fish are released from the hatchery. NMFS expects some annual variability in release numbers based on normal hatchery operations. NMFS will annually determine whether take has been exceeded when final release data become available, unless the number of smolts released after one or two years is so high that attainment of the proposed release numbers across five years is not a reasonable expectation, in which case NMFS will consider the take limit to have been exceeded at that time.

Regarding take associated with non-migrating hatchery fish, NMFS will rely on a surrogate that determines what proportion of the release falls below an emigration size threshold. This is a reasonable, reliable, and measurable surrogate for incidental take because fish below the threshold are unlikely to be physiologically ready to migrate, and if the proportion of the release below the emigration size threshold is exceeded , it is a sign that more fish may have longer freshwater residence times. This threshold will be monitored using proportion of fish below the emigration size threshold prior to release, or other juvenile monitoring techniques developed by the operators and approved by NMFS.

Regarding take associated with residualized Coho, NMFS will rely on a surrogate that consists of the proportion of the release which would be smolts and more likely to be ready to migrate. The five-year running geometric mean of juvenile Coho classified as parr or precocious shall not exceed 10% of the total release of 750,000 sub yearlings and 90,000 age 0 smolts (as described in Table 4). This is a criteria of qualitative categorization based on the body condition and behavior of fish at the time of release was developed. This system is modeled after that described in Tatara et al. 2019 for measuring the degree of steelhead smoltification. Coho will be categorized as one of three types:

- “parr” are fish that display distinct parr marks,
- “transitional” are fish that display fading parr marks, and
- “smolts”are fish that display a predominate absence of parr marks and presence of mostly silver coloration.

This is a reasonable surrogate for incidental take because fish that are released before smlotification are unlikely to be physiologically ready to migrate, and if the released fish are not fully smolts then it is a sign that they may have longer freshwater residence and an increased potential for residualism. This threshold will be monitored using the described classification system above and if parr and precocious fish exceed 5% of the total juvenile release, the expected take from interactions of residualized fish would have likely been exceeded.

In-Hatchery Losses

Under Factor 3, we analyze losses that occur within the hatchery (Section 2.5.2.3.4), which constitutes take of those listed individuals. The egg to release loss rates averaged 20 percent for the Fall Chinook salmon program over the 2004-2015 brood years. Based on the analysis in Section 2.4.2.3.3., when the fall Chinook salmon hatchery program is operating as a genetically-linked program, should in-hatchery losses from egg to release exceed 20 percent annually over three consecutive years, NMFS will need to reevaluate the effect of this loss on the natural fall Chinook salmon population. Therefore, the take associated with this pathway is expected to be no more than 20% of juvenile Chinook salmon inside the hatchery in any one year, and no more than 18% over three consecutive years.

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 result in jeopardy of the Puget Sound Chinook Salmon ESU or the Puget Sound Steelhead DPS or in the destruction or adverse modification of designated critical habitat.

2.9.3. Reasonable and Prudent Measures

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

NMFS concludes that the following reasonable and prudent measures are necessary and appropriate to minimize incidental take. NMFS shall ensure that:

1. The applicants implement the hatchery programs and operate the hatchery facilities as well as guidelines specified in this opinion for their respective programs.
2. The applicants monitor activities and provide reports to SFD annually for all hatchery programs and associated RM&E.

2.9.4. Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the ESA, the Federal action agency must comply (or must ensure that any applicant complies) with the following terms and conditions. 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 incidental take statement (50 CFR 402.14). If the entity to whom a term and condition is directed does not comply with the following terms and conditions, protective coverage for the proposed action would likely lapse. NMFS shall ensure that:

1. The applicants implement the hatchery programs and operate the hatchery facilities as well as guidelines specified in this opinion for their respective programs, including:
    a. Provide advance notice of any change in program operation and implementation that may increase the amount or extent of take, or results in an effect of take not previously considered.

b. Notify NMFS SFD within 48 hours after knowledge of exceeding authorized take. The applicants shall submit a written report, and/or convene a discussion with NMFS to discuss why the authorized take was exceeded.

c. If the five-year running geometric mean of hatchery releases exceeds the proposed release numbers by 10%, or the number of smolts released after one or two years is so high that attainment of the proposed release numbers across five years is not a reasonable expectation, the applicants and NMFS will re-evaluate competition and predation risks to natural Chinook salmon populations.

d. If the five-year running geometric mean of juvenile Coho classified as parr or precocious exceed 10% of the total release, or the number released after one or two years is so high that attainment of the proposed release numbers across five years is not a reasonable expectation, the applicants and NMFS will re-evaluate competition and predation risks to natural Fall Chinook salmon populations.

e. The applicants shall submit a written report or summary of research conducted by MIT and WDFW as discussed in section 1.3.4 once data for all three brood years of non-acclimated releases are obtained.

f. Analysis assumed pHOS in Cedar River would range between 30 and 46 percent while the fall Chinook program is operating as a segregated program (based on analysis in section 2.5.2.2.1). If the five year running average for pHOS in the Cedar River exceeds maximum pHOS (46%; Table 29) or if pHOS after one or two years is so high that attainment of expected pHOS value across five years is not a reasonable expectation, or if data indicates that the assumptions of the model are incorrect, co-managers and NMFS will look more closely at the genetic risks to natural Chinook salmon populations.

g. Provide plans for future projects and/or changes in sampling locations or protocols and obtain concurrence from NMFS prior to implementation of such changes.

2. The applicants provide reports to SFD annually for their respective programs, including associated RM&E. All reports and required notifications are to be submitted electronically to the NMFS, West Coast Region, Sustainable Fisheries Division, APIF Branch. The current point of contact for document submission is Chanté Davis (503-231-2307, chante.davis@noaa.gov).

    a. An annual RM&E report(s) is submitted by applicants no later than April 15 of the year following releases and associated RM&E (e.g., release/RM&E in year 2021, report due April 2022), and should include:

        i. The number and origin (hatchery and natural) of each listed species handled and incidental mortality across all activities and facilities

        ii. Hatchery Environment Monitoring Reporting

            - Number and composition of broodstock, and dates of collection
            - Numbers, dates, locations, size, coefficient of variation, and tag/mark information of released fish

- From a representative sample of 200 fish at time of release, the number of fish that are categorized as either parr, transitional, smolt, or precocious following a qualitative criteria explained in section 2.9.1
- Disease occurrence at hatcheries
- Any problems that may have arisen during hatchery activities
- Any unforeseen effects on listed fish

iii. Natural Environment Monitoring Reporting

- The number of returning hatchery and natural-origin adults
- The number and species of listed fish encountered at each adult collection location, and the number that die
- Mean length, coefficient of variation, number, and age of natural-origin juveniles during RM&E activities

2.9.5. Conservation Recommendations

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

1. Based on analysis in section 2.5.2.2, pHOS in the Cedar River would increase from current levels, falling within a range of 30 – 46%. A range of analysis was evaluated to understand changes in pHOS. There are two locations within Cedar River where HOR may be removed during collection of broodstock for the sockeye program (Landsburg Dam and Cedar River weir). With the removal of HOR at these locations, it is possible to further reduce pHOS by 1 to 15 percentage points depending on scenario (cite Haggarty 2021). This is not included in the proposed action and not assumed to occur in formulating NMFS' opinion.

Table 29: pHOS in Cedar River given each release scenario and removal of hatchery-origin fall-run Chinook salmon at either Cedar River Weir (RM 1.0) or Landsburg Dam (RM 21.9).

Scenario	No removal of HOS		Removal of HOS at Cedar River Weir		Removal of HOS at Landsburg Dam		Removal of HOS at weir and dam	
		4.8 % TE	20% TE	40% TE		4.8 % TE	20% TE	40% TE
1B	36.90%	35.70%	31.80%	25.90%	33.10%	32.10%	28.40%	22.90%
2B	41.90%	40.70%	36.60%	30.20%	37.90%	36.80%	32.90%	26.90%
3B	45.50%	44.30%	40.10%	33.40%	41.50%	40.20%	36.20%	29.80%

2.10. Re-initiation of Consultation

This concludes formal consultation for [*name of action*].

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."

2.11. Not Likely to Adversely Affect Determinations

2.11.1. 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 (NWFSC 2015). 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 (NWFSC 2015).

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 Lake Washington. 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.

2.11.2. Ozette Lake Sockeye Salmon ESU

The Ozette Lake Sockeye Salmon ESU was listed as a threatened species in 1999 (64 FR 14528; March 25, 1999). The ESU includes all naturally spawned populations of sockeye salmon in Ozette Lake and streams and tributaries flowing into Ozette Lake, Washington. The 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), 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).

Lake Ozette sockeye salmon would potentially be encountered by juvenile fish released from our 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 Lake Washington watershed because they are released during the same timeframe, but have a much greater distance to travel. In addition, juvenile sockeye salmon are present close to shore from Cape Flattery to Yakutat in July and August and then move offshore in late Autumn or winter. The nearshore around the Ozette River is a productive, shallow sub-tidal environment (Haggerty et al. 2009), and it is assumed that very few if any of these fish move into Puget Sound marine areas. Thus, NMFS believes that the effects of competition and predation of our 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 action area of the Proposed Action includes habitat described as EFH for Chinook, pink, and coho salmon. Marine EFH for Chinook, coho, and Puget Sound pink salmon in Washington, Oregon, and California includes all estuarine, nearshore and marine waters within the western boundary of the EEZ, 200 miles offshore. Freshwater EFH for Pacific salmon, includes all those streams, lakes, ponds, wetlands, and other water bodies currently, or historically accessible to salmon in Washington, Oregon, Idaho, and California, except areas upstream of certain impassable manmade barriers, and long-standing, naturally-impassable barriers (i.e., natural waterfalls in existence for several hundred years). 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. Marine EFH for Chinook and coho salmon consists of three components, (1) estuarine rearing; (2) ocean rearing; and (3) juvenile and adult migration.

EFH for groundfish includes all waters, substrates and associated biological communities from the mean higher high water line, or the upriver extent of saltwater intrusion in river mouths, seaward to the 3500 meters in depth contour plus specified areas of interest such as seamounts. A more detailed description and identification of EFH for groundfish is found in the Appendix B of Amendment 25 to the Pacific Coast Groundfish Management Plan (PFMC 2016c).

EFH for coastal pelagic species includes all marine and estuarine waters from the shoreline along the coasts of California, Oregon, and Washington offshore to the limits of the EEZ and above the thermocline where sea surface temperatures range between 10°C to 26°C. A more detailed description and identification of EFH for coastal pelagic species is found in Amendment 15 to the Coastal Pelagic Species Fishery Management Plan (PFMC 2016a).

3.2. Adverse Effects on Essential Fish Habitat

3.2.1. EFH for Pacific Salmon

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 Chinook, Coho, and Sockeye salmon programs is to produce fish that will augment harvests for marine and freshwater commercial and recreational fishing areas. Therefore the majority of 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 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 and coho 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 111.3.8 and Table 7, 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 Issaquah hatchery water intake screens on Issaquah creek and Cedar River Hatcheries water intake screens on Cedar River 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 UW ARF hatchery is an infiltration gallery and meets NMFS screening criteria as applicable.

3.2.2. EFH for groundfish and coastal pelagic species

The proposed action is not likely to have adverse effects on EFH for groundfish. Of the potential adverse effects listed in (PFMC 2016b), effect on water quality is listed as a major concern of water use. However, all relevant facilities have NPDES permits to minimize effects on water quality. Altering natural flows is not a concern associated with hatchery operations because the hatcheries are not altering the flow rate in Puget Sound enough for the effects to be detectable in the groundfish EFH. Affecting prey base and entrapping fish through water withdrawal is not adversely affected by hatchery operations because water is not withdrawn within the groundfish EFH. Finally, adverse effects associated with dams are not relevant to hatchery operations because hatchery operations do not affect how dams are operated.

All relevant facilities have NPDES permits to minimize effects on water quality. Altering natural flows is not a concern associated with hatchery operations because the hatcheries are not altering the flow rate in Puget Sound enough for the effects to be detectable in the groundfish EFH. Affecting prey base and entrapping fish through water withdrawal is not adversely affected by hatchery operations because water is not withdrawn within the groundfish EFH. Adverse effects associated with dams are not relevant to hatchery operations because hatchery operations do not affect how dams are operated.

The proposed action is not likely to have adverse effects on EFH for the coastal pelagic species. Of the potential adverse effects listed in (PFMC 2016a) and (PFMC 2016b), effects of hatchery operations could be analogous to adverse effects of aquaculture; organic waste, release of high levels of antibiotics, disease, and escapees. However, these analogous concerns for hatchery operations are not likely to adversely affect coastal pelagic species because all relevant facilities have NPDES permits to minimize effects of organic waste, and antibiotics would be diluted to manufacturer labeling. Concerns of disease transfer from and escapees of salmonid species are not likely to be a concern because coastal pelagic species are not closely related to the salmonid species.

The proposed action is not likely to have adverse effects on EFH for coastal pelagic species or EFH for groundfish.

3.3. Essential Fish Habitat Conservation Recommendations

Because of the pathways by which hatchery programs can potentially effect 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 from NMFS. Such a response must be provided at least 10 days prior to final approval of the action if the response is inconsistent with any of NMFS' EFH Conservation Recommendations, unless NMFS and the Federal agency have agreed to use alternative time frames for the Federal agency response. The response must include a description of measures proposed by the agency for avoiding, mitigating, or offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with NMFS 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.

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 [50 CFR 600.920(l)].

4. DATA QUALITY ACT DOCUMENTATION AND PRE-DISSEMINATION REVIEW

Section 515 of the Treasury and General Government Appropriations Act of 2001 (Public Law 106-554) ("Data Quality Act") specifies three components contributing to the quality of a document. They are utility, integrity, and objectivity. This section of the opinion addresses these

DQA components, document compliance with the Data Quality Act, and certifies that this opinion has undergone pre-dissemination review.

4.1. Utility

Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable, and beneficial to the intended users. NMFS has determined, through this ESA section 7 consultation, that operation of the 5 hatchery programs in Lake Washington 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 Muckleshoot Indian Tribe and WDFW (operators); NMFS (regulatory agency); USFWS (regulatory agency); Seattle Public Utility (funders). The scientific community, resource managers, and stakeholders benefit from the consultation through adult returns of program-origin salmon to Lake Washington watershed 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 600.920(j).

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

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

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

5. APPENDIX A: EFFECTS OF HATCHERY PROGRAMS ON SALMON AND STEELHEAD POPULATIONS: REFERENCE DOCUMENT FOR NMFS ESA HATCHERY CONSULTATIONS (REVISED JULY 29, 2020)[1]

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

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

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

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

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

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

literature we do not cite because we question the methodology, results, or conclusions. In citing sources, we also consider availability, and try to avoid sources that are difficult to access. For this reason, we generally avoid citing master's theses and doctoral dissertations, unless they provide unique information.

5.1. 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

5.2. 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.

5.2.1. Genetic effects (Revised July 29, 2020)

5.2.1.1. 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[2] 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:

- 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 what conservation geneticists would likely call "adaptation to captivity" (Allendorf et al. 2013, pp. 408-409) reflects the fairly unique position of salmon and steelhead among ESA-listed species. In ESA-listed Pacific salmon and steelhead, artificial propagation in hatcheries has been used as a routine management tool for many decades, and in some cases the size and scope of hatchery programs has been a factor in listing decisions.

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

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

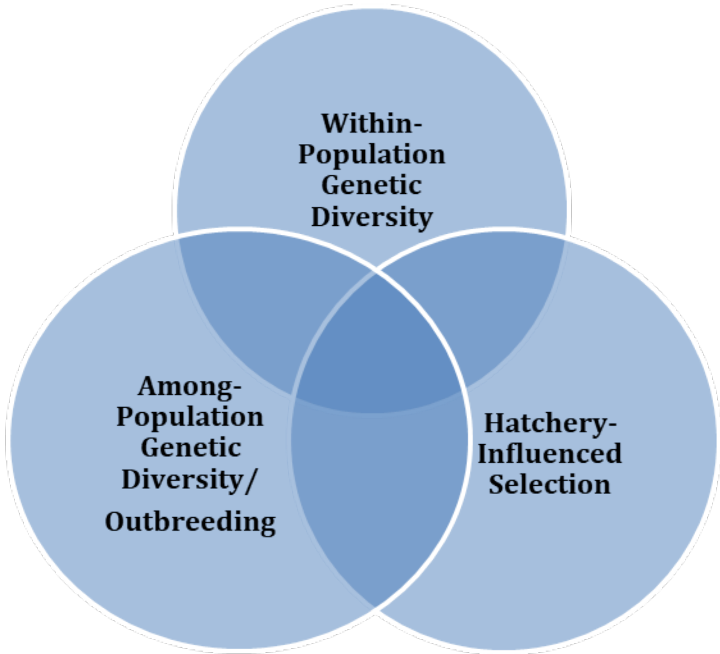

Figure 1. Major categories of hatchery program genetic effects analyzed by NMFS

5.2.1.1.1. Key Terms

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

- **Hatchery-origin (HO)**- refers to fish that have been reared and released by a hatchery program, regardless of the origin of their parents. A series of acronyms has been developed for subclasses of HO fish:
    - **Hatchery-origin recruits (HOR)** – HO fish returning to freshwater as adults or jacks. Usage varies, but typically the term refers to post-harvest fish that will either spawn in nature, used for hatchery broodstock, or surplused.
    - **Hatchery-origin spawners (HOS)**- hatchery-origin fish spawning in nature.
    - **Hatchery-origin broodstock (HOB)**- hatchery-origin fish that are spawned in the hatchery (i.e., are used as broodstock).
- **Natural-origin (NO)**- refers to fish that have resulted from spawning in nature, regardless of the origin of their parents. A series of acronyms has been developed for subclasses of NO fish:
    - **Natural-origin recruits (NOR)** – NO fish returning to freshwater as adults or jacks. Usage varies, but typically the term refers to post-harvest fish that will either spawn in nature or used for hatchery broodstock.

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

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

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

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

  Genetic risk guidelines discussed in Section 5.2.1.4 have been developed based on refinements of pHOS:

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

  - **$pHOS_{eff}$** - $pHOS_{census}$ discounted by the spawning success of HO fish relative to that of NO fish. For example, if HO fish are assumed to be 80 percent as reproductively capable as NO fish, then $pHOS_{eff} \approx 0.8 * pHOS_{census}$[3]

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

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

- **Proportionate natural influence (PNI) -** in a population affected by hatchery programs, the relative selective influence of the natural environment. In populations affected by integrated hatchery programs, PNI is represented mathematically as PNI ≈ pNOB/(pNOB + pHOS). PNI is a confusing concept that we explain in greater detail in Section 5.2.1.4.

[3] We present a more precise equation in Section 5.2.1.4.

5.2.1.1.1.1. pHOS and mating-type frequency

Figure illustrates the expected proportion of mating types in a mixed population of NO and HO fish (denoted as N and H, respectively, in the figure) as a function of $pHOS_{census}$, assuming that NO and HO adults mate randomly[4] (Figure). For example, at a $pHOS_{census}$ level of 10 percent, 81 percent of the matings would be expected to be NxN, 18 percent NxH, and 1 percent HxH.

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

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

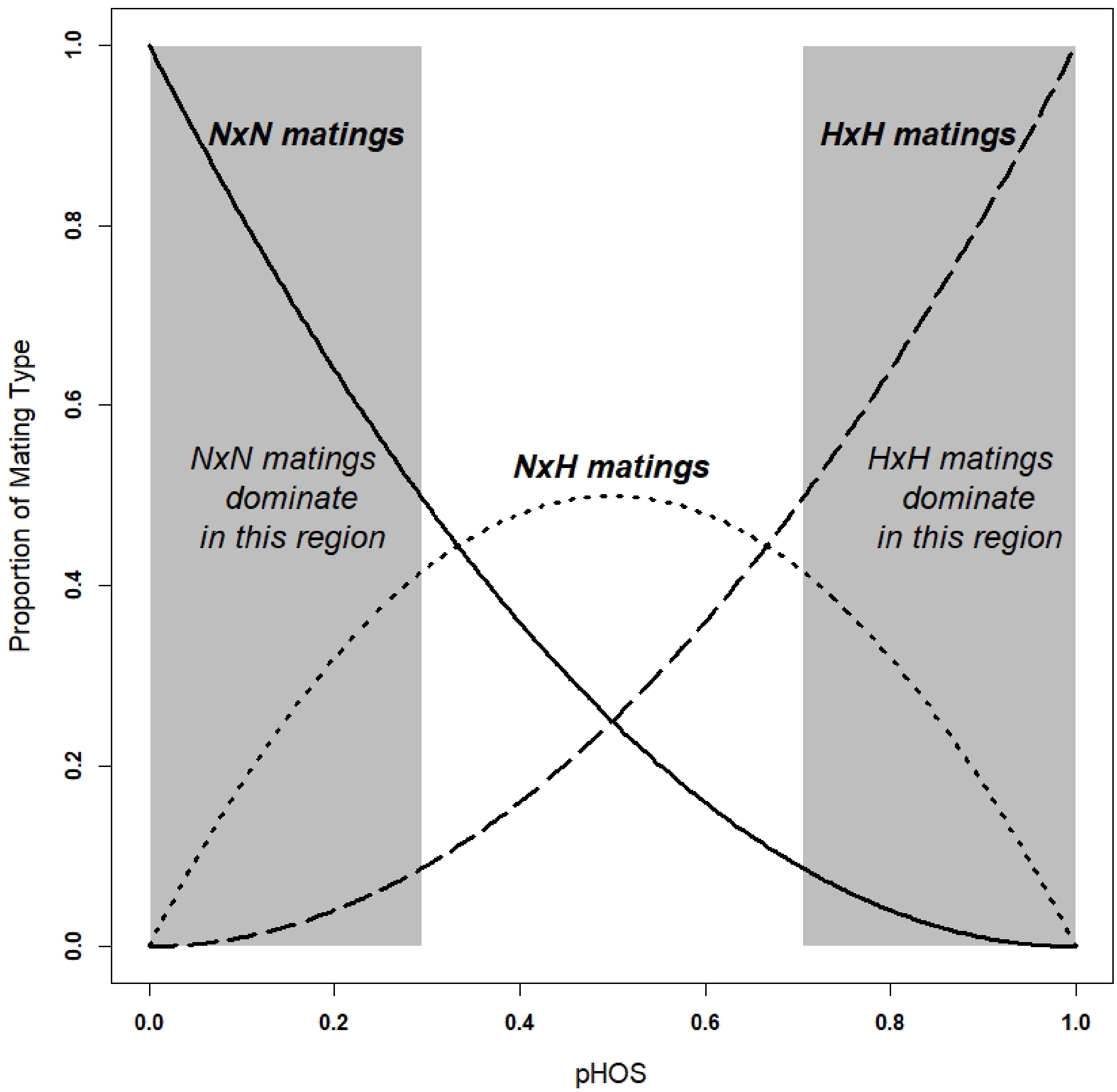


Figure 2. Relative proportions of mating types as a function of proportion of hatchery-origin fish on the spawning grounds (pHOS), assuming random mating. Line codes: solid = NxN, dashed = NxH, dotted = HxH. Shaded rectangles on left and right denote pHOS ranges at which NxN and HxH matings are most probable, respectively.

5.2.1.2. Within-population diversity effects

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

5.2.1.2.1. Genetic drift

Genetic drift is random loss of diversity due to population size. The rate of drift is determined not by the census population size (N_c), but rather by the effective population size (N_e). The effective size of a population is the size of a genetically "ideal" population (i.e., equal numbers of males and females, each with equal opportunity to contribute to the next generation) that will display as much genetic drift as the population being examined (e.g., Falconer and MacKay 1996; Allendorf et al. 2013)[5].

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:

[5] 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.

- 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. 2008a).

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

Hatchery populations should be managed to avoid inbreeding depression. If hatcheries produce inbred fish that return to spawn in natural spawning areas the low genetic variation and increased deleterious mutations can lower the fitness, productivity, and survival of the natural population (Christie et al. 2014b). A captive population that 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 N_e.

5.2.1.2.2. Biased/nonrepresentational sampling

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

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

Another source of biased sampling is non-inclusion of precocious males in broodstock. Precociousness, or early male maturation, is an alternative reproductive tactic employed by Atlantic salmon (Bagliniere and Maisse 1985; Myers et al. 1986), Chinook salmon (Bernier et al. 1993; Larsen et al. 2004), coho salmon (Iwamoto et al. 1964; Silverstein and Hershberger 1992), steelhead (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 5.2.1.4.

5.2.1.3. Among-population diversity/ Outbreeding effects

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

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

Rearing and release practices and ancestral origin of the hatchery fish can all play a role in straying (Quinn 1997). Based on fundamental population genetic principles, a 1995 scientific workgroup convened by NMFS concluded that aggregate gene flow from non-native HO fish from all programs combined should be kept below 5 percent (Grant 1997), and this is the recommendation NMFS uses as a reference in hatchery consultations. It is important to note that this 5% criterion was developed independently and for a different purpose than the HSRG's 5% pHOS criterion that is presented in Section 5.2.1.4.

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

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

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

As discussed in Section 5.2.1.4, pHOS[6] 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).

[6] 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.

5.2.1.4. Hatchery-influenced selection effects

Hatchery-influenced selection (often called domestication[7]), the third major area of genetic effects of hatchery programs that NMFS analyses, occurs when selection pressures imposed by hatchery spawning and rearing differ greatly from those imposed by the natural environment and causes genetic change that is passed on to natural populations through interbreeding with HO fish. These differing selection pressures can be a result of differences in environments or a consequence of protocols and practices used by a hatchery program.

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

[7] 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; Allendorf et al. 2013), and becoming more common in the fish literature (Christie et al. 2011; Fisch et al. 2015) is more precise for species that have been subjected to semi-captive rearing for a few decades. We feel "hatchery-influenced selection" is even more precise, and less subject to confusion.

currently largely focused on gene flow between NO and HO fish[8]. Strong selective fish culture with low hatchery-wild interbreeding can pose less risk than relatively weaker selective fish culture with high levels of interbreeding.

5.2.1.4.1. Relative Reproductive Success Research

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

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

- 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).

[8] 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.

Especially lacking was RRS information on “ocean-type” Chinook. Recent RRS work on Alaskan pink salmon, the species with the shortest hatchery residence time has found very large differences in reproductive success between HO and NO fish. The RRS was 0.42 for females and 0.28 for males (Lescak et al. 2019). This research suggests the “less residence time, less effect” paradigm needs to be revisited.

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

- Coho salmon(Theriault et al. 2011)
- Chum salmon (Berejikian et al. 2009)
- “Ocean-type” Chinook salmon (Anderson et al. 2012; 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)

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

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

This suggests that perhaps the impacts of hatchery-influenced selection on fitness differs between Chinook salmon and steelhead.[9] 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.

5.2.1.4.2. Hatchery Scientific Review Group (HSRG) Guidelines

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

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

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

The HSRG guidelines (HSRG 2009b) vary according to type of program and conservation importance of the population. The HSRG used conservation importance classifications that were developed by the Willamette/Lower Columbia Technical Recovery Team (McElhany et al. 2003).[10] (Table). 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 1. HSRG gene flow guidelines (HSRG 2009b).

	Program classification	
Population conservation importance	**Integrated**	**Segregated**
Primary	**PNI ≥ 0.67 and pHOS ≤ 0.30**	**pHOS ≤ 0.05**
Contributing	**PNI ≥ 0.50 and pHOS ≤ 0.30**	**pHOS ≤ 0.10**
Stabilizing	**Existing conditions**	**Existing conditions**

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

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

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

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

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

NMFS scientists have extended the Ford model for more flexible application of the guidelines to complex situations (Busack 2015) (Section 5.2.1.4.3).

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.

5.2.1.4.2.1. PNI and segregated hatchery programs

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

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

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

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

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

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

(HSRG 2004b) offered additional guidance regarding isolated programs, stating that risk increases dramatically as the level of divergence increases, especially if the hatchery stock has been selected directly or indirectly for characteristics that differ from the natural population. More recently, the HSRG concluded that the guidelines for isolated programs may not provide as much protection from fitness loss as the corresponding guidelines for integrated programs

(HSRG 2014). This can be easily demonstrated using the equation presented in the previous paragraph: a pHOS of 0.05, the standard for a primary population affected by a segregated program, yields a PNI of 0.49, whereas a pHOS of 0.024 yields a PNI of 0.66, virtually the same as the standard for a primary population affected by an integrated program.

5.2.1.4.2.2. The effective pHOS concept

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

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

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

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

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

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

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

5.2.1.4.2.3. Gene flow guidelines in phases of recovery

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

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

The HSRG provided guidance on development of quantitative "triggers" for determining when a population had moved (up or down) from one phase to another. As explained in (HSRG 2015), in the preservation and re-colonization phase, no PNI levels were specified for integrated programs (Table). 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 2. HSRG gene flow guidelines/standards for conservation and harvest programs, based on recovery phase of impacted population (Table 2 from HSRG 2015).

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

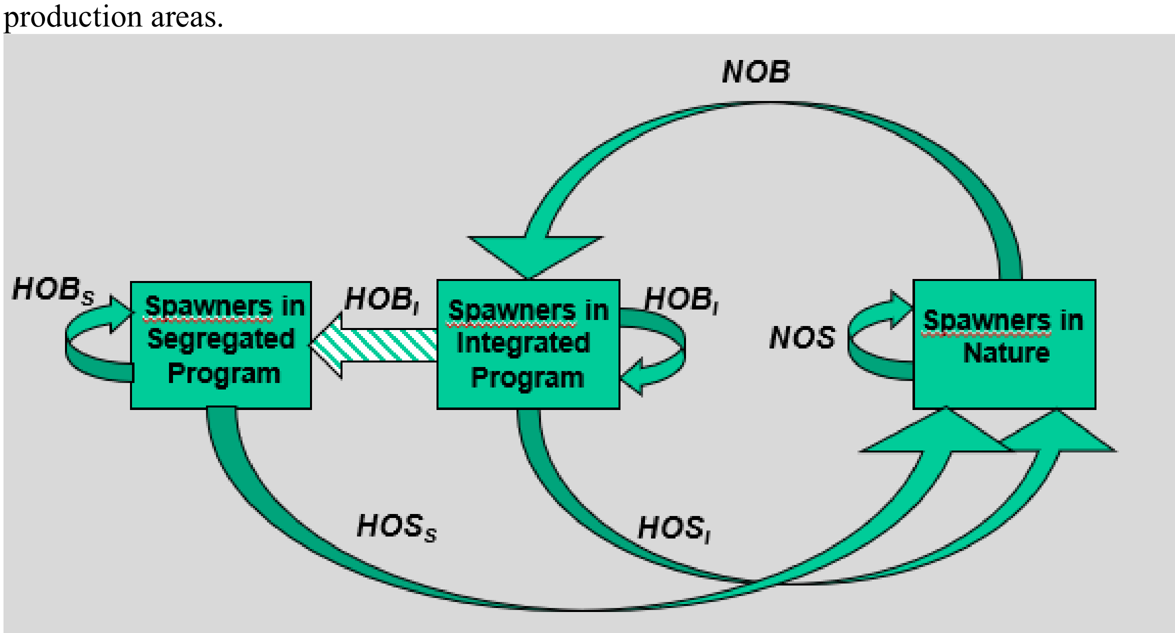
We agree that conservation of populations at perilously low abundance may require prioritization of demographic over genetic concerns, but is concerned that high pHOS/low PNI regimes imposed on small recovering populations may prevent them from advancing to higher recovery phases[11]. A WDFW scientific panel reviewing HSRG principles and guidelines reached the same conclusion (Anderson et al. 2020).

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

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

A good example is a system of genetically linked hatchery programs, an integrated program in which returnees from a (typically smaller) integrated hatchery program are used as broodstock for a larger segregated program, and both programs contribute to pHOS (**Error! Reference source not found.**). It seems logical that this would result in less impact on 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[12](Busack 2015). We have since used the multi-population PNI model in numerous hatchery program consultations in Puget Sound and the Columbia basin, and have extended to it to include as many as ten hatchery programs and natural production areas.



[11] 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).
[12] Such programs can lower the effective size of the system, but the model of Tufto (Section 5.2.1.3) can easily be applied to estimate this impact.

Figure 3 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.

5.2.1.4.4. California HSRG

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

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

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

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

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

5.2.2. Ecological effects

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

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

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

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

5.2.3. Adult Collection Facilities

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

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

5.3. 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.

5.3.1. Competition

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

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

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

A few exceptions to this general stream residence-aggression pattern have been observed (e.g., 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 prior to outmigrating. Other than the (Taylor 1991) and (Hasegawa et al. 2014) papers noted above, we are not aware of any other studies that have looked specifically at interspecific interactions between early-outmigrating species (e.g., sockeye, chum, and pink salmon) and those that rear longer in streams.

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

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

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

- Releasing hatchery smolts that are physiologically ready to migrate. Hatchery fish released as smolts emigrate seaward soon after liberation, minimizing the potential for competition with juvenile natural-origin fish in freshwater (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 areas used for stream-rearing by natural-origin juveniles
- Monitoring the incidence of non-migratory smolts (residuals) after release and adjusting rearing strategies, release location, and release timing if substantial competition with natural-origin juveniles is likely

Critical to analyzing competition risk is information on the quality and quantity of spawning and rearing habitat in the action area,[13] 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.

5.3.2. Predation

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

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

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

Some reports suggest that hatchery fish can prey on fish that are up to 1/2 their length (Pearsons and Fritts 1999; HSRG 2004b), 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

[13] "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.

stream-dwelling salmonids. *O. mykiss* and Pacific salmon were well represented in the reviewed reports. Although there is some variation between species, stream-dwelling salmonids become piscivorous at about 100 mm FL, and then piscivory rate increases with increasing size. For example:

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

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

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

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

5.3.3. Disease

The release of hatchery fish and hatchery effluent into juvenile rearing areas can lead to transmission of pathogens, contact with chemicals or altering of environmental parameters (e.g., dissolved oxygen) that can result in disease outbreaks. Fish diseases can be subdivided into two main categories: infectious and non-infectious. Infectious diseases are those caused by pathogens such as viruses, bacteria, and parasites. Noninfectious diseases are those that cannot be transmitted between fish and are typically caused by genetic or environmental factors (e.g., low dissolved oxygen). Pathogens can also be categorized as exotic or endemic. For our purposes, exotic pathogens are those that have little to no history of occurrence within state boundaries. For example, *Oncorhynchus masou* virus (OMV) would be considered an exotic pathogen if identified anywhere in Washington state. Endemic pathogens are native to a state, but may not be present in all watersheds.

In natural fish populations, the risk of disease associated with hatchery programs may increase through a variety of mechanisms (Naish et al. 2008a), including:

- Introduction of exotic pathogens
- Introduction of endemic pathogens to a new watershed
- Intentional release of infected fish or fish carcasses

- Continual pathogen reservoir
- Pathogen amplification

The transmission of pathogens between hatchery and natural fish can occur indirectly through hatchery water influent/effluent or directly via contact with infected fish. Within a hatchery, the likelihood of transmission leading to an epizootic (i.e., disease outbreak) is increased compared to the natural environment because hatchery fish are reared at higher densities and closer proximity than would naturally occur. During an epizootic, hatchery fish can shed relatively large amounts of pathogen into the hatchery effluent and ultimately, the environment, amplifying pathogen numbers. However, few, if any, examples of hatcheries contributing to an increase in disease in natural populations have been reported (Steward and Bjornn 1990; Naish et al. 2008a). This lack of reporting is because both hatchery and natural-origin salmon and trout are susceptible to the same pathogens (Noakes et al. 2000), which are often endemic and ubiquitous (e.g., *Renibacterium salmoninarum,* the cause of Bacterial Kidney Disease).

Adherence to a number of state, federal, and tribal fish health policies limits the disease risks associated with hatchery programs (IHOT 1995; ODFW 2003; USFWS 2004; WWTIT and WDFW 2006). Specifically, the policies govern the transfer of fish, eggs, carcasses, and water to prevent the spread of exotic and endemic reportable pathogens. For all pathogens, both reportable and non-reportable, pathogen spread and amplification are minimized through regular monitoring (typically monthly) removing mortalities, and disinfecting all eggs. Vaccines may provide additional protection from certain pathogens when available (e.g., *Vibrio anguillarum*). If a pathogen is determined to be the cause of fish mortality, treatments (e.g., antibiotics) will be used to limit further pathogen transmission and amplification. Some pathogens, such as *infectious hematopoietic necrosis virus* (IHNV), have no known treatment. Thus, if an epizootic occurs for those pathogens, the only way to control pathogen amplification is to cull infected individuals or terminate all susceptible fish. In addition, current hatchery operations often rear hatchery fish on a timeline that mimics their natural life history, which limits the presence of fish susceptible to pathogen infection and prevents hatchery fish from becoming a pathogen reservoir when no natural fish hosts are present.

In addition to the state, federal, and tribal fish health policies, disease risks can be further minimized by preventing pathogens from entering the hatchery facility through the treatment of incoming water (e.g., by using ozone) or by leaving the hatchery through hatchery effluent (Naish et al. 2008a). Although preventing the exposure of fish to any pathogens prior to their release into the natural environment may make the hatchery fish more susceptible to infection after release into the natural environment, reduced fish densities in the natural environment compared to hatcheries likely reduces the risk of fish encountering pathogens at infectious levels (Naish et al. 2008a).

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

Noninfectious diseases are those that cannot be transmitted between fish and are typically caused by genetic or environmental factors (e.g., low dissolved oxygen). Hatchery facilities routinely use a variety of chemicals for treatment and sanitation purposes. Chlorine levels in the hatchery effluent, specifically, are monitored with a National Pollutant Discharge Elimination System (NPDES) permit administered by the Environmental Protection Agency. Other chemicals are discharged in accordance with manufacturer instructions. The NPDES permit also requires monitoring of settleable and unsettleable solids, temperature, and dissolved oxygen in the hatchery effluent on a regular basis to ensure compliance with environmental standards and to prevent fish mortality.

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

5.3.4. Ecological Modeling

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

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

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

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

5.3.5. 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:

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

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

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

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

NMFS also considers the overall effectiveness of the RM&E program. There are five factors that NMFS takes into account when it assesses the beneficial and negative effects of hatchery RM&E: (1) the status of the affected species and effects of the proposed RM&E on the species and on designated critical habitat, (2) critical uncertainties concerning effects on the species, (3) performance monitoring and determining the effectiveness of the hatchery program at achieving its goals and objectives, (4) identifying and quantifying collateral effects, and (5) tracking compliance of the hatchery program with the terms and conditions for implementing the program. After assessing the proposed hatchery RM&E, and before it makes any recommendations to the action agency(s) NMFS considers the benefit or usefulness of new or additional information, whether the desired information is available from another source, the effects on ESA-listed species, and cost.

5.4.1. Observing/Harassing

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

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

5.4.2. Capturing/handling

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

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

5.4.3. Fin clipping and tagging

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

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

Most studies have concluded that PIT tags generally have very little effect on growth, mortality, or behavior. Early studies of PIT tags showed no long-term effect on growth or survival (Prentice 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.

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

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

5.4.4. 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.

5.5. 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.

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

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

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

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

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