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

Ten Hatchery Programs for Salmon and Steelhead in the Duwamish/Green River Basin

NMFS Consultation Number: WCR-2016-00014

Action Agencies: National Marine Fisheries Service
Bureau of Indian Affairs

Affected Species and Determinations:

ESA-Listed Species	Status	Is the Action Likely to Adversely Affect Species or Critical Habitat?	Is the Action Likely To Jeopardize the Species?	Is the Action Likely To Destroy or Adversely Modify Critical Habitat?
Puget Sound steelhead (*Oncorhynchus mykiss*)	Threatened	Yes	No	No
Puget Sound Chinook salmon (*O. tshawytscha*)	Threatened	Yes	No	No
Hood Canal Summer Chum (*O. keta)*	Threatened	No	No	No
Ozette Lake Sockeye Salmon (*O. nerka*)	Threatened	No	No	No

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

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

Issued By:

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Assistant Regional Administrator
Sustainable Fisheries Division

Date: April 15, 2019

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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 2 and 3 below. The underlying activities that drive the Proposed Actions are the operation and maintenance of 10 hatchery programs rearing and releasing salmon and steelhead in the Duwamish/Green River Basin (Green River Basin). 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), which were submitted to the National Marine Fisheries Service (NMFS) for review.

Table 1. Green River watershed HGMPs submitted to NMFS for evaluation of ESA-listed salmon and steelhead effects.

Hatchery and Genetics Management Plan	Program Operator[1]	Program Funder[1]
Soos Creek Fall Chinook Hatchery Program	WDFW	WDFW, MIT, PSRE, DJ
Fish Restoration Facility-Fall Chinook Salmon	MIT	MIT, BIA
Fish Restoration Facility Green River Coho Salmon	MIT	MIT, BIA
Keta Creek Complex Yearling Coho Hatchery Program	MIT, SIT	MIT, SIT, BIA
Soos Creek Coho Hatchery Program	WDFW	PSRE, DJ, WDFW
Keta Creek Complex Fall Chum Hatchery Program	MIT	MIT, BIA
Marine Technology Center Coho Hatchery Program	WDFW	PSSC
Fish Restoration Facility Winter Steelhead	MIT	MIT, BIA
Green River Native Winter Steelhead Hatchery Program	WDFW	WDFW, MIT, PSRE, DJ
Green River Summer Steelhead Hatchery Program	WDFW	WDFW, PSRE, DJ

[1]WDFW = Washington Department of Fish and Wildlife; MIT = Muckleshoot Indian Tribe; SIT = Suquamish Indian Tribe; BIA = Bureau of Indian Affairs; PSRE = Puget Sound Recreational Enhancement Fund; DJ = Dingell-Johnson Federal Aid in Sport Fish Restoration Act Fund; PSSC = Puget Sound Skills Center.

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 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 NMFS and the BIA. We also completed an Essential Fish Habitat (EFH) consultation. It was prepared 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 (section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001, Public Law 106-554). The document will be available through the NOAA Institutional Repository approximately two weeks after signature. 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 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, including HGMPs for Green River hatchery programs (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.

After reviewing the HGMPs for the Green River Basin hatchery programs, NMFS determined that they included information sufficient for the agency to complete its determination of whether the HGMPs addressed criteria specified under limit 6 of the ESA (4)d Rule [73 FR 55451 (September 25, 2008)] (Jones 2015; 2016a). For HGMPs determined through NMFS review to satisfy the 4(d) Rule criteria (and, for state HGMPs submitted pursuant to Limit 5 of the Rule, approved), ESA section 9 take prohibitions will not apply to hatchery activities managed in accordance with the plans.

This biological opinion is based on information provided in the Green River Basin HGMPs (Muckleshoot Indian Tribe and Suquamish Indian Tribe 2017; WDFW 2013; WDFW 2014a; WDFW 2014b; WDFW 2014c; WDFW 2017), and addenda created from discussions between NMFS and the co-managers throughout the consultation (Muckleshoot Indian Tribe et al. 2019; Schaffler 2019; Scott 2018). An HGMP for a Soos Creek Hatchery early winter steelhead program in the Green River Basin had been submitted by the co-managers to NMFS for review and approval in 2014 (Scott 2014), but was subsequently withdrawn from consideration by the co-managers (K. Cunningham, WDFW, email sent to Isabel Tinoco, Muckleshoot Indian Tribe, regarding Soos Creek early winter steelhead; and I. Tinoco, Muckleshoot Indian Tribe, email sent to Steve Leider, NMFS, July 8, 2015, regarding Soos Creek early winter steelhead).

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. 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 Actions are: (1) NMFS' determination under limit 6 of the ESA 4(d) rules; and (2) The BIA's ongoing disbursement of funds for operation and maintenance of the tribal hatchery programs listed in Table 1. The objective of this Proposed Action is to document the determination of likely effects on ESA-listed salmon and steelhead and their designated critical habitat resulting from operation and maintenance of the seven salmon and steelhead hatchery programs operating in the Green River Basin. This document evaluates whether the Proposed Actions comply 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.

The purpose of the hatchery programs is to: (1) help meet adult fish loss mitigation responsibilities from past and on-going human developmental activities in the Green River Basin, and from climate change; (2) Expand the prey base for the endangered Southern Resident Killer Whale DPS; (3) Provide salmon and steelhead for harvest for regional recreational and commercial fisheries, tribal treaty fisheries, and Pacific Salmon Treaty harvest sharing agreements with Canada.

The programs have been designed to operate adaptively in response to infrastructure changes, habitat changes, and natural-origin population responses in the Green River watershed. Program modifications are divided amongst four phases: (1) Current infrastructure, (2) Operation of the Fish Restoration Facility, (3) Downstream fish passage provided at Howard Hanson Dam (HHD), (4) Self-sustaining, harvestable, naturally-spawning, natural-origin populations of listed species above HHD. The co-managers have included phases three and four in the Proposed Action to document the long-term intent of the programs, but recognize that information pertinent to the analysis of effects is likely to arise before transition to phases three and four occurs. Thus, the co-managers will contact NMFS prior to moving from phase two to phase three to enable an accurate analysis of the two latter phases on listed species in the Green River watershed.

1.3.1. Proposed hatchery broodstock collection

Details of broodstock origin, collection and number for all programs are listed below in Table 2. The Soos Creek Fall Chinook salmon program will be operated as a genetically linked program, with returns from the integrated component used as broodstock for the segregated component. NMFS defines "integrated" as a program that uses natural-origin fish in the broodstock, and "segregated" or "isolated" as a program that only uses hatchery-origin fish in the broodstock. Once the Fish Restoration Facility (FRF) comes online, this facility will coordinate with the Soos Creek program to produce more fish within the segregated component. More details specific to the two Chinook salmon programs are outlined in Table 3 and Table 4.

The early summer steelhead (ESS) program uses a stock that originates from the Columbia River (Skamania). As a measure to eliminate the potential genetic effects of out of Puget Sound ESS production on the Green River winter steelhead population, the co-managers have included as part of the proposed action that they will transition the Soos Creek Hatchery ESS program to a within Puget Sound summer steelhead stock within 12 spawn years of opinion signature. The details of the transition are yet to be decided by the co-managers.

Table 2. Broodstock collection details. FRF = Fish Restoration Facility; SCH = Soos Creek Hatchery; IC = Icy Creek trap, PP = Palmer Ponds trap; KCC = Keta Creek Complex; TPU = Tacoma Public Utilities fish collection facility; MCH = Miller Creek Hatchery trap; MTC = Marine Technology Center trap.

Program	Local source	Collection Location(s)	Collection Method	Collection/ Holding Target	Collection Duration	pNOB
Soos Creek Fall[1] Chinook: integrated component	Hatchery and natural	SCH, IC, PP, TPU, FRF, Green River	Ladder, weir and trap, seine, net	760[1]	August-October	up to 1
Soos Creek Fall[1] Chinook: segregated component	Hatchery			4,100	August-October	0
FRF Fall Chinook[1]						
FRF Coho	Hatchery and natural	TPU, FRF KCC, SCH, TPU, MTC, MCH	Ladder, weir and trap	4,580	October-December	up to 1
KCC Yearling Coho						up to 1
Soos Creek Coho						up to 1
MTC Coho						0
KCC Fall Chum	Hatchery and natural	KCC	Ladder and trap	5,000	October-December	up to 1
FRF Steelhead[2]	Hatchery and natural	TPU, FRF, SCH, IC, PP Green River	Ladder, weir and trap; Angling, seine, net	280	December-April	up to 1
Green River Native Winter Steelhead[2]	Hatchery and natural				December-April	up to 1
Green River Summer Steelhead[3]	Hatchery: Skamania stock	IC, SCH	Weir and trap	100	July-January	0

[1] Excess natural-origin fall Chinook salmon collected for broodstock will be released back into the mainstem Green River or Soos Creek. The fall Chinook salmon programs will use no more than 40% of the projected natural-origin return post fisheries for broodstock.
[2] Excess natural-origin steelhead broodstock will be released back into the mainstem Green River. The winter steelhead programs will use no more than 20% of the projected natural-origin return post fisheries for broodstock, and target a minimum pNOB of 50%.

Table 3. Summary of Green River Chinook salmon broodstock management for Phases 1 and 2: NOR = natural-origin returns; HOR = hatchery-origin returns; SCH = Soos Creek Hatchery; TPU = Tacoma Public Utilities fish collection facility; FRF = Fish Restoration Facility.

<table>
<tr><th>Phase</th><th>Projected NOR Post Fisheries</th><th>Use of NOR at SCH[1]</th><th>Passage of NOR at Soos Creek</th><th>TPU Trap</th><th>Transport from SCH to Green River</th></tr>
<tr><td rowspan="3">1</td><td>< 500</td><td>Discuss use of NOR</td><td>No NOR passed upstream</td><td>Return HOR when < 4,423 natural spawners; Discuss use of NOR</td><td rowspan="3">Transport HOR to achieve 4,423 natural spawners. Type of transport fish in priority order:
1) NOR
2) integrated HOR[3]
3) segregated HOR</td></tr>
<tr><td>500 - 1,700</td><td rowspan="2">Prioritize NOR for integrated component[2]</td><td>Up to 12% post-fishery NOR passed upstream[4]</td><td rowspan="2">Return HOR when < 4,423 natural spawners; Collect NOR for integrated component</td></tr>
<tr><td>> 1,701</td><td>Up to 200 NOR passed upstream</td></tr>
<tr><th>Phase</th><th>Projected NOR Post Fisheries</th><th>Use of NOR at SCH[1]</th><th>Passage of NOR at Soos Creek</th><th>TPU Trap & FRF</th><th>Transport from SCH to Green River</th></tr>
<tr><td rowspan="3">2</td><td>< 500</td><td>Discuss use of NOR</td><td>No NOR passed upstream</td><td>Collect HOR for FRF; Return surplus HOR to Green River when < 4,423 natural spawners; Discuss use of NOR</td><td rowspan="3">Transport HOR to achieve 4,423 natural spawners. Type of transport fish in priority order:
1) NOR
2) integrated HOR[3]
3) segregated HOR</td></tr>
<tr><td>500 - 1,700</td><td rowspan="2">Prioritize use of collected NOR for integrated component[2]</td><td>Up to 12% of projected post-fishery NOR passed upstream[4]</td><td rowspan="2">Collect HOR for FRF; Return surplus HOR to Green River when < 4,423 natural spawners; Collect NOR for integrated component</td></tr>
<tr><td>> 1,701</td><td>Up to 200 NOR passed upstream</td></tr>
</table>

[1] The use of natural-origin Chinook for broodstock in hatchery programs cannot exceed 40% of the projected post fishery return.
[2] When the projected post-fishery NOR exceeds 500, the priorities for the NORs returning to Soos Creek, the TPU trap, or collected from other locations are as follows: 1) Soos Creek Hatchery integrated program; 2) passage to Soos Creek; and 3) transport to Green River.
[3] The HORs from the integrated component will be prioritized for use as broodstock for the segregated program.
[4] The maximum percentage of NOR passed upstream is abundance dependent as described in Table 4.

The Soos Creek Hatchery weir on Big Soos Creek is operated seasonally to collect Chinook and coho salmon broodstock, as well as summer- and winter steelhead, and the weir would be a temporary barrier to upstream and downstream fish passage. In-channel weirs and traps would also be seasonally operated in association with the Icy Creek, Flaming Geyser, Palmer Ponds, Keta Creek Complex, and the Marine Technology Center facilities. None of the structures used by these facilities are located in surface water areas where listed fish species are present.

Alternative methods may be needed to capture broodstock because of the unknowns associated with the mechanics of the Soos Creek Hatchery rebuild, including how adults will respond to the new fish ladder, weir, and adult ponds in the range of low to high water conditions. These methods could involve seining or netting the area below the new fish ladder entrance down to the bridge at the lower end of the hatchery property, and/or in-river collections at various access points on the Green River to collect natural-origin fish.

Mating Protocols (listed fish only)

Chinook salmon used for broodstock would be selected for spawning randomly as the fish mature, and representatively across the maturation period for the fall Chinook salmon population. If the seasonal egg-take goal for the program is met, but later-spawning females are available, eggs will be collected to represent the later portion of the run, and these eggs will replace the portion of the earlier, segregated eggs collected earlier. 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. Eggs from each female are collected in a separate container and mixed with milt from one male (pairwise spawning). If the male used is not ripe or has little milt, another male is used to assure fertilization.

For the native steelhead programs, broodstock would be selected randomly as the fish mature, and representatively across the maturation period for the steelhead population. Males may be used more than once if primary males are not available on a given spawn day. When this occurs, males would be used no more than four times as primary spawners. Fertilization occurs using factorial crosses, preferably 2x2 or 2x3, when possible, but other combinations may be used. Pairwise spawning would only occur on days when only one female available for spawning.

1.3.2. Proposed Adult Management

For the Chinook salmon programs during phases 1 and 2, the co-managers propose to remove hatchery-origin adults from the various collection sites once the total of naturally spawning fish exceeds 4,423 fish (Table 3). The co-managers also propose to maintain the area in Soos Creek above the weir as a natural production emphasis area by only passing natural-origin adults above the weir. The co-managers will first use any natural-origin Chinook salmon collected in the integrated component of the Soos Creek program up to a 40% use limit on the natural-origin return. Any additional natural-origin adults will then be used to pass above the Soos Creek weir according to a detailed scale, with no more than 200 adults annually (Table 4). In years where natural-origin returns are fewer than 500 fish, the co-managers will discuss adult management with NMFS.

During phase 1, the native winter steelhead program is intended to meet an escapement goal of 2,003 and has no need to manage adults as all adults returning from this program are intended to spawn naturally. During phase 2, the FRF steelhead program intends to release up to 100 returning hatchery-origin adults into Newaukum Creek specifically, and only intends to re-release hatchery-origin adults into the remainder of the Green River Basin to meet an escapement goal of 2,003 spawners (hatchery and natural-origin combined).

None of the other programs propagating non-listed fish species propose to remove adults other than for broodstock purposes and as a result of fisheries.

Table 4. Adult natural-origin Chinook passage above Soos Creek weir based on projected post-fish natural-origin abundance.

Projected Post- Fishery NOR	Maximum Passed Upstream	
	Number	Percent
500	30	6
600	44	7
700	58	8
800	73	9
900	87	10
1,000	101	10
1,100	115	10
1,200	129	11
1,300	143	11
1,400	158	11
1,500	172	11
1,600	186	12
1,700	200	12
> 1,700	200	

1.3.3. 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 5. In the first phase, each program will continue to release fish according to the currently available infrastructure. In phase two, the fish restoration facility comes online, and allows for some juvenile Chinook salmon released at Palmer Ponds to be moved to the FRF. Additional coho and steelhead releases will also take place at this site. In phase three, some of the fish from the FRF site are released upstream of HHD to recolonize salmonid habitat, when recolonization is likely to be successful. In phase four, the releases of fish from the FRF facility upstream of HHD may cease once self-sustaining, naturally-spawning coho, steelhead, and fall Chinook salmon populations are established. Any production required for testing of fish passage at HHD would be in addition to the production detailed in Table 5.

Some additional detail on fish health protocols follows. Prior to hatching, dead eggs are picked on a regular schedule (approximately two times per week) to discourage the spread of fungus. During rearing, regular fish health inspections are conducted. If disease agents are suspected or identified, more frequent inspections will be conducted. Prior to release, final pre-release fish health inspections are conducted by these offices for their respective programs. All fish production is conducted according to the Northwest Indian Fisheries Commission and WDFW fish health policy (NWIFC and WDFW 2006). A few exceptions to this policy occur when fish are transferred as eyed-eggs to various co-operative groups for subsequent rearing and release. For these release groups, which are generally small (< 150,000), co-operative groups contact WDFW personnel if fish start to behave abnormally or if mortality occurs, and fish health specialists are then contacted as needed.

Table 5. Proposed annual release protocols for each program. AD = adipose fin clip; CWT = coded-wire tag; BWT = blank-wire tag; SCH = Soos Creek Hatchery, IC = Icy Creek Rearing Ponds, FGP = Flaming Geyser Ponds, KCC = Keta Creek Complex, MCH = Miller Creek Hatchery, MTC = Marine Technology Center, FRF = Fish Restoration Facility, HHD = Howard Hanson Dam.

Program	Number, life stage, and size (fpp)	Marking and Tagging	Egg incubation and rearing Location	Release Location	Volitional Release?	Release Time
Soos Creek Fall Chinook	3,200,000 subyearling; 80	88% ad; 6% ad and CWT; 6% CWT only	SCH	SCH[2]	No	Early-May to June
	1,000,000 subyearling; 80	100% BWT	SCH	SCH	No	
	2,000,000 subyearling; 45	100% ad	SCH, FRF[3]	Palmer Ponds, SCH, FRF, IC[3]	Yes	June to July 4
	300,000 yearling; 10	100% ad	SCH	IC	Yes	April
FRF Fall Chinook[1]	600,000 subyearling; 65	100% ad; 10% CWT	FRF	FRF, Palmer Ponds	Yes	June
FRF Coho[1]	600,000 yearling; 14	100% ad; 10% CWT	FRF	FRF	Yes	April to May 15
KCC Coho	1,000,000 yearling; 14	100% ad; 10% ad and CWT	KCC	KCC	Yes	April to May 10
	1,000,000 yearling; 9	100% ad; 13% ad and CWT	KCC	Elliott Bay netpens	Yes	June
	50,000 yearling; 14	None	KCC	FRF site	Yes	April to May 15
Soos Creek Coho	600,000 yearling; 17	85% ad; 7.5% ad and CWT; 7.5% CWT	SCH	SCH	Yes	April to May 10
	30,000 yearling; 15	100% ad	SCH	Des Moines Ponds	No	June
	120,000 fed fry; 1500	None	MCH	Miller, Walker and Des Moines Creeks	No	January
KCC Fall Chum	5,000,000 fry; 450-150	None	KCC	KCC	Yes	March 1 to May 15
MTC Coho	10,000 yearling; 11	100% ad	MTC	MTC	No	April
FRF steelhead[1]	250,000 yearling; 5-10	100% ad; 10% CWT	FRF	FRF	No	Mid-April to June 30
Green River Native Winter Steelhead	23,000 yearling; 8	100% BWT	SCH	IC	Yes	May
	15,000 yearling; 8	100% BWT	SCH	FGP	Yes	
	17,000 yearling; 8	100% BWT	SCH	Palmer Ponds	Yes	
Green River Summer Steelhead	100,000 yearling; 5	100% ad	SCH	SCH, IC[4]	Yes[5]	Mid-April to May

[1] These programs are not yet operational.
[2] Up to 1 million subyearlings may undergo final rearing and release at Palmer Ponds as needed as agreed to by the co-managers annually.
[3] Palmer Ponds is the targeted release site for these fish, but other sites listed here may be used as needed or available as agreed to by the co-managers annually. Under phase 2, when the FRF becomes operational, a portion of this release may be reared and released at the FRF.
[4] With co-manager agreement the proportion of the release that occurs at each release site may vary anywhere from 0-1.
[5] Smolts that do not migrate from rearing ponds after a four-week period are collected and planted into non-anadromous waters.

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

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 110% of levels described in the HGMPs and in Table 5; 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) for a species-stage in the Green River is more than 105% of the level described, the co-managers will notify NMFS.

Table 6. Disposition of excess adult hatchery fish, broodstock and post-spawned carcasses.

Program	Disposition
Soos Creek Fall Chinook	• Release hatchery-origin adults into the Green River to achieve the equilibrium escapement goal of 4,423 fish. • Spawned and un-spawned carcasses will be used for nutrient enrichment, donated, and/or sold to a carcass buyer.
FRF Fall Chinook	• Release hatchery-origin adults into the Green River to achieve the equilibrium escapement goal of 4,423 fish. • Spawned and un-spawned carcasses will be used for nutrient enrichment, donated to tribal members, and/or sold to a carcass buyer.
FRF Coho	• Un-spawned adults will be used for nutrient enhancement, donated to tribal members (small quantity), and/or sold to a carcass buyer.
KCC Yearling Coho	• Un-spawned adults will be transferred to the spawning grounds, donated to tribal members (small quantity), and/or sold to a carcass buyer.
Soos Creek Coho	• Release up to 600 natural- and/or hatchery-origin adults into Big Soos Creek
MTC Coho	• Un-spawned adults are killed and frozen on-site for later dissection by students as per the class curriculum.
KCC Fall Chum	• Un-spawned adults will be transferred to the spawning grounds, and spawned and unspawned carcasses will be used for nutrient enrichment, donated, or sold to a carcass buyer.
FRF Steelhead	• Release natural- and/or hatchery-origin adults into Green River Basin tributaries to achieve the escapement goal of 2,003 adults. • Carcasses will be used for nutrient enrichment, donated, or sold to a carcass buyer.
Green River Native Winter Steelhead	• Spawned carcasses will be used for nutrient enrichment, donated, or sold to a carcass buyer.
Green River Summer Steelhead	• Spawned and un-spawned carcasses will be used for nutrient enrichment, donated, or sold to a carcass buyer.

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

All of the Green River Basin hatchery programs include monitoring, evaluation, and adaptive management measures designed to monitor and reduce incidental effects on natural-origin fish populations:

- An adult Chinook salmon monitoring program (stream surveys and biological sampling) would be conducted annually to document HOR/NOR ratios, spawning contributions, spatial structure, diversity, age, sex, and size of natural- and hatchery-origin fish escaping to natural spawning areas and the hatcheries in the Green River Basin.
- Monitoring of Chinook salmon escapement to Green River Basin natural spawning areas to estimate the number of clipped and/or tagged fish escaping to the Green River and basin tributaries each year.
- Foot and boat spawning ground surveys would be implemented to count spawning fish and sample Chinook salmon carcasses for scales, adipose-fin clips, CWT's, and potentially tissues for DNA analysis.
    - The same level and types of biological sampling would be implemented for fish escaping to the hatcheries and collected as broodstock.
- An adult steelhead monitoring program (spawning ground surveys) conducted annually to document abundance and spatial structure of steelhead escaping to natural spawning areas and hatcheries.
- Steelhead genetic samples will be collected and analyzed annually to compare the number of hybrid and hatchery-ancestry.

1.3.6. Proposed operation and maintenance of hatchery facilities

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

Facilities	Surface Water (cfs)	Ground/Spring Water (cfs)	Water Diversion Distance (km)	Water source	Discharge Location	Meet NMFS Screening Criteria (Criteria year)?	NPDES Permit #	WDOE Water Right Permit #
Soos Creek Hatchery	37.64	0.71	0.02	Big Soos Creek	Big Soos Creek	Yes (1995/1996)	WAG 13-3014	S1-000382 (0.71 cfs), S1-000449 (2.64 cfs), S1-21222 (5.0 cfs), and S1-*19055 (30.0 cfs)
Icy Creek Rearing Ponds	20.0	NA	<0.03	Icy Creek	Icy Creek	No	WAG 13-3013	S1-22710
Palmer Rearing Ponds	NA	15.0	NA	NA	Green River	No	WAG 13-3002	S1-*20296
Flaming Geyser Ponds	1.5	NA	0.05	Cristy Creek	Cristy Creek	Yes (2011)	NA[1]	S1-24715
Fish Restoration Facility	Up to 27	Up to 2	1.6	Green River	Green River	Yes (2011)	To be obtained as required	To be obtained
Marine Technology Center	< 5.0	NA	0.05	North Creek	Puget Sound	No	NA[1]	Yes[2]
Keta Creek Complex	10.55	2.0	0.3	Crisp Creek	Crisp Creek	Yes (1995-1996)	WAG 13-0020	S1-23839, S1-24508, S1-22503, and S1-22989
Miller Creek Hatchery	NA	0.04	NA	Miller Creek	Miller Creek	NA	NA[1]	Yes[3]
Elliott Bay Net Pens	NM[4]	NA	NA	Puget Sound	NA	NA	WAG 13-2002	NA
Des Moines Net Pens	NM[4]	NA	NA	Puget Sound	NA	NA	NA	NA

[1] Release less than 20,000 pounds of fish per year and/or feed fish less than 5,000 pounds of fish feed per year and do not require a NPDES permit.
[2] The Marine Technology Center surface water withdrawal rights are regulated under a water rights permit deeded to the Puget Sound Skills Center through a lease with the city of Burien.
[3] The Miller Creek Hatchery water right is held by SWSSD.
[4] Net pens use seawater, passively supplied through tidal flow, for rearing coho salmon, and the amount coursing through the net-pen is not measurable relative to the total amount of water in Puget Sound.

1.4. Interrelated and Interdependent Actions

"Interrelated actions" are those that are part of a larger action and depend on the larger action for their justification. "Interdependent actions" are those that have no independent utility apart from the action under consideration. In determining whether there are interrelated and interdependent actions that should be considered in this consultation, NMFS has considered whether fisheries impacting Green River Hatchery program fish are interrelated or interdependent actions that are subject to analysis in this opinion.

Recreational and tribal fisheries targeting salmon and steelhead produced by the proposed hatchery programs occur within the Green River watershed as well as Puget Sound terminal area marine waters of Elliott Bay. The proposed hatchery programs analyzed in this opinion also contribute to regional fisheries outside of the Green River 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 2016a; NMFS 2017a; NMFS 2018a) and are included in the Environmental Baseline (see Section 2.4.4).

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.

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 for the conservation of a listed species. Such alterations may include, but are not limited to, those that alter the physical or biological features essential to the conservation of a species or that preclude or significantly delay development of such features" (81 FR 7214, February 11, 2016).

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

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
Section 2.5 first describes the various pathways by which hatchery operations can affect ESA-listed salmon and steelhead, then applies that concept to the specific programs considered here.

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) to the proposed action

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

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

This opinion examines the status of each species and designated critical habitat that would be affected by the Proposed Action. The species and the designated critical habitat that are likely to be affected by the Proposed Action, and any existing protective regulations, are described in Table 8. Status of the species is the level of risk that the listed species face based on parameters considered in documents such as recovery plans, status reviews, and ESA listing determinations. The species status section helps to inform the description of the species' current "reproduction, numbers, or distribution" as described in 50 CFR 402.02. The opinion also examines the status and conservation value of critical habitat in the action area and discusses the current function of the essential physical and biological features that help to form that conservation value.

Table 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 collectively at appropriate levels, they maintain a population's capacity to adapt to various environmental conditions and allow it to sustain itself in the natural environment. These parameters or attributes are substantially influenced by habitat and other environmental conditions.

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

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

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

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

In describing the range-wide status of listed species, we rely on viability assessments and criteria in NMFS Technical Recovery Team (TRT) documents and NMFS recovery plans, when available, that describe VSP parameters at the population, major population group (MPG), and species scales (i.e., salmon ESUs and steelhead DPSs). For species with multiple populations, once the biological status of a species’ populations and MPGs have been determined, NMFS assesses the status of the entire species. Considerations for species viability include having multiple populations that are viable, ensuring that populations with unique life histories and phenotypes are viable, and that some viable populations are both widespread to avoid concurrent extinctions from mass catastrophes and spatially close to allow functioning as meta-populations (McElhany et al. 2000).

2.2.1.1. Puget Sound Chinook Salmon ESU

Chinook salmon, *Oncorhynchus tshawytscha,* exhibit a wide variety of life history patterns that include: variation in age at seaward migration; length of freshwater, estuarine, and oceanic residence; ocean distribution; ocean migratory patterns; and age and season of spawning migration. Two distinct races of Chinook salmon are generally recognized: “stream-type” and “ocean-type” (Healey 1991; Myers et al. 1998). Ocean-type Chinook salmon reside in coastal ocean waters for 3 to 4 years, tending to not range very far northward in the Pacific Ocean prior to returning to their natal rivers. Stream-type Chinook salmon, predominantly represented by spring-run Chinook salmon populations, spend 2 to 3 years in the ocean and exhibit extensive offshore ocean migrations. Ocean-type Chinook salmon also enter freshwater later in the season upon returning to spawn than the stream type fish; June through August compared to 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, which 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. Best available information indicates that the Puget Sound Chinook Salmon ESU is at high risk and is threatened with extinction (NWFSC 2015). The Puget Sound Technical Recovery Team (PSTRT) determined that 22 historical natural populations currently contain Chinook salmon and grouped them into five biogeographical regions (BGRs), based on consideration of historical distribution, geographic isolation, dispersal rates, genetic data, life history information, population dynamics, and environmental and ecological diversity. Based on genetic and historical evidence reported in the literature, the TRT also determined that there were 16 additional spawning aggregations or populations in the Puget Sound Chinook Salmon ESU that are now putatively extinct (Ruckelshaus et al. 2006). The ESU encompasses all runs of Chinook salmon from rivers and streams flowing into Puget Sound, including the Strait of Juan de Fuca from the Elwha River eastward, and rivers and streams flowing into Hood Canal, South Sound, North Sound, and the Strait of Georgia in Washington. We use the term ‘‘Puget Sound’’ to refer to this collective area of the ESU. As of 2016, there are 24 artificial propagation programs producing Chinook salmon that are included as part of the listed ESU (71 FR 20802, April 14, 2014). Indices of spatial distribution and diversity have not been developed at the population level, though diversity at the ESU level is declining (NWFSC 2015).

Table 9 summarizes the available information on current abundance and productivity and their trends for the Puget Sound Chinook salmon natural populations including NMFS' critical and rebuilding thresholds and recovery plan targets for abundance and productivity (NMFS 2004a). Most Puget Sound Chinook populations are well below escapement levels and productivity goals required for recovery (Table 9). Abundance across the ESU has generally decreased since the last status review, with only 5 populations showing an increase in natural-origin abundance since the 2010 status review (NWFSC 2015). The remaining 17 populations showed a decline in their 5-year natural-origin abundance as compared to the previous 5-year period. The 5-year geometric mean abundance for the entire ESU was 27,716 natural-origin adults from 2005 through 2009 and only 19,258 from 2010 through 2014; indicating an overall decline of 31% (Table 56 in NWFSC 2015). Natural-origin escapements for 5 populations are above their NMFS-derived rebuilding thresholds (Table 9), while escapements for 10 populations are between their critical and rebuilding thresholds, and natural-origin escapements for 7 populations are below their critical thresholds (Table 9).

Table 9. Estimates of geometric-mean escapement and productivity (1999-2014) for Puget Sound Chinook salmon.

Region	Population	Natural-origin Spawners[1]	Natural-origin Productivity[2]	Critical Escapement Threshold[3]	Rebuilding Escapement Threshold[3]	Recovery Spawner Target with High Productivity[4]	Average % hatchery fish in escapement 1999-2013 (min-max)[5]
Georgia Basin	NF Nooksack	211	0.3	200	Unknown	3,800 (3.4)	85 (63-94)
	SF Nooksack	53	1.7	200	Unknown	2,000 (3.6)	84 (62-96)
Whidbey/Main Basin	Upper Skagit	7,748	1.8	967	7,454	5,380 (3.8)	3 (1-8)
	Lower Sauk	522	1.8	200	681	1,400 (3.0)	1 (0-10)
	Lower Skagit	1,932	1.4	251	2,182	3,900 (3.0)	4 (2-8)
	Upper Sauk	502	1.6	130	330	750 (3.0)	1 (0-5)
	Suiattle	319	1.2	170	400	160 (2.8)	2 (0-5)
	Upper Cascade	291	1.1	170	1,250	290 (3.0)	8 (0-25)
	NF Stillaguamish	582	0.9	300	552	4,000(3.4)	35 (8-62)
	SF Stillaguamish	104	0.7	200	300	3,600 (3.3)	Not Available
	Skykomish	2,052	0.9	1,650	3,500	8,700 (3.4)	30 (8-36)
	Snoqualmie	1,142	1.5	400	1250	5,500 (3.6)	19 (3-62)
Central/South Sound	Cedar	802	1.9	200	1,250	2,000 (3.1)	20 (10-36)
	Sammamish	128	0.5	200	1,250	1,000 (3.0)	86 (66-95)
	Duwamish/Green	1,179	1.1	835	5,523	Unknown	57 (33-75)
	White[6]	1,268	0.6	200	1,100	Unknown	39 (15-49)
	Puyallup[7]	655	0.8	200	522	5,300 (2.3)	53 (18-77)
	Nisqually	522	1.0	200	1,200	3,400 (3.0)	72 (53-85)
Hood Canal	Skokomish	345	0.8	452	1,160	Unknown	66 (7-95)
	Mid-Hood Canal[8]	Not available	Not available	200	1,250	1,300 (3.0)	66
Strait of Juan de Fuca	Dungeness	114	0.6	200	925	1,200 (3.0)	67 (39-96)
	Elwha[9]	117	Not available	200	1,250	6,900 (4.6)	94 (92-95)

Source: (NWFSC 2015)

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

[2] Source is Abundance and Productivity Tables from NWFSC database; measured as the mean of observed recruits/observed spawners. Sammamish productivity estimate has not been revised to include Issaquah Creek.

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

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

[5] Estimates of the fraction of hatchery fish in natural spawning escapements are from the Abundance and Productivity Tables and co-manager postseason reports on the Puget Sound Chinook Harvest Management Plan (PSIT and WDFW 2013; WDFW and PSTIT 2005; WDFW and PSTIT 2008; WDFW and PSTIT 2009; WDFW and PSTIT 2010; WDFW and PSTIT 2011; WDFW and PSTIT 2012)and the 2010-2014 Puget Sound Chinook Harvest Management Plan (PSIT and WDFW 2010). North Fork and South Fork Nooksack estimates are through 2011 and 2010, respectively. Skagit estimates are through 2011.
[6] Captive broodstock program for early run Chinook salmon ended in 2000; estimates of natural spawning escapement include an unknown fraction of naturally spawning hatchery-origin fish from late- and early run hatchery programs in the White and Puyallup River basins.
[7] South Prairie index area provides a more accurate trend in the escapement for the Puyallup River because it is the only area in the Puyallup River for which spawners or redds can be consistently counted (PSIT and WDFW 2010).
[8] The Puget Sound TRT considers Chinook salmon spawning in the Dosewallips, Duckabush, and Hamma Hamma rivers to be subpopulations of the same historically independent population; annual counts in those three streams are variable due to inconsistent visibility during spawning ground surveys. Data on the contribution of hatchery fish is very limited; primarily based on returns to the Hamma Hamma River.
[9] Estimates of natural escapement do not include volitional returns to the hatchery or those fish gaffed or seined from spawning grounds for broodstock collection.

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

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

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

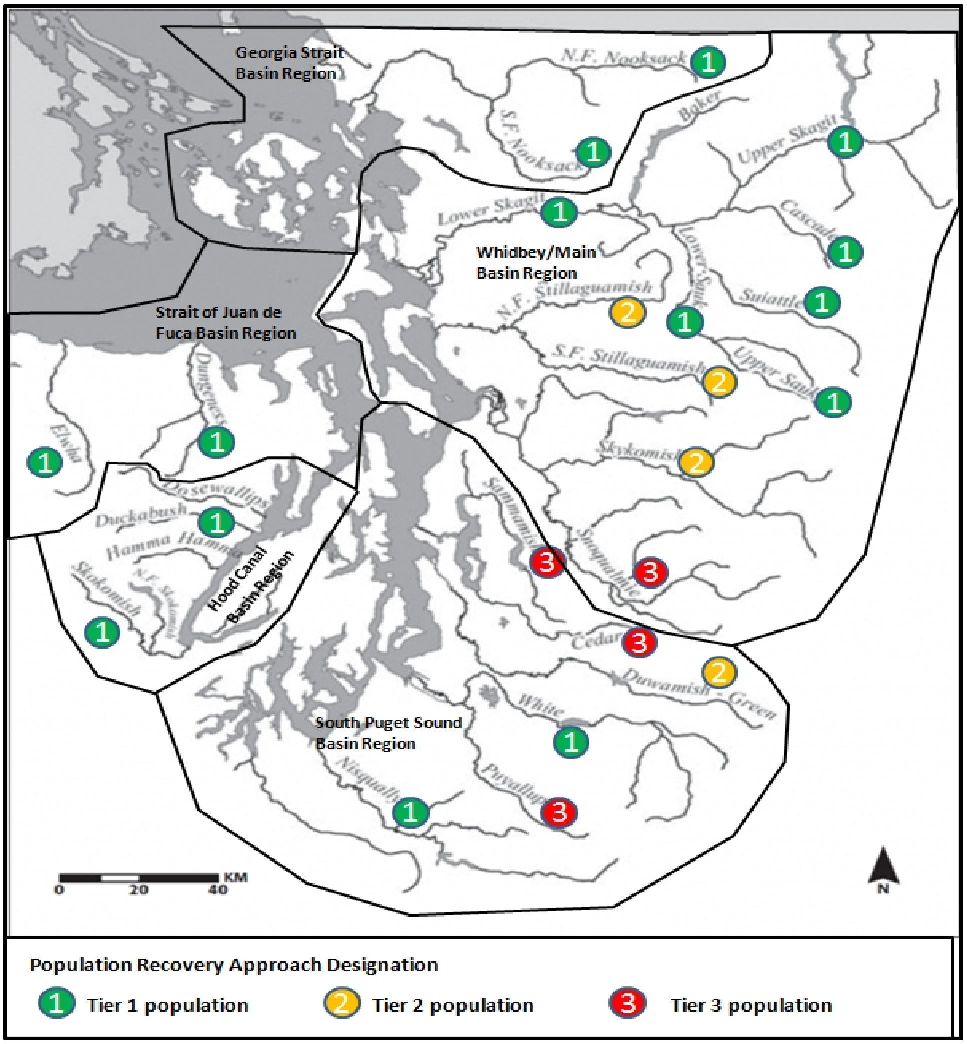

Figure 1. Populations delineated by NMFS for the Puget Sound Chinook salmon ESU (NMFS 2010b; SSPS 2007) and their assigned Population Recovery Approach tier status (NMFS 2010b; SSPS 2007)). Note: Dosewallips, Duckabush and Hamma Hamma River Chinook salmon are aggregated as the "Mid Hood Canal" population.

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

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

- Salmon harvest management: Total fishery exploitation rates have decreased 14 to 63% from rates in the 1980s, but low natural-origin Chinook salmon population abundance in Puget Sound still require enhanced protective measures to reduce the risk of overharvest.

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

Central-South Puget Sound BGR and the Green River Population

The Central-South Sound BGR contains seven extinct and six extant Chinook salmon populations—the extant populations are the Sammamish, Cedar, Green, Puyallup, White, and Nisqually. The early-spawning White River population and the late-spawning Nisqually population would need to be viable for recovery of the ESU (NMFS 2006b). The majority of the existing spawning aggregations are genetically similar and appear to reflect extensive influence of hatchery releases, mostly from the Green River hatchery program. Evidence suggests that much of the life-history diversity represented by early-type populations or population components that existed historically in the Puget Sound Chinook Salmon ESU has been lost, so protection of the remaining early-type populations like the White River population is particularly important to recovery of the ESU.

The extant Green River Chinook salmon population is considered a fall-timed (or “late”) population, based on spawn timing (Ruckelshaus et al. 2006). Most maturing Green River Chinook salmon migrate south along the coastal waters of British Columbia and enter Puget Sound beginning in June and July (Ruggerone and Goetz 2004). A mark and recapture study conducted in the 1970s indicated that entry-timing into the lower Duwamish River was from late-July through September, with little difference in the entry-timing between hatchery- and natural-origin Chinook salmon (Tribe and USFWS 1977). The Chinook salmon population spawns in the watershed from mid-September through October (WDFW and WWTIT 1994). Chinook salmon spawn in the mainstem Green River from river mile (RM) 24 to 61, up to the point where the Tacoma Power Utility diversion structure blocks upstream migration. Spawning distribution in the tributaries is limited to primarily Big Soos and Newaukum Creeks (Eric Warner, MIT, personal communication).

Five potential juvenile Chinook salmon rearing life-history trajectories have been identified in the Green River watershed, with the most common trajectories currently expressed being: (1) fry that migrate soon (days to weeks) after emergence from the spawning grounds in the middle Green River and then rear in the lower river and/or in brackish water (for up to 3 months); and (2) juveniles that rear near their spawning grounds for 3 to 4 months before migrating relatively quickly through the lower river and into the Puget Sound (Ruggerone and Weitkamp 2004). Typically, juvenile emigration monitoring occurs from mid-January through early-July in the mainstem Green River (Topping and Anderson 2016). Green River juvenile Chinook salmon emigration is bi-modal with a peak migration of fry-sized Chinook salmon occurring in February, followed by a parr-size fish migration that peaks in May or June.

The current abundance of Green River natural-origin Chinook salmon is substantially reduced from historical levels, which are estimated to have ranged from 9,000 to 37,700 adult fish (Watershed Resource Inventory Area 9 Steering Committee 2005). Between 1999 and 2014, the geometric mean total annual naturally spawning Chinook salmon escapement was 1,179 natural-origin spawners compared with the recovery goal of 27,000 fish at low productivity (NMFS 2006b). Hatchery-origin Chinook salmon associated with Soos Creek Chinook salmon hatchery program make up a sizable fraction of the annual naturally spawning adult abundance; averaging 65% for the basin (range: 36-79%; see Figure 2). The most recent age-at-return data (2007-2012) indicates that adults mature primarily at age four (71%), with age-3 and age-5 adults comprising 25% and 4%, of the annual returns, respectively (Topping and Anderson 2016).

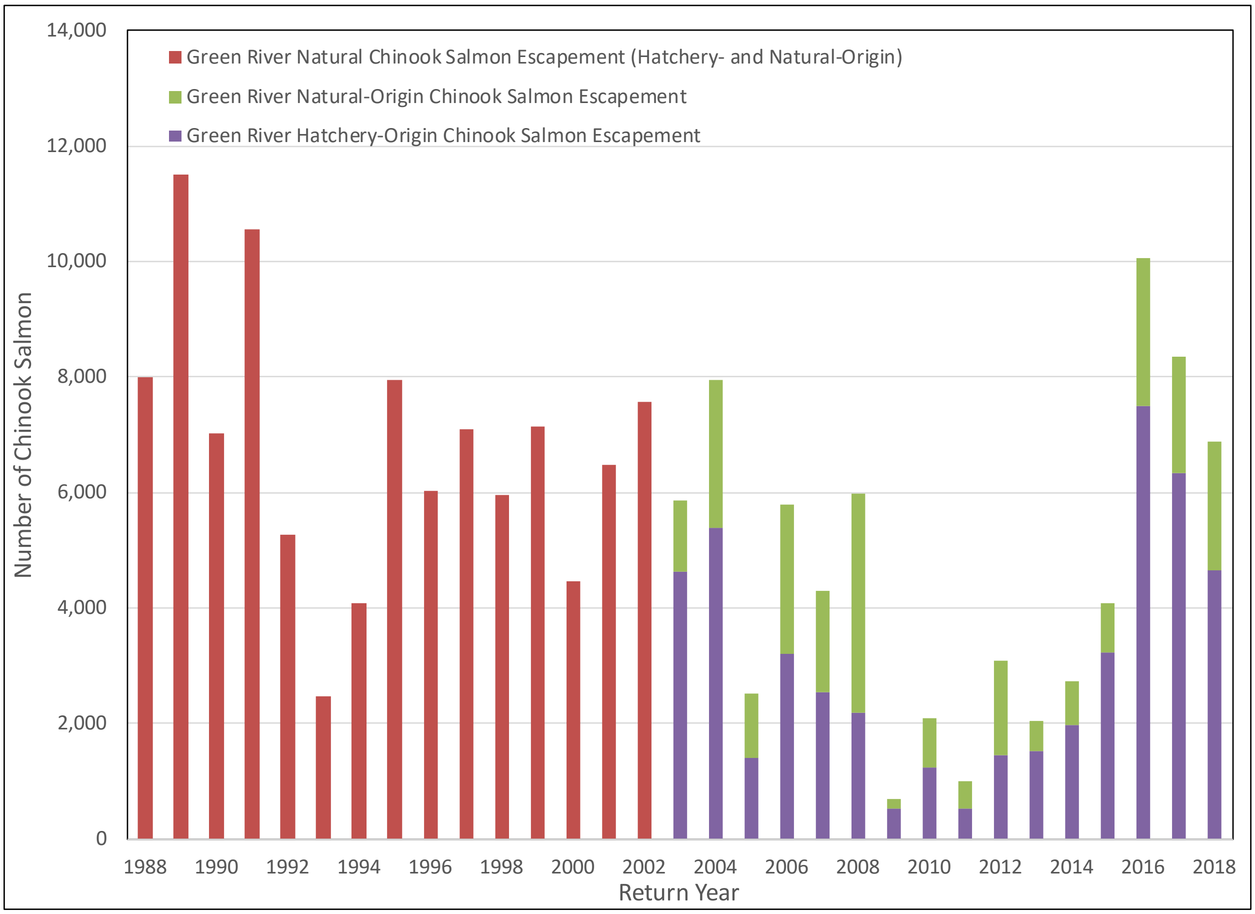

Figure 2. Estimated annual naturally spawning Chinook salmon escapement abundance in the Green River from 1988-2018. Natural- and hatchery-origin breakouts are included for years where data are available (WDFW Score).

Due to the advent of mass marking of hatchery fish, return year 2003 is the first year in which escapement can be differentiated between hatchery- and natural-origin Chinook salmon within the basin. Escapement estimates include all Chinook salmon spawning within the mainstem Green River and within the Newaukum Creek subbasin, but do not include Chinook salmon, which escape and spawn within Big Soos Creek. The most recent NMFS status review for the ESU found that natural productivity has been below replacement for the Green River population since the mid-1980s (NWFSC 2015). However, more recent data included in Topping and Anderson (2016) indicates that at least one brood year (2009) had a spawner-to-spawner replacement rate greater than one.

Spatial structure and diversity for the Green River Chinook population has also been adversely affected over time relative to historical levels. A full spanning double-rack weir was operated in the mainstem Green River in association with the Green River Hatchery program from 1902 to the mid-1920s. The weir restricted upstream access by Chinook salmon and spawning in the middle- and upper- Green River watershed for approximately 25 years (Becker 1967). Tacoma Public Utilities (TPU) completed construction of the Green River Headworks Dam in 1913 at RM 61.0, which acts as a complete barrier to upstream fish migration. Dams, dikes, levees, and other actions to control the lower reaches of the river and tributaries have adversely affected population spatial structure, particularly through adverse impacts on estuarine, wetland, mainstem, side-channel, and tributary habitats (Watershed Resource Inventory Area 9 Steering Committee 2005). These actions have degraded available spawning and migration areas for adult fish, and refugia for rearing juvenile salmon.

2.2.1.2. Status of Critical Habitat for Puget Sound Chinook Salmon

Designated critical habitat for the Puget Sound Chinook ESU 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, Green, 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 (HUC5 basins) 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). All nineteen nearshore marine areas also received a rating of high conservation value. Of the 4,597 miles of stream and nearshore habitat eligible for designation, 3,852 miles are designated critical habitat (NMFS 2005a). Of the three subbasins within the action area (Lower Green, Middle Green and Upper Green), two received high and one medium (Upper Green) conservation value ratings (NMFS 2005a).

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 the Green River salmon populations, include:

1. Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation and larval development.
2. Freshwater rearing sites with: (i) Water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; (ii) Water

quality and forage supporting juvenile development; and (iii) Natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.

3. Freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival.
4. Estuarine areas free of obstruction and excessive predation with: (i) Water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh- and saltwater; (ii) Natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels; and (iii) Juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation.
5. Nearshore marine areas free of obstruction and excessive predation with: (i) Water quality and quantity conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation; and (ii) Natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels.
6. Offshore marine areas with water-quality conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation.

Critical habitat is designated for Puget Sound Chinook salmon within the Green River Basin action area. Critical habitat includes the estuarine areas and the stream channels within the proposed stream reaches of the Green River watershed, and includes a lateral extent as defined by the ordinary high-water line (33 CFR 319.11). The Puget Sound Critical Habitat Analytical Review Team identified management activities that may affect the PCEs in the three subbasins including agriculture, channel modifications/diking, dams, forestry, urbanization, and irrigation and water withdrawals (NMFS 2005a).

2.2.1.3. Puget Sound Steelhead DPS

Oncorhynchus mykiss has an anadromous form, commonly referred to as steelhead. Steelhead differ from other Pacific salmon in that they are iteroparous (capable of spawning more than once before death). Adult steelhead that have spawned and returned to the sea are referred to as kelts. Averaging across all West Coast steelhead populations, 8% of spawning adults have spawned previously, with coastal populations containing a higher incidence of repeat spawning compared to inland populations (Busby et al. 1996). Steelhead express two major life history types—summer and winter. Puget Sound steelhead are dominated by the winter life history type and typically migrate as smolts to sea at age two. Seaward emigration occurs from April to mid-May, with fish typically spending one to three years in the ocean before returning to freshwater. They migrate directly offshore during their first summer, and move southward and eastward during the fall and winter (Hartt and Dell 1986). Adults return from December to May, and peak spawning occurs from March through May. Summer steelhead adults return from May through October and peak spawning occurs the following January to May (Hard et al. 2007) . Temporal overlap exists in spawn timing between the two life history types, particularly in northern Puget Sound where both summer and winter steelhead are present, although summer steelhead typically spawn farther upstream above obstacles that are largely impassable to winter steelhead (Behnke and American Fisheries Society 1992; Busby et al. 1996).

The Puget Sound steelhead DPS was listed as threatened on May 11, 2007 (72 FR 26722), and the 2015 status review determined that the DPS should remain threatened (NWFSC 2015). The DPS includes all naturally spawned anadromous winter and summer steelhead populations within the river basins of the Strait of Juan de Fuca, Puget Sound, and Hood Canal, Washington, bounded to the west by the Elwha River (inclusive) and to the north by the Nooksack River and Dakota Creek (inclusive) (see Figure 3). 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 (FR 79 20802, April 14, 2014). Non-anadromous "resident" *O. mykiss* occur within the range of Puget Sound steelhead, but are not part of the DPS due to key differences in physical, physiological, ecological, and behavioral characteristics (Hard et al. 2007). Puget Sound steelhead populations are aggregated into three extant Major Population Groups (MPGs) containing a total of 32 Demographically Independent Populations (DIPs) based on genetic, environmental, and life history characteristics (Myers et al. 2015) (Table 10).

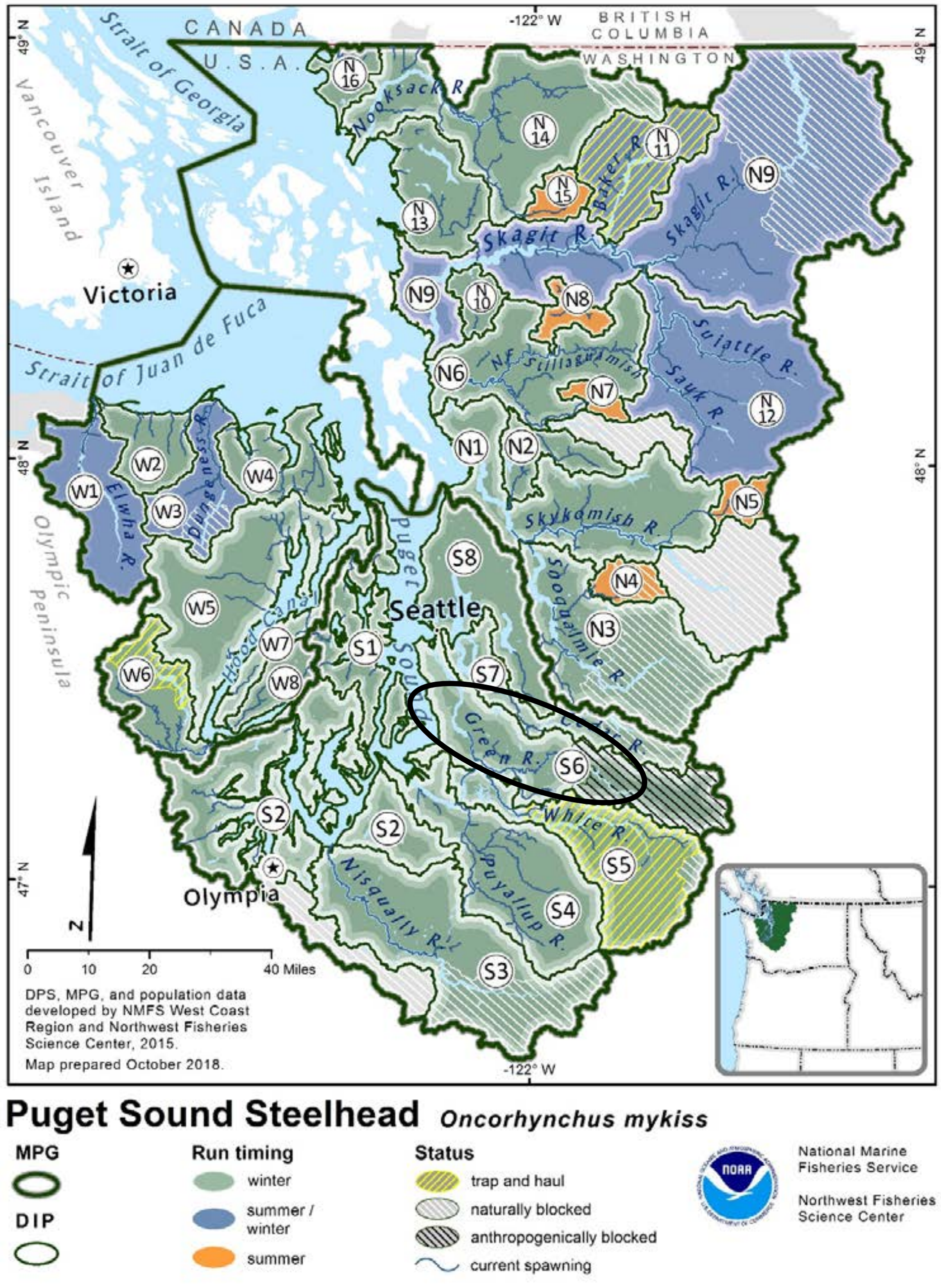

Figure 3. Location of the Green River steelhead population in the Puget Sound DPS (generalized location indicated by the black oval).

Table 10. Puget Sound steelhead populations and extinction risks (Hard et al. 2015).

MPG	Population (Run Time)	Extinction Risk[1]	QET[1]
Northern Cascades	Drayton Harbor Tributaries (winter)	Unable to calculate	--
	SF Nooksack River (summer)	Unable to calculate	--
	Nooksack River (winter)	Unable to calculate	--
	Samish River/Bellingham Bay (winter)	Low-30% within 100 years	31
	Skagit River (summer/winter)	Low-10% within 100 years	157
	Baker River (summer/winter)	Unable to calculate	--
	Sauk River (summer/winter)	Unable to calculate	--
	Snohomish/Skykomish River (winter)	Low-40% within 100 years	73
	Stillaguamish River (winter)	High-90% within 25 years	67
	Deer Creek (summer)	Unable to calculate	--
	Canyon Creek (summer)	Unable to calculate	--
	Tolt River (summer)	High-80% within 100 years	25
	NF Skykomish River (summer)	Unable to calculate	--
	Snoqualmie (winter)	High-70% within 100 years	58
	Nookachamps (winter)	Unable to calculate	--
	Pilchuck (winter)	Low-40% within 100 years	34
Central and South Puget Sound	Sammamish (winter)	Unable to calculate	--
	Cedar River (summer/winter)	High-90% within the next few years	36
	Green River (winter)	Moderately high-50% within 100 years	69
	Nisqually River (winter)	High-90% within 25 years	55
	Puyallup/Carbon River (winter)	High-90% within 25-30 years	--
	White River (winter)	Low-40% within 100 years	64
	South Sound Tributaries (winter)	Unable to calculate	--
	East Kitsap (winter)	Unable to calculate	--
Hood Canal and Strait of Juan de Fuca	Elwha River (summer[2]/winter)	High-90% currently	41
	Dungeness River (summer/winter)	High-90% within 20 years	30
	South Hood Canal (winter)	High-90% within 20 years	30
	West Hood Canal (winter)	Low-20% within 100 years	32
	East Hood Canal (winter)	Low-40% within 100 years	27
	Skokomish River (winter)	High-70% within 100 years	50
	Sequim/Discovery Bay Independent Tributaries (winter)	High-90% within 100 years (Snow Creek)	25
	Strait of Juan de Fuca Independent Tributaries (winter)	High-90% within 60 years (Morse & McDonald creeks)	26

[1] Defined as the probability of decline to an established quasi-extinction threshold (QET; numbers of fish) for each population.
[2] Native summer in the Elwha River basin may no longer be present. Further work is needed to distinguish whether existing feral summer steelhead are derived from introduced Skamania Hatchery (Columbia River) summer run.

The 2015 status review indicated some minor increases in spawner abundance and/or improving productivity over the last few years for Puget Sound steelhead; however abundance and productivity throughout the DPS remain at levels of concern. The recent increases in abundance observed in a few populations are encouraging, but are within the range of variability observed in the past several years and overall trends in abundance of natural-origin spawners remain predominately negative. Reductions in hatchery production for both summer and winter steelhead, as well as reduced harvest, have reduced adverse effects on natural populations in recent years.

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

- Continued destruction and modification of steelhead habitat
- Widespread declines in adult abundance (total run size), despite significant reductions in harvest in recent years
- Threats to diversity from non-local hatchery steelhead stocks
- Declining diversity in the DPS
- A reduction in spatial structure for steelhead in the DPS
- Reduced habitat quality through changes in river hydrology, temperature profile, downstream gravel recruitment, and reduced movement of large woody debris
- Increased flood frequency and peak flows during storms, and reduced groundwater-driven summer flows have resulted in gravel scour, bank erosion, and sediment deposition
- Dikes, hardening of banks with riprap, and channelization have reduced river braiding and sinuosity, and increased the likelihood of gravel scour and dislocation of rearing juveniles

The Central and South Puget Sound MPG and the Green River Population

The Central and South Puget Sound MPG encompassing the Green River Basin, which is the focus of this consultation, has 8 winter DIPs (Table 10), and accounts for 13% of the steelhead abundance in the DPS (NWFSC 2015). Although information on the DIPs is limited, abundance varies greatly among the populations with the Green, White, Puyallup, and Nisqually populations comprising the majority of steelhead in the MPG (Table 11). Risk assessment by the PSTRT indicated three populations are at high risk of extinction (Cedar, Nisqually, and Puyallup/Carbon), one at moderately high risk (Green), and one at low risk (White) (Table 10).

Table 11. Naturally spawning steelhead abundance and trends for DIPs within the Central and South Puget Sound MPG for which information is available; NA = Not available.

Population	2005-2009 Geometric Mean Spawners	2010-2014 Geometric Mean Spawners	Percent Change
Cedar River winter	12	4	-67
Sammamish winter	12	NA	NA
Green River winter[1]	986	621	-37
Puyallup and Carbon River winter	326	386	18
White River winter[2]	237	361	53
Nisqually River winter	446	478	7

Source: modified and updated from NWFSC 2015; WDFW Score Database; and Unpublished WDFW Puget Sound steelhead escapement spreadsheet.
[1] Includes hatchery-origin steelhead from WDFW's integrated conservation program and natural-origin escapement.
[2] Includes only natural-origin spawners upstream of Mud Mountain Dam. Approximately 25% of the annual spawning escapement spawns below the dam. Spawners is this area may include both natural- and hatchery-origin steelhead.

Winter steelhead in the Green River Basin enter freshwater as adults between November and May. Spawning occurs from March through June, with peak spawning in April (Hard et al. 2007). Most Green River winter steelhead return to spawn as four-year-old (45%) and five-year-old fish (44%) (Myers et al. 2015). Winter steelhead spawn throughout the mainstem, as well as in side-channels and the larger tributaries (e.g., Big Soos, Covington, Jenkins, and Newaukum Creeks). In the past, tributary spawning (primarily in Bog Soos and Newaukum Creeks) accounted for up to 55% (1984) of the total wild escapement in the basin. The five-year mean tributary contribution has dropped from 40% in 1987, to less than 11% since 2005 (WDFW 2017). Intrinsic potential (IP) production estimates[1] based on basin geological, hydrologic, and ecological characteristics indicate the Green River Basin could support a total winter steelhead abundance of approximately 19,768 to 39,537 adults (Myers et al. 2015). By comparison, the recent 5-year (2014-2018) combined mean escapement for the winter population in the Green River Basin is 1,342 fish (WDFW Score Database).

Age data collected from migrating steelhead smolts from 2011 through 2015 indicate that 48, 50, and 2% of the smolts trapped in the Green River were age 1+, age 2+, and age 3+, respectively (Topping and Anderson 2016). Note that age and length data may not be representative of the population at large because different-aged and -sized fish may have different capture rates at the juvenile trap. Typically, median smolt catch occurs during the first or second week of May. Estimates of total steelhead smolt production upstream of the smolt trap located at RM 34.5 are only available for four of the 16 years the trap has operated. Production ranged from a low of 15,333 fish (2013) to a high of 71,710 fish (2010) averaging 36,215 fish for trapping years 2009, 2010, 2013, and 2014 (Topping and Anderson 2016). IP production estimates indicate that historically the basin could support a total winter steelhead abundance of approximately 197,680 smolts (Myers et al. 2015).

[1] The intrinsic potential estimates include all habitat upstream of the estuary, including the mainstem and tributaries, as well as all habitat upstream of TPU diversion structure.

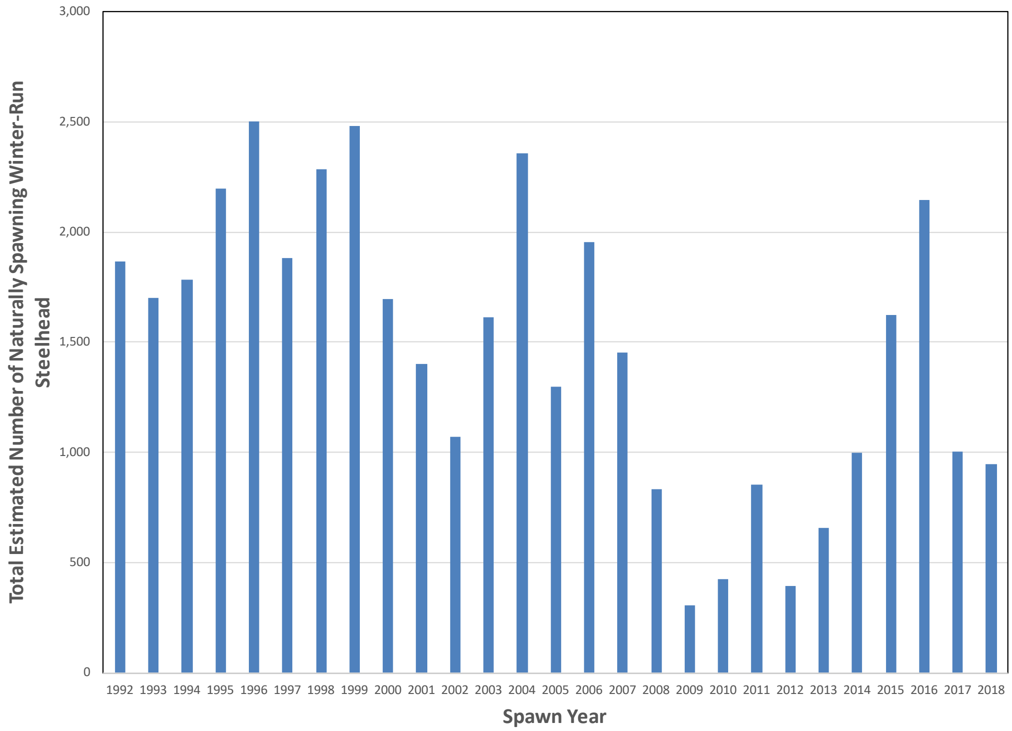

Figure 4. Number of naturally spawning Green River winter steelhead from 1992-2018. Note returns after 2002 may include hatchery-origin steelhead from the Green River integrated conservation hatchery program (WDFW Score Database).

Human developmental activities in the Green River Basin have reduced steelhead population spatial structure. Scott and Gill (2008) reported that the distribution of winter steelhead in the basin has been reduced from 34% to 48% (currently 116 miles) from the pre-development distribution of 175 to 225 miles of riverine habitat. Data are not available to evaluate changes in the diversity of steelhead in the Green River Basin. However, it is likely that the degradation and loss of habitat in the watershed, tributary diversion, dam construction, and past harvest practices that disproportionately affected the earliest returning fish, have reduced the diversity of the species relative to historical levels. In addition, releases of early winter and summer steelhead from hatcheries have likely reduced the genetic diversity of the native winter population in watershed areas where spawn timing for natural and hatchery-origin fish have overlapped.

2.2.1.4. Status of Critical Habitat for Puget Sound Steelhead

Critical habitat has been designated for Puget Sound steelhead (81 FR 9252, February 24, 2016). 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. Steelhead move rapidly out of freshwater and into offshore marine areas, unlike other salmonid species including Puget Sound Chinook salmon and Hood Canal summer chum salmon. It also does not include offshore marine areas. There are 18 subbasins (HUC4 basins) containing 66 occupied watersheds (HUC5 basins) within the range of this DPS. Nine watersheds received a low conservation value rating, 16 received a medium rating, and 41 received a high rating to the DPS (78 FR 2726, January 14, 2013). There are three watersheds (HUC 5 basins) within the Green River Basin: Upper Green River, Middle Green River, and Lower Green River. All three received a high conservation rating. In the proposed and final rules for Puget Sound steelhead (78 FR 2726; 81 FR 9252), PCEs were the same as those detailed above for Puget Sound Chinook salmon (section 2.2.1.2).

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 2013) 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.

2.3. Action Area

The "action area" means all areas to be affected directly or indirectly by the Proposed Action, in which the effects of the action can be meaningfully detected, measured, and evaluated (50 CFR 402.02). The action area resulting from this analysis includes the places within or near (i.e., Snoqualmie River) the Green River Basin where salmon and steelhead originating from the proposed hatchery programs would migrate, and spawn naturally (Figure 5). The action area also includes the marine waters of the Salish Sea to Cape Flattery off the Washington Coast in the Pacific Ocean.

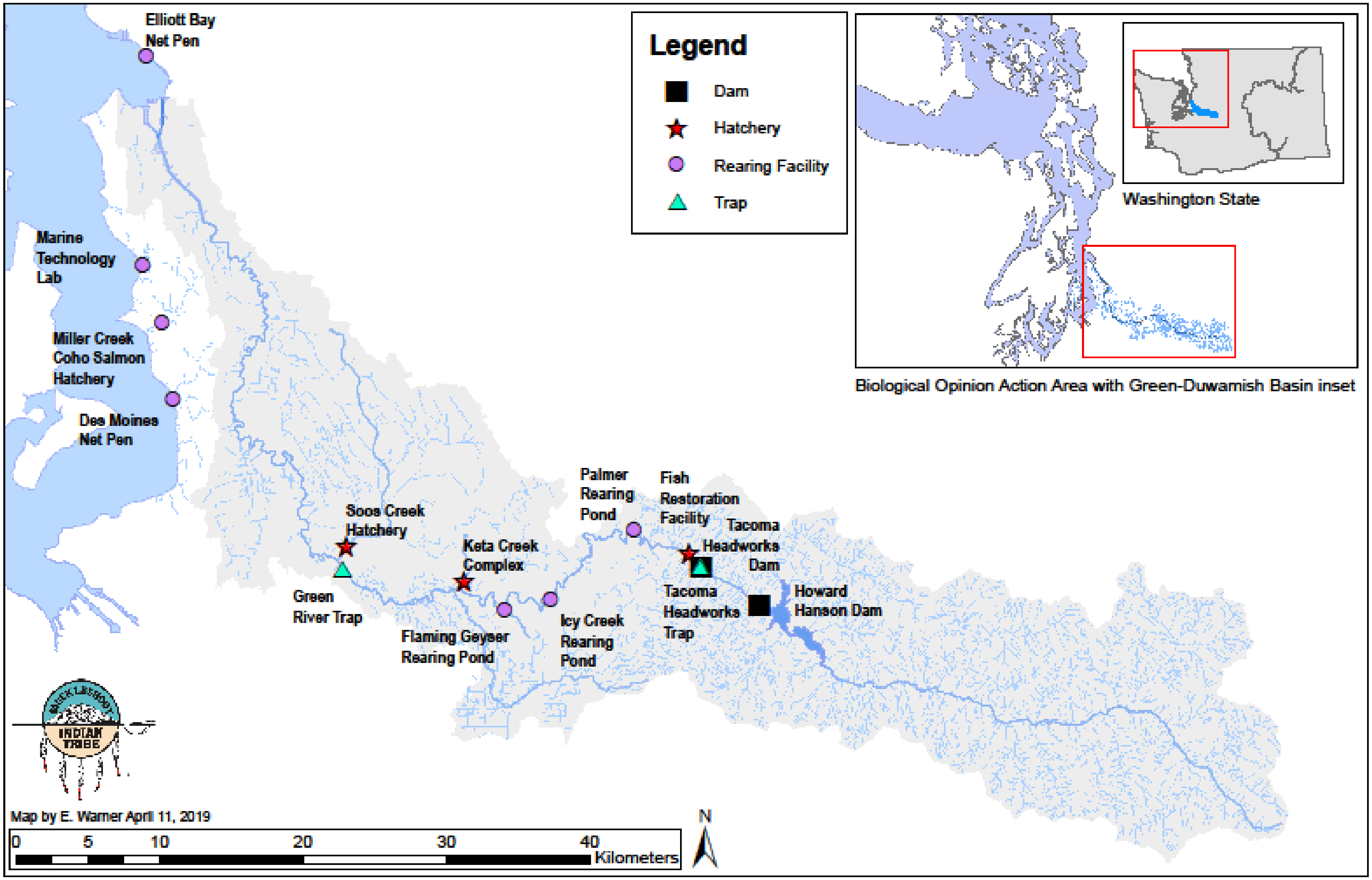

Figure 5. The Green River watershed, adjacent nearshore areas, and the location of hatchery facilities where salmon and steelhead hatchery programs would be implemented.

2.4. Environmental Baseline

Under the Environmental Baseline, NMFS describes what is affecting listed species and designated critical habitat before including any effects resulting from 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 and the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation (50 CFR 402.02).

2.4.1. Habitat

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 2008b) and the National Flood Plain Insurance Program (NMFS 2008c). 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.

The Green River originates in the Cascade Mountains approximately 30 miles northeast of Mount Rainer and flows 93 miles before entering the Puget Sound at Elliott Bay in Seattle. The climate within the basin is generally mild, with wet winters and dry, cool summers. Annual precipitation varies widely across the watershed with greater than 100 inches in the upper basin, decreasing into the down-basin portion of the watershed to 35 inches in Seattle (WRIA 2000). Nearly 87% of annual peak flows occur from November through February; since the construction of the HHD, 44% of annual peak flows have occurred in January (as compared to 11% prior to dam construction). Annual peak flows prior to dam construction ranged from 5,150 cfs to 28,100 cfs; averaging 12,266 cfs. Since dam construction annual peak flows have ranged from 3,510 cfs to 12,400 cfs; averaging 8,654 cfs, indicating that average annual peak flows have been reduced by dam operation by nearly 30%.

Historically, the Green River joined the White River (near Auburn) and downstream of Auburn was called the White River (USGS 1897) . The White River then joined the Black River (near Renton) and became the Duwamish River. In 1911, the U.S. Army Corps of Engineers routed the White River through the Stuck River Valley and into the Puyallup River (Watershed Resource Inventory Area 9 Steering Committee 2005). Collectively, the diversion of the White, Black, and Cedar Rivers reduced the drainage area of the Duwamish River by 70% (Collins and Montgomery 2011).

In addition to the hydro modifications described above, the Green River watershed has had extensive land-use alterations that affected habitat diversity, quantity, and quality. Development in the basin started in the mid-1800s with the construction of settlements and homesteads near Tukwila and Kent. In the 1870s through the 1890s, major railroad lines were constructed within the basin, and from the 1870s through 1910s the initial round of lowland logging occurred (WRIA 2000). In 1917, the construction of the Duwamish River waterway was complete and it resulted in the conversion of 17.5 miles of meandering, distributed channel into 10 miles of deep, uniform channel with a substantially hardened shoreline (Schaefer et al. 2000 in WRIA 2000). The materials dredged to create the waterway were used to fill adjacent intertidal shallows and wetlands. The pre-development estuary included 1,230 acres of tidal freshwater marshes, 1,270 acres of tidal marshland, and 1,450 acres of intertidal mudflats and shallows. By 1940, essentially all of the estuarine habitat and associated wetlands were converted and filled (WRIA 2000).

Tacoma Public Utilities (TPU) completed construction of the Green River Headworks diversion dam in 1913, with a pipeline capacity of 65 cfs, and in 1948, the total diversion capacity was expanded to 112 cfs. In 1999, a second supply pipeline was constructed for a total diversion of up to 213 cfs under their water rights. The U.S. Army Corps of Engineers began filling the Howard Hanson Reservoir on December 5, 1961. The dam functions as a flood control dam with the goal of prevention of peak flows over 12,000 cfs at Auburn. In 1975, TPU acquired a large well field along the North Fork Green River to provide drinking water during times of high turbidity in the Green River (WRIA 9 Steering Committee 2005). The well-field capacity is 72 million gallons per day or 111 cfs (Culhane et al. 1995).

The Puget Sound region (especially King, Pierce, and Snohomish Counties) experienced a dramatic increase in human population in the early twentieth century (Watershed Resource Inventory Area 9 Steering Committee 2005). The Green River Basin human population growth was most pronounced in the urban areas within the western third of the basin. In the last third of the twentieth century, the basin experienced increasing urbanization, and by 2004 the population reached 630,000 people with 89% of the population living in urban areas and the remaining 11% in rural areas. Most future growth is projected to be within the middle Green River and nearshore areas (WRIA 2000).

The WRIA 9 limiting factors analysis and Green/Duwamish salmon habitat plan divided the Green River Basin into four subbasins: Duwamish River Estuary (RM 0 to 11), Lower Green River (RM 11.0 to 32), Middle Green River (RM 32 to 64.5), the upper Green River from RM 64.5 to RM 93.0 (Watershed Resource Inventory Area 9 Steering Committee 2005; WRIA 2000). Both documents also included a nearshore subbasin analysis, and set of recommended actions, and the information in the following sections is summarized from these two sources (Figure 6).

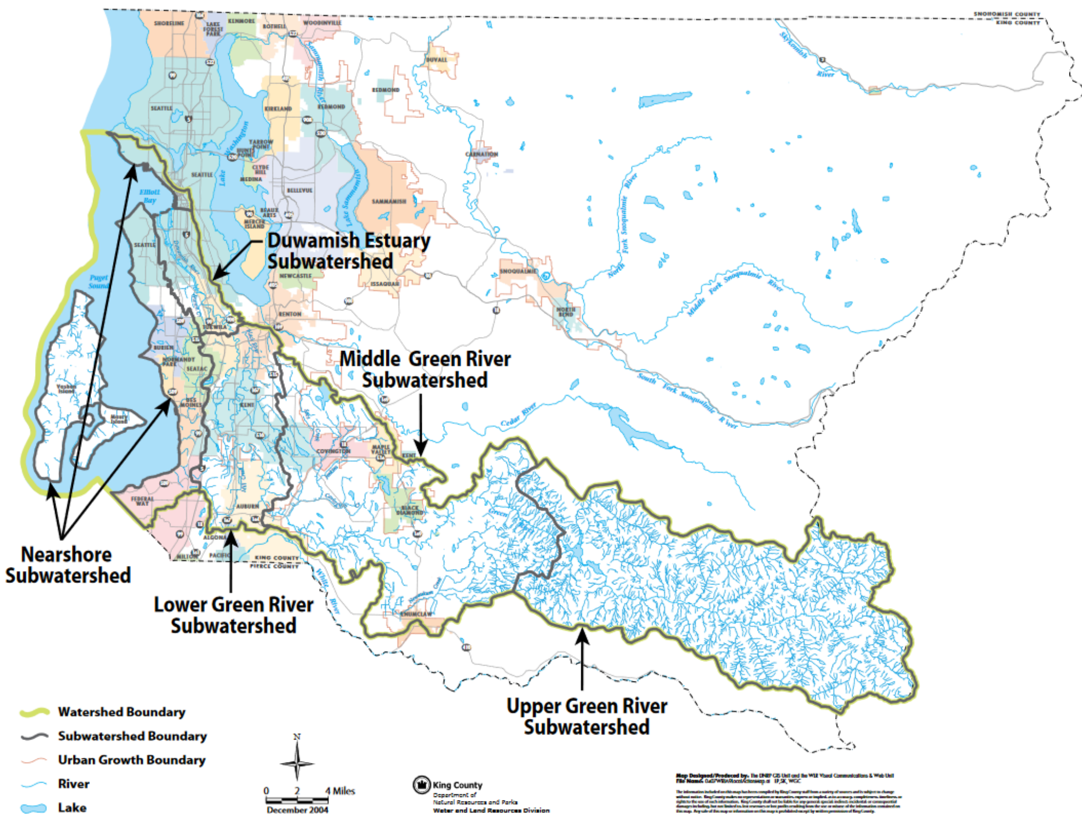

Figure 6. Map depicting Green River and WRIA 9 subbasins (source: King County Dept. of Natural Resources and Parks- Water and Land Resources Division 2004).

Upper Green River

The Upper Green River subbasin includes the headwaters of the Green River and represents approximately 45% of the land area within the Green River watershed. The river flows more or less from the eastern watershed divide to the west and northwest through 30 miles of steep, forested valleys. The upper Green River watershed is almost entirely utilized for industrial forestry. Anadromous fish passage is blocked by the TPU diversion at RM 61 (contained within the middle Green River subbasin). The HHD is also an anadromous fish barrier (dam at RM 64.5). The reservoir, when filled, inundates 4.5 and 3.0 miles of mainstem and tributary habitat, respectively. The construction of logging roads and railroads immediately adjacent to the mainstem and tributary streams within this subbasin have reduced and degraded riparian function. These roads have also reduced the creation of new habitat by limiting channel migration and habitat forming processes. Increased rates of erosion and alteration of sediment transport processes due to logging and road construction have resulted in channel aggradation. Within upper Green River tributaries, logging and road construction have reduced riparian function, increased sedimentation rates, reduced water quality, and altered stream hydrology. Logging road and railroad networks have also resulted in numerous fish passage barriers.

Middle Green River

The Middle Green River subbasin flows through the Green River Gorge after passing over the TPU diversion dam and emerges into a broad, nearly mile-wide valley. The two biggest tributaries to the Middle Green River Basin are: Newaukum Creek (left bank at RM 40.7) and Big Soos Creek (right bank tributary at RM 33.6). Much of the river downstream of the Green River Gorge is bound by levees and revetments which constrain the channel and limit habitat forming processes. Land use within this subbasin is 50% residential, 27% forestry, 11% agricultural, with the remaining 12% utilized by parks and open space, mineral extraction, commercial and industrial, and other mixed uses. The construction of dams, levees, and revetments and residential and agricultural land use along the middle Green River mainstem have altered the natural flow regime, caused sediment starvation and scouring, reduced the quantity and size of large woody debris, reduced channel complexity, reduced and/or eliminated side channel and other off-channel habitats, and reduced or degraded riparian habitat.

HHD not only blocks adult fish passage but it also inhibits the downstream transport of large woody debris and sediment. The lack of downstream sediment transport has created a sediment deficit resulting in downstream channel incision and subsequent channel armoring. This has resulted in degraded spawning habitat quantity and quality. Channel incision may also help reduce the quantity, quality, and type of rearing habitats available to juvenile salmonids. Development (residential, agricultural, and urban) within the Big Soos and Newaukum creek watersheds, as well as other tributaries has reduced and degraded wetland and riparian functions and habitat forming processes. Development activities have reduced forest cover and increased impervious surfaces altering the hydrology and streamflow; and degraded channel habitat conditions, increased sedimentation, and decreased water quality. Road construction and other land protection measures have rechanneled streams, limited their lateral migration, and created barriers to fish passage.

Lower Green River

The mainstem Green River meanders across a broad, flat floodplain from south to north. Levees and revetments are present on at least one side the river for approximately 80% of the mainstem length. There are three major tributaries within this subbasin: Springbrook Creek, Mill Creek, and Mullen Slough. Land use within this subbasin is 50% residential, 27% industrial and commercial, 5% agricultural, with the remaining 18% utilized by parks and open space and other mixed uses. Urbanization, levees, and revetments have resulted in a disconnected floodplain, which limits juvenile salmonid access to sloughs and wetland habitat that provide off-channel habitat.

Currently, juvenile salmonids rearing and migrating in the mainstem have few places to take refuge from high flows. The lack of riparian forest and downstream transport of large woody debris have decreased habitat complexity and result in degraded rearing conditions. For example, lower river temperatures regularly exceed Washington state water quality criteria of a16°C 7-day average daily maximum for core summer salmonid habitat, and 17.5°C for salmonid spawning, rearing and migration, and can at times can reach lethal levels of 22°C or higher (WDOE 2011). Low flows associated with water withdrawals and the diversion of the White River have exacerbated low flow conditions and contributed to adult salmon migration problems. Human development activities within this subbasin have caused chronic water quality problems.

Duwamish Estuary

Land use within this subbasin is 45% industrial and commercial and 39% residential, with the remaining 16% utilized by parks and open space and other mixed uses. Tributaries within this subbasin include: Hamm Creek, Longfellow Creek, and Riverton Creek. The entire mainstem has been dredged and straightened with 97% of historical estuarine mudflats, marshes, and forested riparian wetlands filled. There is almost no native forest or vegetation along the lower five miles of the mainstem. Urban and industrial development along this reach has generated substantial pollution, and sediment is degraded and contaminated.

Heavy development, industrial use of the floodplain and estuarine wetlands, and shoreline modifications, combined with river diversions upstream have resulted in a reduction of estuarine habitat, which is critically important for juvenile salmonids when making the transition from fresh water to the marine environment. The near complete elimination of marshes and intertidal wetlands has substantially reduced the estuary's ability to support juvenile rearing. The lack of riparian forest and infestation of non-native riparian vegetation, bank armoring, and piers has resulted in severely degraded habitat conditions. Collectively, these changes have dramatically reduced the diversity, quality, and quantity of estuarine habitat, which is especially important to juvenile Chinook salmon.

Nearshore

The marine nearshore habitats included in the WRIA 9 recovery plan contain the Puget Sound shorelines along the mainland and Vashon Island south of West Point to the King-Pierce County border. Tributary streams within the Green River Basin nearshore include: Fauntleroy, Salmon, Miller, Des Moines, Massey, McSorley, Lakota, and Joe's Creeks. Nearshore land use along the mainland is composed of 68% residential, 10% industrial, 8% parks and open space, 6% commercial with the remaining 8% of land use classified as mixed and other uses. The nearshore land use along Vashon Island is composed of 92% residential, 4% agricultural, 3% parks and open space, and 1% mineral extraction.

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. This loss is mainly caused by disconnection of nearshore habitat forming processes (e.g., loss of sediment sources). 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. 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
- Before 1900, 4,000 acres of tidal marshes and mudflats once existed up to RM 5.5 where Harbor Island and the East and West Waterways now stand in Elliott Bay, Seattle
- 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/Mitgation

The federally approved Recovery Plan for Puget Sound Chinook Salmon describes on-going and proposed state, tribal, and local government restoration and recovery activities for listed Chinook salmon in the Green River Basin. The WRIA 9 Salmon Habitat Plan was prepared by the WRIA 9 Steering Committee, which updates the recovery work plan annually through 3-year work plan updates. Green River Basin habitat restoration activities are also guided by the State of Our Watersheds report, which examines key indicators of habitat quality and quantity within the Muckleshoot Tribes' usual and accustomed fishing area.

Since the Salmon Habitat Plan was adopted, WRIA 9 and its partners have secured over $137 million from all funding sources to implement salmon and steelhead recovery projects and programs (Watershed Resource Inventory Area 9 Steering Committee 2005). Recent examples of habitat restoration/mitigation and salmon recovery projects funded with PCSRF, state, and local sources that are expected to benefit listed Green River Chinook salmon and steelhead population viability include:

- The Seahurst Park Restoration Project was a two phase project which removed an existing bulkhead and created almost a mile of natural shoreline. The project included extensive planning and coordination between the U.S. Army Corps of Engineers, the City of Burien, and the Puget Sound Partnership.
- Dockton Restoration Project created a salt marsh and enhanced shoreline processes by removing 375 feet of marine shoreline armoring, fill material, and approximately 100 pilings along the nearshore. New beach material was added to mitigate for lost sediment supply from the up drift armored shoreline.
- North Wind's Weir Restoration Project was completed in 2010 along the Duwamish River at RM 6.3. The project created 2.5 acres of high quality shallow water habitat, providing a new area for juvenile Chinook salmon to feed and grow while making their transition from fresh water to the marine environment.
- Duwamish Gardens Restoration Project was completed in 2015 along the Duwamish River at RM 6.8. The project was constructed on a 2.4-acre parcel owned by the City of Tukwila. The project removed 30,000 cubic yards of fill material to reestablish 0.9 acres of shallow water mudflat and estuarine marsh. In addition to the marsh habitat created, the project restored 1.24 acres of riparian habitat.
- Riverview Park Ecosystem Restoration Project was completed in 2012 along the lower Green River, opposite Mill Creek. The project created an 800-foot-long side channel, 1.7 acres of flood refuge habitat, and 2,000 feet of newly established riparian habitat.
- Pautzke Levee Setback Project was completed in 2011 along the middle Green River at RM 32.5. The project removed 1,800 feet of levee and now allows the river to freely migrate across 21 acres of floodplain previously disconnected from the river.
- Kanaskat Acquisition Project was a multiphase acquisition project along the middle Green River. The three-phased project acquired 75 acres of property along a remnant side channel just below the TPU Headworks facility.

- Middle Green River gravel and LWD supplementation. This is an ongoing annual project which places LWD and gravel at RM 60.0 to mitigate for LWD losses and the lack of sediment transport through HHD.
- The TPU Fish Passage Facility construction was completed in 2007. The project included construction of a trap and haul facility and screens to protect juveniles migrating downstream.

2.4.2. Dams

Tacoma Public Utilities (TPU) completed construction of the Green River Headworks Dam in 1913 at RM 61.0. When the dam was constructed, there was no provision for fish passage, so through the present day, the structure acts as a complete barrier to upstream fish migration.

The Howard Hanson Dam (HHD) was constructed for flood control. The reservoir created by the dam collects runoff from a 220 square mile drainage basin upstream of the dam. However, the HHD and reservoir interrupts the transport of sediment and large woody debris to the downstream channel and alters the natural hydrology of the Green River by reducing winter peak flows and average spring flows during reservoir refill (WRIA 2000). Flood flows held during the winter months are then released as soon as possible to make storage space for future storm events.

When the probability of flood flows has diminished, the dam is operated to fulfill its second function: water storage. The refill period in late February through May is important for several life stages, and refill rates can impact lateral habitats downstream, emigration travel times, and survival for fry and smolts (NHC 2005).The reservoir is allowed to slowly fill, and the stored water is used to augment low flows during the summer season. Augmentation from storage is critical to maintain adequate summer and early fall flows in the Green River for successful fish migration and spawning in late-summer and early-fall, and also enhances streamflow conditions for sport fishing for summer steelhead, and coho and Chinook salmon (when sufficient abundance is available for a directed sport fishery).

HHD is also operated to help ensure that minimum flows are maintained; in the 1990s the system was operated to ensure that a minimum of 223 cfs were released from the dam during the lowest flow period (Culhane et al. 1995). In April 1997, approval was granted under Section 1135 of the 1986 Water Resources Development Act (WRDA), as amended, for an ecosystem restoration project to increase the volume of summer conservation storage at HHD for the purpose of release during the summer months to augment low streamflows, thereby improving downstream fish habitat and fish survival. The ecosystem restoration project included additional water storage of up to 5,000 acre-feet to augment low streamflows and a collection of habitat restoration projects around the reservoir. Water capture and use was to be adaptively managed, depending on ecosystem restoration objectives.

Operations at the Corps' HHD and Tacoma's Headworks Dam are both governed by the Additional Water Storage Project (AWSP). This project was authorized by Congress under the 1999 Federal Water Resources Development Act (PL 106-53), which directed the Corps to store an additional 20,000 acre-feet of water behind HHD to be subsequently released for Tacoma's municipal water supply use. The 1999 WRDA also authorized several ecosystem restoration projects, including construction of facilities to improve downstream fish passage at HHD. The AWSP was designed to operate as a partnership between the Corps and Tacoma, including cost-sharing, implementing ecosystem restoration measures, and restoring Puget Sound Chinook salmon and steelhead to the upper Green River watershed.

Tacoma addressed the effects of the AWSP in its July 2001 ESA Section 10(a)(1)(B) Habitat Conservation Plan (Tacoma 2001) and to date, Tacoma has implemented its HCP in accordance with the Implementing Agreement between Tacoma, NMFS, and the U.S. Fish and Wildlife Service, signed in July 2001[2]. The HCP includes: minimum instream flows downstream from Headworks Dam, an adult fish trap and haul system at the Headworks Dam, screening to protect juvenile fish at Tacoma's diversion, and numerous fish and wildlife habitat improvement measures upstream of HHD where the city of Tacoma owns about 10% of the upper Green River watershed. Tacoma has completed most fish protection elements of the HCP, including the upstream passage trap and haul system, but the facility has not been operated pending the Corps' completion of safe and effective downstream fish passage facilities at HHD. Recently NMFS completed a jeopardy Opinion with a reasonable prudent alternative to provide downstream fish passage by 2030, and an interim reasonable prudent alternative to manage river flows to minimize redd scour (NMFS 2019b).

The AWSP is a joint project between the Corps and Tacoma. Tacoma and the Corps have different responsibilities under the ESA because one is a federal agency and the other is non-federal. Federal entities are obligated to consult under section 7 of the ESA to ensure that their actions do not jeopardize the continued existence of ESA-listed species, or destroy or adversely modify their critical habitats. Non-federal entities may obtain an incidental take permit (ITP) to avoid potential take liability under the ESA for their covered activities. To obtain an ITP, Tacoma submitted an application that included an HCP to NMFS in 2000. NMFS determined that the HCP (among other parts of the application package), met the ESA section 10 issuance criteria, including the requirement to minimize to the maximum extent practicable, the effects of the AWSP for which Tacoma is responsible, and issued an ITP to Tacoma (Tacoma Public Utilities 2001). In 2000, the Corps consulted with NMFS on its proposed actions at HHD, including the AWSP (which, in turn, included downstream passage), and NMFS concluded that the Corps' proposed action in its 2000 BA avoided jeopardy and destruction and adverse modification of critical habitat. Another ESA consultation with NMFS is currently underway, in response to the Corps' proposed action for changes in the suite of actions approved by NMFS in 2001. Tacoma's ITP and conservation measures adopted under the HCP are part of the environmental baseline being considered, and the Corps' actions that they have completed are part of the environmental baseline for that consultation.

This context is vital to understanding the overall effects of the continued operation and maintenance of HHD. The presence of the dams and their effects on habitat has made hatchery

[2] Tacoma's HCP covers all aspects of Tacoma's water supply project in the Green River basin, including the AWSP. Reintroducing anadromous fish to the upper Green River watershed is a part of the AWSP, including an upstream adult fish passage system at Headworks dam, a system for collecting and safely passing outmigrating juvenile fish at HHD, and screening to exclude juvenile fish from Tacoma's diversion. Tacoma has completed the adult fish trap and haul system and the juvenile exclusion screening at its Headworks facility.

programs a part of the management strategy within the Green River Basin, and their presence must be considered when assessing hatchery effects because of the limited amount of habitat available below the dams compared to what was available to anadromous fish historically. HHD's originally authorized purposes of flood control and fish conservation (via water storage and release) have been amended to provide water storage for Tacoma's municipal supply and use (AWSP). Developing new facilities to provide downstream fish passage at HHD and several fish habitat improvement measures have been authorized under the AWSP. Upstream fish passage, maintenance of minimum instream flows downstream from the Headworks Dam, and habitat projects in the upper watershed have been implemented by Tacoma under the auspices of its HCP. This package of actions is designed and intended to serve the interests of flood control, municipal water supply, and fish and wildlife conservation, including the survival and recovery of ESA-listed species.

2.4.3. Climate Change

Climate change has negative implications for designated critical habitats in the Pacific Northwest (Climate Impacts Group 2004; ISAB 2007; Scheuerell and Williams 2005; Zabel et al. 2006). The distribution and productivity of salmonid populations in the region are likely to be affected (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. As climate change progresses and stream temperatures warm, thermal refugia will be essential to persistence of many salmonid populations. Thermal refugia are important for providing salmon and steelhead with patches of suitable habitat while allowing them to undertake migrations through, or to make foraging forays into, areas with greater than optimal temperatures. To avoid waters above summer maximum temperatures, juvenile rearing may be increasingly found only in the confluence of colder tributaries or other areas of cold water refugia (Mantua et al. 2009).

These changes will not be spatially homogeneous across the entire Pacific Northwest. Low-lying areas are likely to be more affected. Climate change may have long-term effects that include, but are not limited to, depletion of cold water habitat, variation in quality and quantity of tributary rearing habitat, alterations to migration patterns, accelerated embryo development, premature emergence of fry, and increased competition among species (ISAB 2007). In the Green River Basin, the WRIA (2017) predicts that the lower elevation tributaries, such as Soos Creek, will see increased winter rain intensities, and lower flows, but snow-dominated river sections are likely to see the greatest impacts. Temperature will be a concern for the whole watershed, but temperatures are likely to be more problematic for salmonids in the mainstem, as this river section is already generally warmer than the tributaries. Increased peak flows and decreased summer base flows could also contribute to increased sedimentation and stormwater runoff. These effects could result in increased pollutant concentrations that could negatively affect fish physiology and survival. The persistence of cold water "refugia" within rivers and the diversity among salmon populations will be critical in helping salmon populations adapt to future climate conditions. Similar types of effects on salmon may occur in the marine ecosystem including warmer water temperatures, loss of coastal habitat due to sea level rise, ocean acidification, and changes in water quality and freshwater inputs (Mauger et al. 2015). More detailed discussions about the likely effects of large-scale environmental variation on salmonids, including climate change, are found in biological opinions on the Snohomish Basin Salmonid Hatchery Operations (NMFS 2017e) and the implementation of the Mitchell Act (NMFS 2017b).

Habitat preservation and restoration actions can help mitigate the adverse impacts of climate change on salmonids. For example, restoring connections to historical floodplains and freshwater and estuarine habitats would provide fish refugia and areas to store excess floodwaters (Battin et al. 2007; ISAB 2007). For the Green River, WRIA (2017), recommended some actions that could help mitigate climate change effects, such as protecting cold water refugia to moderate temperature effects, and restoring riparian buffers to moderate temperatures, reduce sediment inputs, and minimize erosion. Harvest and hatchery actions can respond to changing conditions associated with climate change by incorporating greater uncertainty in assumptions about environmental conditions, and conservative assumptions about salmon survival, in setting management and program objectives and in determining rearing and release strategies (Beer and Anderson 2013).

2.4.4. Fisheries

Impacts on Chinook Salmon

Hatchery-origin Chinook salmon produced through the WDFW program have in past years been subject to directed commercial harvest in terminal area net fisheries in marine and estuarine waters, and recreational fisheries in marine waters and in the Green River. During this time period, listed hatchery-origin Puget Sound Chinook salmon were caught incidentally in fisheries targeting non-listed salmon or in small scale tribal ceremonial and subsistence fisheries. From 2007 through 2011, annual Chinook salmon gillnet harvest in Elliott Bay ranged from 98 to 2,023 fish; averaging 1,119 fish. During the same time period, Chinook salmon gillnet harvest in the Green River ranged from 511 to 9,195 fish; averaging 5,554 fish. From 2012 through 2016 there were no directed commercial fisheries for Chinook salmon in the terminal area; directed commercial fisheries for Chinook salmon did occur in 2017 and 2018 (Jason Schaffler, MIT, personal communication; Unsworth and Grayum 2016; Warren and Bowhay 2016; WDFW and PSTIT 2012; WDFW and PSTIT 2013; WDFW and PSTIT 2014).

Recreational fisheries targeting Green River salmon occur in the Green River, Elliott Bay, and Catch Area 10[3]. Regulations vary by time, area, and species contingent on the availability of fish surplus to escapement needs. From 2007 through 2009, recreational harvest of hatchery-origin Chinook salmon in the Green River ranged from 122 to 363 fish, averaging 236 fish (WDFW 2008; WDFW 2010a; WDFW 2010b). Recreational salmon harvest regulations required the release of both natural- and hatchery-origin Chinook salmon in the Green River in return years 2010 through 2016; regulations in 2017 and 2018 allowed the limited retention Chinook salmon.

There is currently no fishery (tribal, commercial, or recreational) that targets natural-origin Green River Chinook salmon. However, natural-origin Green River Chinook salmon may be impacted incidentally in fisheries directed at hatchery-origin Chinook, chum, and coho salmon. Harvest of Green River natural- and hatchery-origin Chinook salmon occurs in mixed stock marine area fisheries in U.S. and Canadian waters. From 2005 through 2012, the total exploitation rate averaged 50% and the escapement goal was achieved in only one out of eight years (NMFS 2015; PSIT and WDFW 2010).

Between 2010 and 2014, under the most recent multi-year Puget Sound harvest resource management plan, southern U.S. pre-terminal fisheries' impacts on Green River Chinook salmon were managed to not exceed a 15% rate, as estimated by the Fishery Regulation and Assessment Model (FRAM). When preseason planning indicates that a low abundance threshold of 1,800 natural spawners would not be met, southern U.S. pre-terminal fisheries' impacts on Green River Chinook salmon were managed to not exceed a 12% exploitation rate.

In the years since 2014, the Puget Sound fisheries have been managed under a series of single-year ESA authorizations, while the co-managers and NMFS have worked on a new multi-year resource management plan for consideration. Management objectives for the Green River Chinook salmon during this period have evolved based on updated stock-recruitment work by the co-managers. This has led to annual management objectives transitioning from historical spawning escapement goals with higher allowable southern U.S. pre-terminal exploitation rates (up to 15%) to revised spawning escapement thresholds and more restrictive (overall) southern U.S. pre-terminal limits (13% upper limit). Prior to conducting terminal area (Elliott Bay and Green River) fisheries, abundance is evaluated in-season through a test fishery that informs managers whether sufficient Chinook salmon are available to implement modeled commercial and recreational Chinook salmon fisheries.

Impacts on Steelhead

Within the action area, tribal commercial and ceremonial and subsistence fisheries for primarily hatchery-origin steelhead occur seasonally in the lower Green River, contingent on the availability of fish surplus to escapement needs. Non-treaty commercial fishing is closed to steelhead in all areas, although there may be some incidental mortality in salmon-directed fisheries. Recreational fisheries for salmon and non-listed steelhead managed by WDFW occur in the Green River and Big Soos Creek.

[3] Catch Area 10 is defined as the marine waters bound at the north by a line from Apple Cove Point to Point Edwards and at the south by a line from the Southworth Ferry Dock to approximately 600 feet south of Brace Point.

Between 2000 and 2014, annual tribal and non-tribal fishery harvest of ESA-listed winter steelhead in the Green River averaged 49 and 20 fish, respectively (WDFW et al. 2017). Following the ESA-listing of Puget Sound steelhead, the tribal harvest of natural-origin steelhead was reduced from an annual 10-year average of 115 to 5 fish. Sport fishing regulations restricted the harvest of natural-origin winter steelhead after the winter of 2002. From 2007/08 through the 2013/14 steelhead catch period, terminal harvest rates of natural-origin steelhead have ranged from 0.3% (2008/09) to 3.5% (2007/08); averaging 1.6% (NMFS 2017a).

Recreational harvest of summer and winter steelhead in the marine Catch Area 10 from 2000 through 2013 averaged 7 and 2 fish, respectively. An annual average of 176 steelhead have been encountered in marine treaty and non-treaty commercial, ceremonial and subsistence, and recreational fisheries (49 treaty marine; 5 non-treaty commercial; 122 non-treaty recreational) for the most recent time period (2008/2009 to 2013/2014). Since not all fish in marine area fisheries are sampled for marks, this annual estimate includes both encounters (fish that will be caught and released) and incidental mortality of ESA-listed natural- and hatchery-origin steelhead, and non-listed hatchery-origin fish. Overall, marine treaty and non-treaty fisheries have demonstrated a decrease in natural-origin steelhead harvest of -46% from 2008/2009 to 2013/2014 as compared to the previous 2001/2002 to 2006/2007 time period (NMFS 2017a).

2.4.5. Hatcheries

Another important aspect of the Environmental Baseline is hatchery effects, including past effects from salmon and steelhead hatchery programs operating in the action area and effects from fish that stray into the action area from hatchery programs located outside the Green River watershed. Effects of the on-going operation for the Soos Creek Fall Chinook salmon, the Green River native steelhead and summer steelhead programs, and the chum and coho salmon programs are discussed in detail in Section 2.5.2. Here, we describe effects associated with the historical operation and structural presence of elements of the programs. Hatcheries in the Green River 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 and steelhead habitat. Currently, one program operates solely for conservation purposes in the basin—WDFW's Green River native steelhead hatchery program. The remaining programs are designed primarily to produce fish for harvest.

Soos Creek Fall Chinook Program

Construction of the Soos Creek Hatchery (also known as the Green River Hatchery) on Big Soos Creek started in 1899 and was completed in 1901 (Becker 1967, and following). At the time of construction, Chinook salmon did not enter Big Soos Creek to any extent and double racks were used in the mainstem Green River starting in 1902 to provide Chinook salmon broodstock. The hatchery produced 369,500 juvenile Chinook, 528,000 coho, 328,000 pink salmon and 96,800 steelhead in 1903. By 1924, sufficient adult returns of Chinook salmon were trapped at the Green River Hatchery (the name was changed to Soos Creek Hatchery in 1994) to provide a self-sustaining program. From 1901 to present, there have been multiple upgrades to the facility, focusing on increasing egg incubation and juvenile rearing capacity. The original egg incubation capacity was 2 million eggs, and by 1921, egg incubation capacity had increased to 10 million eggs. In 1926, a completely new hatchery facility was constructed which increased egg incubation capacity to 40 million eggs, as well as capacity to rear 27 million fry. The hatchery facility was again reconstructed in 1948, and, since that time, further upgrades to the facility have been made. The most recent upgrade occurred in 2018 to improve fish screens, the egg incubation area, juvenile raceways, and off-channel adult holding ponds.

Peak egg takes occurred in 1935, when 36.9 million Chinook salmon eggs were collected. From 1998 through 2015, egg take was substantially reduced. The Soos Creek Chinook Salmon Hatchery program has reared and released yearling Chinook salmon at the Icy Creek facility since 1983 for the Blackmouth fishery (WDFW 2013). Subyearling Chinook salmon have been released through the program from the Palmer Ponds facility since 2011.

The collection of natural-origin fish at the Tacoma Power Utility (TPU) trap and from the mainstem Green River and Big Soos Creek has reduced the number of natural-origin fish spawning naturally, which may have had negative genetic diversity and productivity consequences for the Green River population. However, improved hatchery practices have been applied to help ensure broodstock collection, selection, mating, rearing, and release practices would reduce potential adverse demographic (e.g., mining), genetic and ecological effects on the listed Chinook salmon population. Chinook salmon have been passed upstream of the Big Soos Creek weir to seed natural habitat, and migration and blockage effects have been minimized at the weir through timely handling of trapped fish. In addition, there has been a consistent practice of hauling excess hatchery-origin adult Chinook salmon and releasing them into the mainstem Green River to seed underutilized habitat with spawners. Although produced for harvest, Green River Chinook salmon propagated through the WDFW hatchery program are part of the ESA-listed Green River population.

Coho and Fall Chum Salmon Hatchery Programs

The first coho salmon releases of 528,000 from the Soos Creek Hatchery were in 1903, and the program became self-sustaining by 1924. The peak coho egg take occurred in 1935 with 13.9 million eggs. Since then, egg take has decreased to meet the needs of the proposed release goal. The associated Trout Unlimited Co-Op program was initiated in 1983 with unfed fry releases (WDFW 2014c). The first remote site incubator (RSI) was installed on Miller Creek (independent tributary to the Puget Sound WRIA 09.0371) in 1984, with the first plants beginning in 1986. The Trout Unlimited Miller Creek Coho Salmon Hatchery was constructed at the Southwest Suburban Sewer District (SWSSD) Miller Creek Water Treatment Plant in 1987. The program shifted from releasing unfed fry to fed fry with releases in 2014. The Marine Technology Center Coho Hatchery Program has been supported by eggs and/or fry transferred from the Soos Creek Hatchery and has been in operation since 1970 (WDFW 2014a).

All coho used in the Keta Creek Complex program, including juveniles transferred from the Soos Creek Hatchery, have originated from the Green River. Some additional stocks were occasionally imported in the early days of hatchery operation at Soos Creek, but their contribution was relatively small. In 1975, the WDFW began the coho rearing program at Crisp Ponds with juvenile transfers from the Soos Creek Hatchery. The ponds were taken over by the Muckleshoot Tribe in 1992. The Keta Creek Complex yearling coho salmon program has released smolts from the Elliott Bay Net Pens since 1993 (Muckleshoot Indian Tribe and Suquamish Indian Tribe 2017).

The Keta Creek Complex fall chum salmon hatchery program has operated on Crisp Creek since 1975 (Muckleshoot Indian Tribe 2014). For the first year of operations (1975), chum eggs were made available by U.S. Fish and Wildlife Service from Quilcene National Fish Hatchery on Hood Canal. For the second year and several years following, chum eggs were received from the WDFW Hoodsport Hatchery, also located on Hood Canal. In 1989, stock management issues mandated that the Keta Creek hatchery program on the Green River use a Mid-Sound chum salmon stock. To accomplish that, the Tribe discontinued spawning the returning fish that originated from the Hood Canal stocks. Starting in 1990, program eggs were transferred in from East Kitsap and continued until sufficient returns allowed the program to be self-sufficient again (Muckleshoot Indian Tribe 2014).

Green River native winter steelhead hatchery program

The Green River native winter steelhead hatchery program is operated as a conservation program and was initiated in 2001 (WDFW 2017). The donor broodstock source for the program is natural-origin winter steelhead collected in the mainstem of the Green River. Starting in 2009, hatchery practices have allowed for up to 50% of the broodstock used for spawning to come from first generation adult returns from the Green River native winter program. Recent data indicate that the vast majority of broodstock used originate from naturally spawning winter steelhead captured in the mainstem Green River. From 2011 through 2016, natural-origin steelhead made up 93% of the spawners used as broodstock (WDFW unpublished weekly hatchery escapement reports). The one-year-old smolt size has ranged from 5 to 8 fpp; averaging 6.7 fpp. Two-year-old smolts have averaged 5.5 fpp, but have represented less than 3% of the smolts released. Annual smolt releases have ranged from 2,891 fish (2010) to 46,000 fish (2005); averaging 25,915 fish.

Early Winter Steelhead Program (terminated)

From 1903 through 1940, an average of 185,812 subyearling steelhead were released in the Green River Basin (Myers et al. 2015). Beginning in 1935, steelhead returning to Chambers Creek were used to establish a hatchery stock that was subsequently released throughout much of Puget Sound (Crawford 1979), including in the Green River Basin (WDFW 2014b). Advances in culture techniques during the 1960s led to further development of the Chambers Creek (i.e., Early Winter Steelhead [EWS]) hatchery-origin stock through broodstock selection and accelerated rearing practices (Crawford 1979), all for the purpose of producing fish for harvest.

In the Green River, Palmer Ponds Hatchery began producing EWS in 1969. Prior to 2001, no adult trapping of EWS occurred within the basin and program broodstock were obtained from egg transfers from Tokul Creek Hatchery in the Snohomish River Basin. In order to produce a local EWS stock, broodstock collection, egg incubation, and rearing was shifted to the Soos Creek Hatchery in 2002. In 2003, juveniles were reared and released from the Icy Creek facility. Releases were initiated at Flaming Geyser Ponds in 2004 and discontinued in 2012. The last release of EWS from the Soos Creek Hatchery and Icy Creek facilities occurred in 2013 and 2014, respectively. From 2002 through 2014, an average of 138,100 EWS smolts were released annually (WDFW 2014c; RMIS database query 2016). The last adult returns from this program are expected this year (2019).

Early Summer Steelhead Program

Early summer steelhead (ESS) in Puget Sound were derived about 50 years ago from transplanted Columbia River basin Washougal and Klickitat River stock. The ESS program in the Green River system was initiated in the 1960s, with releases from Palmer Ponds from 1969 through 2009 (WDFW 2015). In order to produce a local ESS stock, broodstock collection, egg incubation, and rearing was shifted to the Soos Creek Hatchery in 2002. Rearing and releases from the Icy Creek rearing ponds began in 1999 with broodstock collection added in 2012. Intermittent smolt releases from Flaming Geyser occurred from 2004 through 2010. From 2002 through 2015, an average of 76,200 ESS smolts were released into the Green River Basin annually. There has been some limited natural production by feral ESS in the Green River. Although Hard et al. (2007) estimated that only 3% of the returning ESS hatchery population spawns naturally each year, in modeling potential genetic risks to natural steelhead, WDFW has assumed that 20% to 30% of escaping ESS spawn naturally each year (WDFW 2015). The remainder of returning ESS are collected at the hatchery racks or are harvested in freshwater fisheries.

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

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; Jones 2006; McElhany et al. 2000; NMFS 2004b; NMFS 2005b; NMFS 2008a; NMFS 2011b). For Pacific salmon, NMFS evaluates extinction processes and effects of the Proposed Action beginning at the population scale (McElhany et al. 2000). NMFS defines population performance measures in terms of natural-origin fish and four key parameters or attributes; abundance, productivity, spatial structure, and diversity 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 must be included in an HGMP. Draft HGMPs are reviewed by NMFS for their sufficiency before formal review and analysis of the Proposed Action can begin. Analysis of an HGMP or Proposed Action for its effects on ESA-listed species and on designated critical habitat depends on six factors. These factors are:

1. The hatchery program does or does not remove fish from the natural population and use them for hatchery broodstock
2. Hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds and encounters with natural-origin and hatchery fish at adult collection facilities
3. Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas, migratory corridor, estuary and ocean
4. 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. 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

Both of the fall Chinook salmon hatchery programs remove fish from the local natural population for broodstock, leading to a negative effect for Chinook salmon. The 2013 to 2017 natural-origin adult escapement to the Green River has averaged 1,842 fish, and ranged from 806 to 3,588 fish (WDFW Score). The average number of adult natural-origin fish removed from the river for broodstock from 2013 through 2017 was 498 fish, about 27% of the average natural-origin return. During this time, removal for the hatchery program ranged from 18 to 35% of the natural-origin return. In the Proposed Action through all four phases, the co-managers propose to limit the removal of natural-origin Chinook salmon for hatchery program broodstock to 40% of the natural-origin return.

NMFS believes this to be an acceptable level of removal because the Chinook programs are closely linked to each other through their broodstock practices and allow some spawning by hatchery-origin returns. Thus, some genetic material from those natural-origin Chinook salmon spawned in the hatchery is likely to remain in the natural environment. In addition, all of the fish used for broodstock are spawned in the hatchery, leading to higher egg-to-smolt survival rates than in the wild. The net effect is anticipated to be an increase in abundance—potential adverse effects of naturally spawning hatchery fish are discussed in the following subsection.

Winter Steelhead Broodstock

Both of the winter steelhead hatchery programs remove fish from the local natural population for broodstock, leading to a negative effect for steelhead. From 2014 to 2018, the annual natural-origin return averaged 1,200 fish, and ranged from 622 to 2,111 fish (WDFW 2018a). For both steelhead programs combined, a maximum of 20% of the natural-origin steelhead return may be used as broodstock; this rate is not expected to increase through all four phases. This 20% maximum applied to data from 2014 to 2018 would have provided 240 fish on average for both steelhead programs, and would have ranged from 124 to 422 steelhead.

NMFS believes this to be an acceptable level of removal similar to the reasons described above for Chinook salmon; both steelhead programs are integrated, they allow some spawning by hatchery-origin returns, and all of the fish are spawned in the hatchery, leading to higher egg-to-smolt survival rates than in the wild. In addition, starting in brood year 2010, adult broodstock were live-spawned when possible depending upon fish condition, with spawned fish allowed to recover and return to the stream (WDFW 2017). The net effect is anticipated to be an increase in abundance—potential adverse effects of naturally spawning hatchery fish are discussed in the following subsection. We also anticipate that with passage at HHD potentially opening up new spawning habitat, abundance may increase further into the future.

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 Chinook salmon and steelhead populations. This supplementation is designed to increase population abundance and productivity by increasing the number of adult returns. In addition, spatial structure and diversity are also likely to be improved through the creation of a few natural-origin Chinook salmon only areas, and the supplementation of hatchery-origin steelhead into Newaukum Creek (see details below).

The coho and chum programs do not have any genetic effects on listed Chinook salmon and steelhead populations because these species do not interbreed. However, the ecological risks of redd superimposition and spawning site competition are likely greater between species, such as coho and Chinook salmon, than between hatchery and natural fish of the same species. Thus, NMFS believes that the net effect of the steelhead and Chinook programs on listed species is beneficial, while the coho and chum programs are likely to have a small negative effect on listed species through ecological effects.

2.5.2.2.1. Genetic Effects

For each program, NMFS considers three major areas of genetic effects: within-population diversity, outbreeding effects, and hatchery-influenced selection. The within-population diversity area covers such topics as effective size and mating protocols. Assessment of the other two categories occurs simultaneously using the pHOS metric. For segregated programs, genetic effects are assessed by considering how many fish from each program may 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 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).

NMFS has not adopted Hatchery Scientific Review Group (HSRG) gene flow (i.e., pHOS, pNOB, PNI) standards per se. However, at present the HSRG standards and the 5% (or 0.05) stray standard (from segregated programs) from Grant (1997) are the only acknowledged quantitative standards available, so NMFS considers them a useful screening tool. For a particular program, NMFS may, based on specifics of the program, broodstock composition, 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.[4]

2.5.2.2.1.1. *Within-population Diversity*

Early summer steelhead program

No interbreeding between the returning summer steelhead and the natural winter steelhead program is intended. Because of low expected reproductive success expected from the few returning hatchery fish that do spawn in the wild (see gene flow analysis below) and the large size of the natural population, we see a negligible risk to the effective size of the natural population through a Ryman-Laikre (Ryman et al. 1995; Ryman and Laikre 1991). In previous Opinions on segregated winter steelhead programs in Puget Sound (e.g., NMFS 2016c) we evaluated their potential to lower effective size due to natural fish production being wasted by spawning with low-fitness hatchery-origin fish and concluded that risk was very low. Given the continued ratios favoring natural-origin steelhead on the spawning grounds, we conclude that this risk for the ESS program will be similarly very low.

Winter steelhead programs

In any integrated program the hatchery can potentially have a large impact on local effective size, lowering it through a Ryman-Laikre effect if the broodstock is small and the spawning success of hatchery-origin fish high compared to natural-origin fish. Duchesne and Bernatchez (2002) provided a method for calculating the multi-generational impact of hatchery programs on effective size. Using the pNOB pHOS and escapement counts values in Table 14, and assuming broodstock sizes of 60 for the WDFW program and 280 for the FRF program, we calculate that the current WDFW program reduces the local effective number of breeders by 19,5% (relative to the total of broodstock and natural spawners). With over 1000 spawners per year, even if it is assumed that the N_b:N_c is 0.25, the per-generation effective size is over 1000. Once the FRF program is operational, the local effective size reduction is expected to be less than 1% because of the increase in overall (natural spawning + broodstock) number of spawners. Note that the above language uses the term *local*. The calculations assume a closed population. In reality gene flow between salmon and steelhead populations at low levels is common. Analysis using the metapopulation model of Duchesne and Bernatchez (2002) indicate that gene flow of slightly more than 1%, well within the range of what could be expected, would compensate for the local effective size depression that may be caused by the current WDFW program.

Fall Chinook salmon program

Unfortunately it is not clear at this point how to apply the Duchesne and Bernatchez approach to capture the complexity of this program. However, given the size of the broodstock relative to

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[4] The only exception to date is the case of steelhead programs using highly domesticated broodstocks, where NMFS has imposed more stringent guidelines (NMFS. 2016c. Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat (EFH) Consultation. National Marine Fisheries Service (NMFS) Evaluation of Two Hatchery and Genetic Management Plans for Early Winter Steelhead in the Snohomish River basin under Limit 6 of the Endangered Species Act Section 4(d) Rule. April 15, 2016. NMFS Consultation No.: WCR-2015-3441. 189p.).

natural spawning, the operational details are not important. As a worst case scenario, we assumed a broodstock size of 4860, a pNOB of between 0 and 16%, and a pHOS of 95%. Under these conditions, the local N_b reduction will range from 31% to 48%, but assuming a N_b:N_c of 25%, annual N_b will still be over 1000 per year, posing no risk to effective size. If the future pNOB, pHOS, and PNI values are achieved as in Table 12, effective size should be even higher.

2.5.2.2.1.2. *Gene Flow Assessment for the Green River Fall Chinook Salmon Population*

The potential negative genetic effects from the Soos Creek Fall Chinook Salmon program, and the FRF Fall Chinook Salmon program to be added in phase 2, 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, and for a tier 2 population under NMFS' Population Recovery Approach is the long-term goal.

Best available data suggests that the current population has a PNI of ~ 0.09, based on average data from 2013-2017 (Table 12). In the future, we anticipate a PNI of ~0.41 during phase 1 if natural-origin returns remain similar to what they have been on average for the last five years. However, Figure 7 depicts what PNI will look like over a range of natural-origin returns. Over the course of the consultation, the co-managers have agreed to some key changes in fall Chinook program operation that are anticipated to result in a substantially higher PNI value 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
- A 40% limit on the removal of natural-origin returns for hatchery program broodstock
- Creation of a natural production emphasis area in Soos Creek, where only natural-origin fish are passed above the weir
- Removals of hatchery-origin fish at existing collection facilities when total spawner abundance is > 4,432 adults
- Shift the integrated program component to Soos Creek Hatchery where adult collection is possible, and fish are likely to home to the site[5] from an off-station release site (Palmer Ponds)
- 100% marking of integrated component fish with a BWT or CWT or a combination of BWT and CWT to enable easy identification as hatchery fish from that program component
- An increase in Soos Creek Hatchery program production from 4.5 to 6.5 million to address the potential shortage of prey for endangered southern resident killer whales (SROTF 2018)

However, these changes cannot be implemented until brood are collected in the fall of 2019. Thus, NMFS expects there will be a period of relatively low PNI, similar to past values, before the benefits of the program modifications can begin to be realized. Integrated adult hatchery-

[5] 11% within basin straying for Soos Creek Hatchery releases compared to 86% within-basin straying for off-station releases, and 55% for Icy Creek yearling releases

origin fish will begin to return in 2022 (age-3 fish) and by 2024 the highly integrated program will have all age classes of returning to fish to supply broodstock to the segregated program. After five-years (2029) all returning segregated fish will have been derived from integrated broodstock.

Phase 2 is defined by the operation of the FRF (see section 1.3), and movement into this phase is anticipated to lead to an increase in PNI through the movement of some off-station fish to the new FRF, which increases the ability to collect returning hatchery-origin adults and remove them from the naturally spawning population. Thus, during phase 2, we anticipate a PNI of 0.42-0.45 if natural-origin returns remain similar to what they have been on average for the last five years depending on how many fish are released from acclimation sites. However, Figure 7 depicts what PNI will look like over a range of natural-origin returns.

We relied on a number of assumptions to populate the parameters of the model. We assumed pre-spawn mortality of 8% for natural-origin fish held for broodstock at the Soos Creek hatchery. We also assumed that SAE (smolt-to-adult-escapement) values for the FRF program and homing would be similar (0.338%) to those we calculated for the currently operating Soos Creek Hatchery program. The model also assumed that 20% of hatchery-origin fish would be removed when the equilibrium escapement goal was projected to be met. In addition, these calculations incorporated an additional 10% of juveniles produced on top of the program release goal.

The co-managers and other stakeholders in the basin have yet to detail what reintroduction entails once passage upstream and downstream of HHD is possible. However, it may be prudent to first conduct recolonization with hatchery-origin fish, which may initially cause a decrease in PNI during phase 3. But, in phase 4, we anticipate an increase in PNI as natural-origin fish are passed upstream of HHD to ensure self-sustaining, natural populations, in effect, creating a second natural production emphasis area above HHD. NMFS recommends that a group composed of federal, state, and tribal entities be formed to plan fish passage and reintroduction well before fish passage is estimated to occur no later than 2030 (NMFS 2018).

Table 12. Current and proposed Proportionate Natural Influence (PNI) for the Green River Natural fall Chinook salmon Population; pHOS = proportion of hatchery-origin spawners, pNOS = proportion of natural-origin spawners, pNOB = proportion of natural-origin broodstock, pIB = proportion of integrated hatchery-origin broodstock, and pSB = proportion of segregated hatchery-origin broodstock.

Time period	Natural-origin Returns	$pNOS_{SC}$[1]	$pNOS_{GR}$[1]	pHOSsc[1]	$pHOS_{I}$[1]	$pHOS_{S}$[1]	Integrated Program			Segregated Program			PNI
							pNOB	pIB	pSB	pNOB	pIB	pSB	
Current[2]	1,842	0.0	0.25	1.0	0.75		0.27	0.73	0	0	0.80	0.20	0.09
Phase 1[3]	1,842	1.0	0.11	0.0	0.04	0.85	0.97	0.03	0	0	0.80	0.20	0.42
Phase 1[3]	1,842	1.0	0.09	0.0	0.03	0.88	0.97	0.03	0	0	0.80	0.20	0.41
Phase 2[4]	1,842	1.0	0.15	0.0	0.05	0.8	0.97	0.03	0	0	0.80	0.20	0.42
Phase 2[4]	1,842	1.0	0.25	0.0	0.09	0.66	0.97	0.03	0	0	0.80	0.20	0.45

[1] The subscripts in the first row of the table are defined as follows: SC=Soos Creek, GR= Green River, I=integrated, S=segregated.
[2] For ease of comparison we divided pHOS into integrated and segregated components, but at this time, both components use natural-origin fish in the broodstock, with pNOB higher in what is designated here as the integrated component (26% of the 27% shown).
[3] The upper phase 1 row assumes 2 million segregated fish are released from acclimation sites, and the lower assumes 3 million segregated fish are released from acclimation sites.
[4] The upper phase 2 row assumes 1 million segregated fish are released from acclimation sites, and the lower assumes no segregated fish are released from acclimation sites.

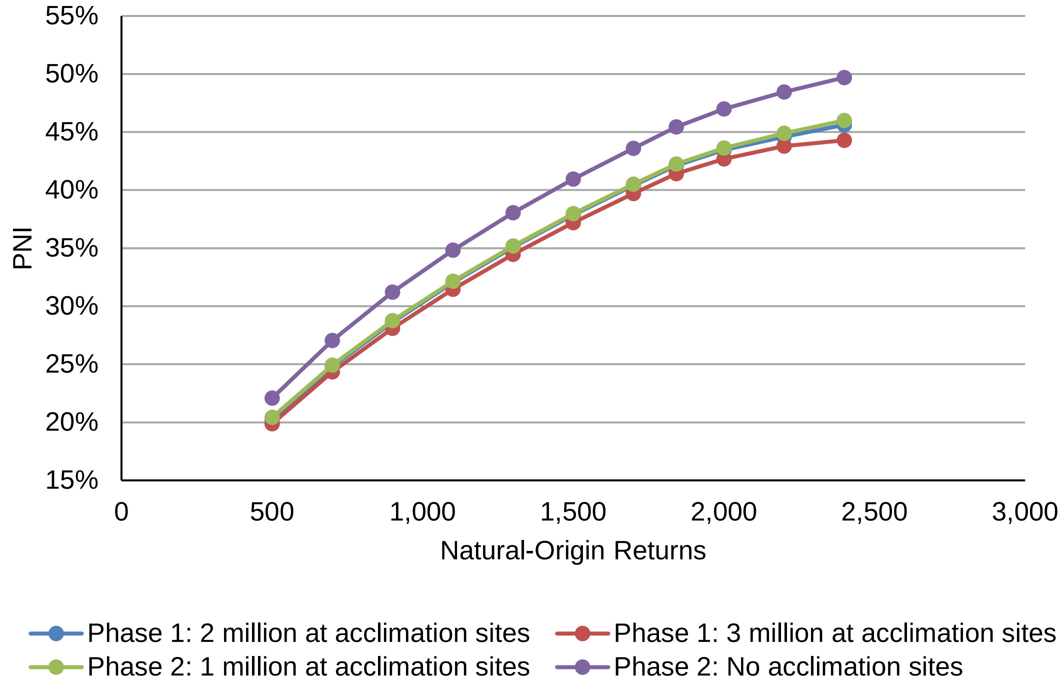

Figure 7. The range of PNI values achievable in phases 1 and 2 with varying numbers of Chinook salmon released.

2.5.2.2.1.3. *Green River Chinook salmon outbreeding effects*

Within the Green River Basin

The genetic diversity of the Green River Chinook salmon population could be adversely affected if the proposed hatchery programs incorporated as broodstock Chinook salmon originated from other Puget Sound populations. Inter-mixing the Green River stock with other Puget Sound Chinook salmon populations could decrease genetic differences between, and uniqueness of, the currently distinct, independent population in the ESU. To examine in detail the potential for gene flow from other populations into the Green River Chinook salmon population, (Haggerty 2019b) examined CWT recoveries in the Green River watershed for return years 2006 through 2015. This span of years was determined to best represent current patterns of straying that would likely occur for the Chinook salmon program operating in the basin.

Within the Green River Basin, Chinook salmon CWTs were recovered from 13 different hatchery programs including the three Green River programs. From 2006 through 2015, a total of 31,783 Chinook salmon are estimated to have spawned within the Green River salmon population’s natural spawning areas (excluding Big Soos Creek). A total of 18,378 were estimated to be hatchery-origin Chinook salmon based on carcass sampling, for an estimated pHOS of 57.8%. Using CWTs as a method to expand for the number of hatchery-origin fish yields an estimate of 7,833, suggesting there is likely a large amount of error using this CWT expansion method to reconcile which hatchery fish belong to which hatchery program, because it underestimates the number of hatchery-origin fish.

There are two explanations for why the CWT method underestimates the number of hatchery fish on the spawning grounds. The first is that despite a low percentage of CWT fish from Icy Creek (13.8%; no CWTs in 4 of 12 brood years), Icy Creek CWT Chinook salmon were five times more likely to be recovered on the spawning grounds as compared to Soos Creek Hatchery fish. Second, about half (107 of 215) of all CWTs recovered on the spawning grounds were recovered in Newaukum Creek, but because there were no CWT expansion factors for Newaukum Creek (for some years), this likely underestimates the number of hatchery-origin fish spawning naturally.

Based on CWT recoveries, sampling expansion, and tag expansion, the main contributor to the pHOS level observed in the Green River Basin were from the three Green River hatchery programs (92.2%). Out-of-basin hatchery strays accounted for 7.8% of the hatchery-origin fish spawning naturally. The biggest contributors to out-basin hatchery spawners were the George Adams and Bernie Gobin (discontinued) fall Chinook salmon programs at 2.8 and 2.5% respectively. The other out-of-basin spawners each contributed less than 1%.

Similar analysis of CWTs recovered at the Green River hatchery facilities revealed that 99.8% of the fish were from the Green River hatchery programs.

Outside the Green River Basin

The two Chinook salmon programs 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 which influence those populations. We evaluated freshwater spawning ground and hatchery CWT recoveries for a total of 5.427 million CWT Chinook (brood years 2000-2011) released from the Green River Basin hatcheries (excluding Palmer Ponds). A total of 61 observed tags were recovered out-of-basin, and adjusting tag recoveries for sampling rates by recovery location resulted in 175 estimated tags in out-of-basin sites (Table 13). For context, for every 72 estimated CWTs within the basin, one tag was recovered out-of-basin, suggesting an out-of-basin stray rate of 1.3%.

When estimated tags were expanded for the number of non-CWT fish in associated releases it was estimated that at total of 1,166 hatchery fish strayed into out-of-basin areas; with 944 straying onto natural spawning areas and 222 straying to out-of-basin hatcheries. It was estimated that only 15 of the 944 fish that strayed onto the natural spawning grounds strayed to stream systems outside of the Snohomish River basin (Boise Creek, Nisqually River, and Wenatchee River). A detailed analysis of CWT recoveries in the Snoqualmie River estimated that nearly 38% of the hatchery-origin fish with a known hatchery-origin originated from Green River hatchery facilities. Within the Skykomish River population, it was estimated that 13% of the hatchery origin fish with a known hatchery-origin originated from Green River hatchery facilities.

Table 13. Number of observed and estimated coded-wire tagged (CWT) Green River hatchery-origin fish, and estimated total number of Green River hatchery-origin fish that stray out of the Green River.

	Spawning Grounds			Hatcheries		
	Observed CWT	**Estimated CWT**	**Expanded hatchery-origin fish**	**Observed CWT**	**Estimated CWT**	**Expanded hatchery-origin fish**
Total Number	35	147	944	26	28	222
Number in Snohomish	32	135	508 Snoqualmie; 421 Skykomish	11	11	119
Number in other Basins	3	12	15	15	17[1]	103

[1] 8 of these were recovered in the Puyallup River Hatcheries, and the other 9 were recovered in 7 other basins.

For return years 2006 through 2015 it was estimated that unadjusted Green River hatchery-origin chinook made up 3.4%, 1.3%, and .03% of the total spawning escapement for the Snoqualmie, Skykomish, and Wenatchee Chinook salmon populations, respectively. When adjusted proportionally for hatchery-origin fish with known origin, Green River fish made up 6.9% and 3.7% of the total escapement for the Snoqualmie and Skykomish Chinook salmon populations, respectively. No Icy Creek yearlings CWTs were found in out-of-basin natural spawning areas.

To determine the amount of dispersion likely to occur into the future from Green River Chinook salmon programs, we used a tool ("recipients per year") developed during the Puget Sound dispersion analysis that includes the dispersion rate of each Puget Sound Chinook salmon hatchery program for the donor population's base period (brood years 2000 through 2011) into each of the 22 ESA-listed recipient population's (base period: return years 2006 through 2015). The tool includes a data field for annual hatchery releases for each donor population, and a population specific correction factor derived from the recipient population analysis. These two metrics along with program-to-population dispersion rates allows us to estimate future numbers of hatchery-origin fish from each program into each of the Puget Sound Chinook salmon populations.

We assumed no straying from the yearling program into the Snoqualmie and 6.8 million subyearlings with an adjusted smolt-to-adult-Snoqualmie spawner rate of 0.002412%, to estimate that on average, 164 Green River Basin hatchery-origin Chinook would stray into the Snoqualmie population. Natural-origin Chinook spawners in the Snoqualmie have averaged 1,129 (from recipient base period) and the total number of hatchery-origin spawners in the Snoqualmie is estimated to be 514 (based on currently proposed production levels), for a total average abundance of 1,643. We estimate that pHOS in the Snoqualmie River attributable to the Green River program at a release of 6.8 million subyearlings will average 10% (164/1,643).

This level of pHOS exceeds the 5% stray recommendation from Grant (1997) into the donor population. However, the authors considered all populations to be at the same tier, and did not vary the recommendation for populations at three different tiers. The Snoqualmie population is a tier 3 population under the PRA for Puget Sound Chinook, and is monitored annually for pHOS composition. Although recent data suggests that contribution from the Green River programs into the Snoqualmie population is > 5%, this estimate does not include data from the Palmer Ponds releases, or the changes in broodstock and adult management outlined in this Opinion. We will ensure this is revisited during the 5-year review, when we will have data for a complete brood year of fish released from Palmer Ponds.

2.5.2.2.1.4. *Gene Flow Assessment for the Green River Winter Steelhead Population*

The potential negative genetic effects from the two winter steelhead programs, Soos Creek and the FRF, are considered along with the demographic benefit of increasing population abundance. To perform our analysis, we used a customized model based on Busack (2015), similar to the one used for fall Chinook salmon that uses the best available information to determine the likely PNI of the population based on the applicants' proposed pNOB and the pHOS in natural spawning areas. As previously mentioned, a PNI of > 0.5 indicates that natural selective forces outweigh hatchery-influenced selective forces, but because a recovery plan for the Puget Sound Steelhead DPS has not been finalized, the role of each population in recovery is unclear and thus we must treat all populations as primary, or tier 1. Moreover, the current draft plan (NMFS 2018c) calls for the Green River winter steelhead population to reach viability. Thus, our long-term goal for the population is a PNI of ≥ 0.67, which ensures that natural selection outweighs natural-origin selection.

Best available data suggests that, with only the Green River Native late winter steelhead program in operation, PNI has averaged about 0.86 (Table 14; based on average data from 2014-2018). This PNI is likely to continue through phase 1 because this will remain the only operational winter steelhead program To calculate the potential PNI in phase 2, which adds in the FRF winter steelhead program, and some outplanting of hatchery-origin fish into Newaukum Creek, we modeled the Green River native late winter program and the FRF program with an SAR of 0.32% (based on returns from the now terminated early winter steelhead program). We assumed an average natural-origin return of 1,200 adults (based on average data from 2014-2018), a 65% homing rate of returning adults to the FRF, and assumed that all fish that returned to the hatchery and/or the TPU trap would be removed from the system and not allowed to spawn, with the exception of 100 hatchery-origin fish into Newaukum Creek. We also assumed that the Green River native late winter program would maintain an average pNOB and number of hatchery-origin spawners similar to what they were for 2014-2018.

The additional outplanting of up to 100 hatchery-origin returns to the FRF steelhead program into Newaukum Creek did not have a great effect on PNI, but may be one way to address the decline in tributary steelhead spawners (see Figure 8), and improve the spatial structure of the population. With this approach, PNI is likely to be ≥ 0.67, and we anticipate that this will increase in the future as long as returns of natural-origin fish increase. Of note, our model accounted for a 4.2% harvest rate (both phases), but we also modeled a 15% harvest rate at the request of the co-managers (phase 2 only). We anticipate that PNI will continue to remain at or exceed a PNI of 0.67 in phases 3 and 4, once passage upstream and downstream of HHD is possible, as improved passage above HHD is likely to increase the amount of available spawning habitat.

Table 14. Current and expected future proportionate natural influence (PNI) for the Green River natural steelhead population. Row shading denotes the difference in PNI between a 4.2% harvest rate (unshaded), and a 15% harvest rate (shaded); pHOS = proportion of hatchery-origin spawners, pNOS = proportion of natural-origin spawners, pNOB = proportion of natural-origin broodstock.

Time period	Average Natural-origin Returns	$pHOS_S$	$pHOS_F$	pNOS	$pNOB_S$	$pNOB_F$	PNI
Current/Phase 1	1200	0.16	NA	0.84	0.89	NA	0.86
Phase 2	1200	0.12	0.20	0.68	0.88	0.5	0.67
Phase 2	1200	0.12	0.13	0.75	0.88	0.5	0.67

Source: (Haggerty and Hurst 2019)

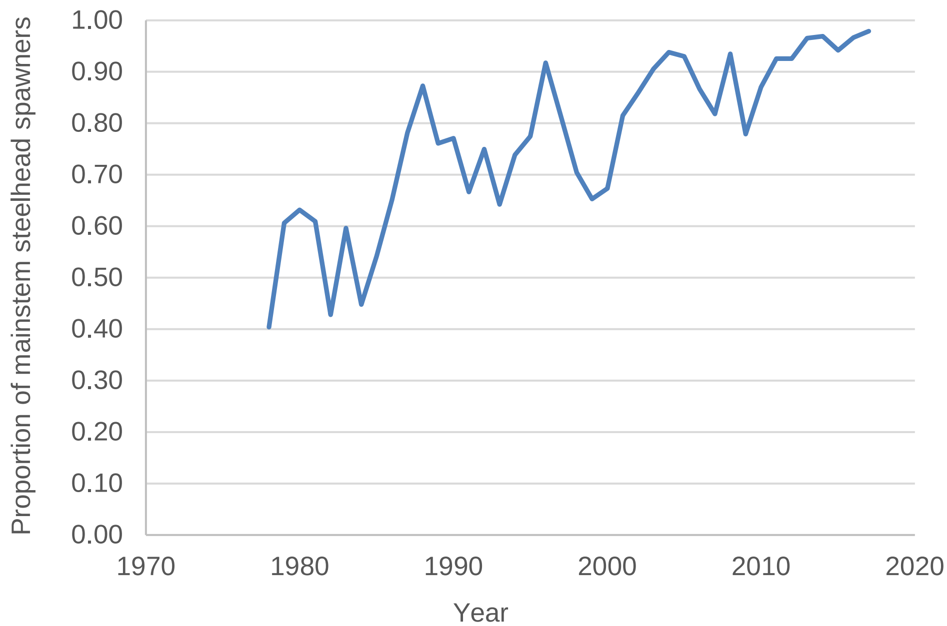

Figure 8. The proportion of steelhead spawners in the Green River Basin that spawn in the mainstem section of the River from 1978 to 2017(WDFW et al. 2017).

2.5.2.2.1.5. *Green River winter steelhead outbreeding effects from winter steelhead programs*

Within the Green River Basin

The genetic diversity of the Green River steelhead population could be adversely affected if the proposed winter-run steelhead hatchery programs incorporated broodstock originating from other Puget Sound steelhead populations. Inter-mixing the Green River stock with other Puget Sound steelhead populations could decrease genetic differences between, and uniqueness of, currently distinct, independent populations in the DPS.

The only potential hatchery-origin steelhead that could be mistaken for a Green River steelhead with the same marking scheme would be White River hatchery-origin steelhead. The White River steelhead population is the closest location of an independent population where straying of hatchery-origin steelhead would be likely (due to the population's proximity to the hatchery fish release sites). It is unknown if, or how many, White River hatchery-origin winter steelhead stray into the Green River each year. However, propagating and releasing only hatchery- and natural-origin fish identified by return timing, return location, and marks/tag presence/absence as part of the Green River steelhead population is likely to limit the risk of outbreeding effects resulting from returning adult hatchery-origin winter steelhead.

Outside the Green River Basin

The two winter steelhead programs could also pose risk to other Puget Sound steelhead populations if fish from the Green River programs comprise a substantial portion of the natural spawners in other steelhead populations or of the broodstock in programs that influence those populations. Recent (2009-2015) steelhead escapement data from the Cedar River where, on average, fewer than three natural-spawning steelhead have been observed per year, suggest few, if any, Green River hatchery-origin fish are straying into the Cedar River.

As described above, White and Green River winter steelhead programs have the same marking scheme and cannot be differentiated from one another. The risk of straying to other nearby steelhead populations appears to be very low (based on Cedar River steelhead abundance), but is unknown in the White and Puyallup Rivers. However, dispersion into watersheds where other natural-origin steelhead populations exist would be monitored and analyzed through mark and tag recovery at hatchery broodstock collection sites, and through carcass recoveries during spawning ground surveys. In addition, to reduce the risk of dispersion, juvenile hatchery fish would be acclimated to their sites of release at Soos Creek Hatchery, Icy Creek, Flaming Geyser, and the FRF (or upstream release sites) to encourage a high adult return fidelity to release location.

2.5.2.2.1.6. *Gene-flow impacts on Green River winter steelhead from the early summer steelhead (ESS) program*

Fish returning from the ESS program could have negative effects on the natural steelhead population if interbreeding occurs. Outbreeding effects are a concern whenever the hatchery- and natural-origin fish are from different populations, and this is certainly the case with the ESS and the natural population considered in this Proposed Action. The stock, having originated in the Columbia River Basin (Crawford 1979), is genetically distinct from all native Puget Sound steelhead populations (Busby et al. 1996; Phelps et al. 1997). In addition to its out-of-DPS origin, the ESS stock has been subjected to many years of intense artificial selection for early smolting, which has resulted not only in smolting predominantly at one year of age, compared to two years, or more, in natural populations, but also earlier spawning time (Crawford 1979). NMFS has previously voiced concerns about the genetic risks of ESS programs in Puget Sound (Hard et al. 2007; McMillan et al. 2010).

Evaluation of outbreeding effects is very difficult. The best existing management guidance for avoiding outbreeding effects is the conclusion of the 1995 straying workshop (Grant 1997), that gene flow between populations (measured as immigration rates) should be under 5%. The HSRG (2009a) generally recommended that for primary populations (those of high conservation value) affected by isolated hatchery programs, the proportion of natural spawners consisting of hatchery-origin fish (pHOS) not exceed 5%, and more recently (HSRG 2014) suggested that this level should be reduced. WDFW used the Ford (2002) model to evaluate the hatchery-influenced selection risk of ESS programs, and concluded they posed less risk than integrated native-stock programs at gene flow levels below 2%, but greater risk at levels above that (Scott and Gill 2008).

Some explanation is needed at this point of the relationship between pHOS and gene flow, because the two can easily be confused. Genetic impacts from hatchery programs are caused by gene flow from hatchery fish into a naturally spawning population. Thus, if hatchery-origin fish equal natural-origin fish in reproductive success, pHOS represents the maximum proportionate contribution of hatchery-origin parents to the next generation of natural-origin fish. In the absence of other information, pHOS is an estimate of maximum gene flow on the spawning grounds. However, highly domesticated steelhead stocks are known to have low fitness in the wild (e.g., Araki et al. 2007; Chilcote et al. 1986), so gene flow is likely lower than that predicted by the Ford model. Second, the partially overlapping spawning distributions will decrease the proportion of HxN matings and increase the proportion of HxH matings relative to what it would be with total temporal overlap of spawners. Focusing attention on gene flow rates rather than pHOS is thus always advisable if feasible, and especially so in the case of ESS spawning in the wild, in which pHOS levels may considerably overestimate gene flow levels.

Gene flow is a seemingly simple concept, but developing straightforward ways to measure it is not simple. For one thing, gene flow from hatchery fish into natural populations is commonly referred to as interbreeding or hybridization. This is an oversimplification. In reality, gene flow occurs by two processes: hatchery-origin fish spawning with natural-origin fish and hatchery-origin fish spawning with each other. How well the hatchery-origin fish spawn and how well their progeny survive, determines the rate at which genes from the hatchery population are incorporated into the natural population. The importance of including the progeny of HxH matings (i.e., the progeny of two hatchery fish spawning in the wild) as a potential “vector” for gene flow is illustrated by the observation that these fish may have a considerably longer and later spawning season than hatchery-origin fish (Seamons et al. 2012). An appropriate metric for gene flow needs to measure the contributions of both types of matings to the natural population being analyzed. Another consideration is temporal scale. Although there may have been effects from gene flow from earlier more intensive and widespread hatchery activities, for the purposes of analyzing these proposed programs, what must be measured is the current rate of gene flow, which is best represented as the proportion of the current naturally produced progeny gene pool:

$Gene\ flow = (2f(HH) + f(NH))/2$, where *f(HH)* is the proportion of naturally produced progeny produced from HxH matings, and *f(NH)* the proportion of progeny produced by NxH[6] matings

[6] As in earlier usage in this document, this is meant to represent both matings between natural-origin females and hatchery-origin males, and vice versa.

WDFW has developed two metrics for measuring gene flow in this way. The first is based on actual genetic data, and is called proportionate effective hatchery contribution (PEHC; Warheit 2014a), hereafter called the Warheit method. WDFW also has developed an alternative demographic method, hereafter called the Scott-Gill method, for calculating the expected gene flow that is based on demographic and life history data rather than genetic data (Scott and Gill 2008). Both methods and their results for the Green River Natural Steelhead population are described below.

Estimation of gene flow using genetic data

Introduction to Warheit method

Estimation of PEHC in Puget Sound steelhead is difficult because, in terms of genetic markers that are currently available, the differences between the hatchery-origin fish and natural-origin fish are slight, due to common ancestry and likely gene flow in the past. Researchers at WDFW have struggled with this problem for several years. Dr. Ken Warheit, director of the Molecular Genetics Laboratory at WDFW, in association with Dr. Shannon Knapp (formerly at WDFW, now at the University of Arizona), developed a method for estimating PEHC in situations like this (Warheit 2014a). The method is still undergoing refinement, and for that reason has received limited peer review. However, the method has been extensively reviewed by NMFS staff, and refined in response to that review.

The Warheit method involves, in part, comparing genotypes of natural-origin and hatchery-origin fish using the *Structure* program (Pritchard et al. 2000; Pritchard et al. 2010). *Structure* is one of the most widely used programs for inferring population structure, and has also been used for detecting hybrid individuals, frequently between wild and domestic populations. The WDFW Molecular Genetics Laboratory has many years' experience using the program. *Structure* makes use of each individual's multilocus genotype to infer population structure (e.g., hatchery versus wild), given an a priori assumed number of groups or populations. The program will probabilistically assign individuals to populations, or if the admixture option is used, will assign a portion of an individual's genome to populations. Through a recent detailed series of simulations, Warheit has recently determined that PEHC estimates derived from the method are upwardly biased; i.e., actual PEHC (true gene flow) will always be less than its estimate (NMFS 2019a). For more background on this method please see NMFS (2016b); NMFS (2016c).

Application of Warheit method to the Green River Basin steelhead population

WDFW has applied the Warheit method to the Green River natural steelhead population, as well as several other Puget Sound steelhead populations. Table 15 reports PEHC information provided in Warheit (2014b) for the Green River watershed natural steelhead population from the ESS program, along with sampling details. The table also reports projected PEHC values, which reflects the proportionate ESS program change expected[7].

[7] Projected gene flow is determined by adjusting the current or past estimate for changes that are expected under the proposed action. Simple example: if PEHC is estimated to be 1%, and the program is expected to be double, the projected PEHC would be 2%. The equation for projected values is included in WDFW (2015c).

Table 15. PEHC estimates and confidence intervals (CI) based on past practices (2004-2013), and from the proposed ESS hatchery program for the Green River steelhead population (WDFW 2015).

Listed Population	Sample Size[1]	Past PEHC (%) and 90% CI	Projected PEHC (%) under Proposed HGMPs
Green River Winter	165	1.0; 1.0-2.0	2.0

[1]From juveniles and adults sampled in 2004, 2007, 2008, and 2013.

PEHC estimates are likely overestimates of gene flow. The Warheit method is intended to estimate current gene flow, but it is inevitable that some mixed lineage fish that are not the immediate result of HxH or HxN matings will be identified as such (Warheit 2014a), inflating the PEHC estimate. The degree to which these misidentifications inflate PEHC has not been explored, and the effect on confidence intervals is unknown, but the effect will increase with increasing gene flow. These issues all need to be clarified in further development and updating of the method. However, assuming that PEHC has not been systemically underestimated in some way due to a bias in the estimation process, and considering the confidence intervals, recent gene flow from the ESS program into this basin appears to have been about 1%. The expectation is that PEHC will remain at less than 2% based on a four year average (one steelhead generation) in recognition of annual variability. A monitoring plan specific for the Green River to verify the PEHC estimate will be developed by the co-managers and submitted to NMFS within four months of Opinion signature.

Estimation of gene flow using demographic methods

Scott-Gill Method

Direct measurement of gene flow is preferred over estimation of gene flow based on demographic parameters, but WDFW has developed a demographic approach called the Scott-Gill method (WDFW 2008). The method assumes that the spatial and temporal distribution overlap of spawning of hatchery-origin and natural-origin fish can be divided into three regions: A, where only HxH matings are possible; B, where HxH, HxN, and NxN are possible; and C, where only NxN matings occur.

The Scott-Gill method assumes random mating within mating region, and uses estimates of the proportion of spawners that are of hatchery origin (pHOS[8]), the proportion of hatchery-origin and natural-origin spawners in region B, and the relative reproductive success (RRS) of the HxH and NxH mating types to compute the proportion of the offspring gene pool produced by hatchery-origin fish. Although the value produced by the equation appears to be analytically identical to PEHC, we will call it DGF (demographic gene flow) to prevent confusion as to which metric we are discussing, and to distinguish the metric from the concept. Please see Hoffmann (2014) for more information on this method for calculating gene flow.

[8] Symbolized by q in the equation in WDFW documents.

Table 16 presents the NMFS-derived DGF values for the Green River steelhead natural population computed with the same assumed values about RRS (0.09 to 0.18 for HxH ESS matings and 0.60 for ESS HxN), and pHOS as proportion of hatchery-origin escapement (30%), as was done for Hoffmann (2014) case 6b in the Skykomish River basin (NMFS 2016c). This assumption of 30% of the hatchery-origin escapement remaining in the river to spawn was considered to be conservative (i.e., greater or higher) in comparison to earlier estimates by the HSRG of 10-20%. PEHC estimates were based on whatever samples were available and deemed appropriate, rather than data collected on a regular schedule over the years. The years of demographic data used for DGF estimates were selected by NMFS from those available to best represent existing demographic variation (i.e., most recent 5-years).

The Scott-Gill results indicate that gene flow has been about 2% in the Green River steelhead natural population and it is likely to remain the same or slightly increase to approximately 2.2% under the proposed action. However, there is uncertainty around this conclusion because of the assumed stray rates and RRS values that require validation. Whatever error exists in the DGF estimate is predominantly due to parameter uncertainty, rather than error associated with assumed statistical distributions, so no confidence intervals are included with the estimates in Table 16. We did not complete a comprehensive sensitivity analysis, but did discuss our concerns previously in (NMFS 2016b); NMFS (2016c).

Table 16. DGF values generated from the Scott-Gill equation for the Green River winter steelhead natural population. For recent past pHOS and DGF, means are reported with maxima in parentheses and assume a 30% stray rate and 0.18 RRS value. Projected DGF values are based on an assumed 30% stray rates and a 0.18 RRS value.

Parameter	Values (%)
Escapement years	2014-2018
O_N	1.28
O_H	27.9
Recent past pHOS	4.4 (10.3)
Recent past DGF	1.1 (2.4)
Projected pHOS	9.1
Projected DGF	2.1

Summary

Both metrics indicate that gene flow into the Green River natural steelhead population from the ESS program is likely to be approximately 2.0%, a value previously determined by NMFS to be acceptable in the similar early winter programs in Puget Sound (e.g., NMFS 2016b). The co-managers have committed to the annual gathering and analysis of data, and will also be required to implement the terms and conditions of the ITS (Section 2.9). Thus, NMFS concludes that gene flow from the proposed action is approximately 2% into the Green River natural steelhead population, and any negative effect is likely to decrease as the co-managers transition to a Puget Sound summer steelhead stock with the intent of minimizing genetic effects of any naturally spawning summer steelhead.

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 Green River Basin, providing food resources for naturally produced Chinook salmon and steelhead. 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 and steelhead 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 17. It was estimated that these naturally spawning hatchery-origin salmon and steelhead would contribute 232.7 kg of phosphorous to the action area annually during phase 1. We also assumed that all returning steelhead would die after spawning, but there is likely some portion of the steelhead spawners that leave the system as kelts, and return to spawn again in subsequent years. Excluded from this table are the coho released from the Des Moines and Elliott Bay net pens because data suggests that about 96% are harvested in pre-terminal fisheries (average from 2009-2013; Schaffler 2018). Marine Technology Center coho releases are also not included below, as these fish do not return to the Green River watershed. In phase 2, the nutrient concentration increases to 240.3 kg, because of the additional release of Chinook and coho salmon, and steelhead at the FRF. This contribution is likely to be similar in phases 3 and 4 as no additional fish releases are proposed.

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 17. 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). Italicized rows are those programs that are only included in phase 2. NA = not applicable; FRF = Fish Restoration Facility; KCC = Keta Creek Complex; SCH = Soos Creek Hatchery; SAE = smolt to adult escapement.

Program	Species	Release Size	SAE (%)	Percentage on natural spawning grounds	Percent Removed	Hatchery Spawners	Adult Weight (Kg)	Phosphorous Concentration	Phosphorous Imported Kg/Y
SCH	Chinook	3,520,000	0.338	11.3	20	1078	5.5	0.0038	22.5
Icy Creek	Chinook	330,000	0.295	55.4	20	432	5.5	0.0038	9.0
Palmer Ponds	Chinook	3,300,000	0.338	86.4	20	7709	5.5	0.0038	161.1
FRF	*Chinook*	*660,000*	*0.338*	*11.3*	*20*	*202*	*5.5*	*0.0038*	*4.2*
SCH	Coho	660,000	2.065	1.6	0	215	2.7	0.0038	2.2
KCC	Coho	1,100,000	3.498	1.6	0	608	2.4	0.0038	5.5
KCC Off Station	Coho	55,000	3.498	1.6	0	30	2.4	0.0038	0.3
FRF	*Coho*	*660,000*	*2.065*	*1.6*	*0*	*215*	*2.7*	*0.0038*	*2.2*
KCC	Chum	5,500,000	0.343	10	0	1886	4.3	0.0038	30.8
FRF Native	*Steelhead*	*275,000*	*0.307*	*35*	*0*	*295*	*3.6*	*0.0038*	*1.2*
Green River Native	Steelhead	60,500	0.307	100	0	179	3.6	0.0038	0.7
Green River Summer	Steelhead	110,000	0.491	30	0	162	3.2	0.0038	0.6
Total (phase 1)									232.7
Total (phase 2)									240.3

Sources: fall Chinook parameters were from Haggerty 2018(Haggerty 2018); coho salmon SAE to hatchery survival from CWT recoveries in RY 2009 through 2015 (RMIS query), coho escapement and pHOS from WDFW (WDFW coho escapement workbook, 2019); fall chum SAEs from WDFW's 2019 chum salmon forecast, assumed 10% stray rate; winter steelhead parameters were calculated in (Haggerty 2018), assumes FRF pHOB removed from mainstem, and 30% in-river post spawning mortality; and summer steelhead parameters from demographic gene flow calculations.

2.5.2.2.2.2. *Spawning ground competition and redd superimposition*

Chinook Salmon

Hatchery-origin adult salmon and steelhead produced through the within-basin hatchery salmon and steelhead programs that escape to spawn naturally have the potential to adversely affect listed Chinook salmon through competition for spawning sites and redd superimposition. For the Green River population, natural-origin returns have averaged less than 2,000 fish, and Chinook returns from the proposed programs, after accounting for harvest and hatchery rack returns are estimated to be about 9,600 fish (Table 17). The current spawning stock size at equilibrium is 4,423. 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.

Coho salmon produced through the Marine Technology Center Coho Hatchery Program, components of the Soos Creek Coho Hatchery Program (TU Miller Creek Hatchery Co-Op, Des Moines Net Pen, and Miller Creek egg transfers), and half of the coho salmon smolts produced by the Keta Creek Complex Yearling Coho Hatchery Program, are released outside of the Green River Basin. Of those released within the basin during phase 1, an estimated 854 are expected to escape to spawn naturally. We assume that, once the FRF comes online, harvest rates and hatchery rack returns for coho originating from the FRF program will be similar to the other programs within the basin. Thus, the program is estimated to result in an additional 2,015 fish to the spawning grounds during phase 2.

It is important to note that coho and Chinook have always existed in the watershed together. Furthermore, based on spawn timing and spawning habitat preference differences between coho and Chinook salmon, effects of competition for spawning sites and/or redd superimposition are expected to be low as a result of coho salmon production in the action area across all four phases. When coho return, water availability is greater, which allows coho to migrate further upstream in the tributaries. The few coho salmon that spawn in the mainstem or side channels tend to spawn in areas that had been too shallow for Chinook salmon (Eric Warner, MIT, personal communication, November 5, 2018). NMFS anticipates that the number of hatchery-origin fish on the spawning grounds will not increase by more than 50% of the number in Table 17 (i.e., 535 spawners) based on a 5-year running average beginning in 2019 (average of 2015-2019).

Hatchery-origin chum salmon spawn in the areas used by Chinook salmon. However, competition for spawning sites and redd superimposition are unlikely to occur for a number of reasons. First, Chinook salmon redds are usually constructed in reaches with larger substrate size (Kondolf and Wolman 1993), deeper water, faster water velocities, and deeper egg pockets than those constructed by chum salmon (DeVries 1997; Geist et al. 2002; Quinn 2005). Second, most Chinook salmon spawning in the Green River is complete before the onset of chum salmon spawning (Table 18). Third, habitat availability during chum salmon spawning differs from when Chinook salmon spawned due to higher water levels associated with later spawn timing (Geist et al. 2011; Eric Warner, MIT, personal communication, March 21, 2019). Fourth, a study by Burns et al. (2018) found that chum salmon also spawned in upwelling water that was significantly warmer than the surrounding river water. In contrast, fall chinook salmon constructed redds at downwelling sites, where there was no difference in temperature between the river and its bed. Finally, the spawning distribution for chum is weighted lower in the watershed than for Chinook. Only a third of chum make it as far upstream as the mouth of Crisp Creek (< 3% at Flaming Geyser Park), and it is unclear if these chum salmon spawn successfully. A substantial portion spawns below Soos Creek. By comparison, Chinook salmon spawn from the mouth of Soos Creek upstream to the Headworks dam (Eric Warner, MIT, personal communication, March 21, 2019). For the reasons detailed above, spawning site competition and redd superimposition between Chinook salmon and hatchery chum salmon is unlikely to occur.

Hatchery-origin winter steelhead return at low relative abundances compared to Chinook salmon within the Green River Basin. In addition, Chinook salmon spawning peaks in mid-October, whereas winter steelhead spawning peaks in mid-April (Table 18), and there is no temporal overlap between the two spawning aggregations (WDFW spawning ground survey database). Therefore, there is no competition for spawning sites between the two species. Redd superimposition is not possible since Chinook salmon eggs will have hatched prior to the onset of hatchery winter steelhead spawning.

Summer hatchery-origin steelhead within the Green River Basin have a spawn timing that starts and peaks in January but extends through mid-March. Based on spawning habitat preference and spawn timing, there are unlikely to be any spawning habitat competition effects on Chinook salmon from hatchery summer steelhead.

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. Green River Chinook salmon spawn from mid-September through early-November (Table 18), well before the earliest spawning winter steelhead enter the river as returning adults. Coho salmon spawn from late-October through mid-January, also well before the earliest-timed winter steelhead. Chum salmon have spawn timing similar to that of coho, from mid-November through December. Thus, there are unlikely to be any competition and redd superimposition effects of hatchery salmon on winter steelhead due to temporal separation.

The primary intent of the two hatchery winter steelhead programs is to produce native stock adult fish for conservation purposes, with a goal of using hatchery-origin fish to seed the mainstem and tributaries to meet an escapement goal of 2,003 fish, which was only met in one of the last five years (WDFW Score). This is well below the intrinsic potential estimates of 20,000-40,000 for the population (Myers et al. 2015). Thus, the watershed is likely under-seeded with naturally spawning steelhead, making competition and redd superimposition from the steelhead programs unlikely to occur as space is not limiting.

ESS straying into natural spawning areas are likely to occupy the same or similar habitat used by natural-origin winter steelhead. Hoffmann (2014) estimated that only ~1% of all natural-origin winter steelhead spawning occurred prior to March 15, suggesting that temporal overlap between ESS and winter steelhead is very small. It is anticipated that a majority of the total annual ESS adult returns will be removed through harvest and escapement to the hatcheries, decreasing the number of hatchery fish available for straying (estimated to average 90-150 per year (assuming

20% to 30% stray rates) into natural steelhead spawning areas (Hard et al. 2007; WDFW 2015). Thus the temporal separation between ESS and natural steelhead spawners, and the likely low number of steelhead remaining in the rivers after harvest and hatchery escapement, decreases the likelihood of competition for spawning sites and makes redd superimposition unlikely.

Table 18. Terminal area/river entry timing, spawn timing, and spawning location for Green River Basin Chinook, chum, and coho salmon, and steelhead populations.

Species	Terminal Area/River Entry Timing	Spawn Timing	Spawning Locations
Chinook salmon	Late-July to September	September 15 to early-November	Mainstem Green River and Newaukum and Big Soos Creeks
Chum salmon	November to early-December	Mid-November to December	Mainstem Green River, side channels, various tributaries
Coho salmon	September to early-November	Late-October to mid-January	Green River and various tributaries
Winter steelhead	November to April	March to May	Mainstem Green River and Newaukum and Big Soos Creeks
Summer steelhead	June to early-October	Late-December to March	Green River and various tributaries

Sources: (WDFW spawning ground database;Tribe and USFWS 1977; WDFW and WWTIT 1994)

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 Green River, *Flavobacterium psychrophilum*, *Aeromonas salmonicida*, *Nanophyetes salmincola*, *Ichthyopthirius multifiliis*, *Saprolegnia sp.*, and *Henneguya salmincola* were all detected. These pathogens are all native to the Green River Subbasin and did not result in any disease outbreaks in adults over the most recent three years of data. 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.

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 and steelhead (Table 19). Samples for genetic analyses may also be taken from all steelhead regardless of origin at the time of collection. The proposed handling numbers are higher than the most recent five years would suggest are needed to account for increases in both the currently operated Chinook (2 million subyearlings) and steelhead programs (22,000 smolts) in phase 1, and for the addition of the FRF steelhead program in phase 2 (250,000 smolts). Alternative methods may be needed to capture broodstock because of the unknowns associated with the mechanics of the Soos Creek Hatchery rebuild, including how adults will respond to the new fish ladder, weir, and adult ponds in the range of low to high water conditions. These methods could involve seining or netting the area below the new fish ladder entrance down to the bridge at the lower end of the hatchery property, and/or in-river collections at various access points on the Green River to collect natural-origin fish. In addition, the TPU trap is likely to be operated for a longer period of time, resulting in an increase in handling at that site compared to previous years. Handling of listed species in phases 3 and 4 is likely to be similar for hatchery fish, but may increase for natural-origin fish if returns improve.

Table 19. Number of ESA-listed Chinook salmon and steelhead 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 (mortalities)	Proposed (mortality)	Average; range (mortalities)	Proposed (mortality)
Soos Creek Hatchery Weir	Natural	688; 163-1497[1]	2,000 (40)[2]	1 (0)	10 (1)
	Hatchery	10670; 3964-17454[1]	25,000 (500)[3]	0	10 (1)
Icy Creek Weir	Natural	4 handled (4)[1]	10 (1)	0	5 (0)
	Hatchery	0-202 (0)	10 (0)	0	200 (0)
Keta Creek Complex Weir	Natural	52; 5-199 (5)	250 (25)	0	5 (5)
	Hatchery	120; 12-465 (10)	750 (150)	0	10 (5)
Fish Restoration Facility	Natural	0	2,000 (50)	0	400 (20)
	Hatchery	0	8,000 (240)	0	400 (40)
Miller Creek Hatchery	Natural	0	5 (0)	0	2 (0)
	Hatchery	0	5 (0)	0	5 (0)
TPU Trap	Natural	107; 0-498 (1)	1,000 (10)	5; 0-12 (1)	400 (20)
	Hatchery	206; 0-696 (3)	8,000 (40)	13; 4-34 (0)	400 (40)
Marine Technology Center	Natural	0	5 (0)	0	2 (0)
	Hatchery	0	5 (0)	0	5 (0)

Sources: (Coccoli 2018b; WDFW 2018b)

[1] The configuration of Soos Creek Hatchery is such that fish cannot move upstream of the hatchery unless they first go through the hatchery. Thus, there is no handling of fish without some period of holding, and this mortality is already captured in the collection and holding values in Table 2.

[2] These values also account for the handling effects of alternative broodstocking methods such as seining and netting at various access points on the Green River to collect natural-origin fish.

[3] The hatchery handling number was based on the increase in production from 4.5 to 6.5 million, and the best survival rate observed in recent years. We expect up to 2% incidental mortality may occur in the future with the redesigned weir and adult holding ponds.

Other effects of weir operation are the potential for delayed migration and changes in spatial distribution of listed species. Though adult passage may be delayed slightly, weir operation guidelines and monitoring of weirs by the co-managers minimize the delays to and impacts on fish; fish generally are not delayed for more than 24 hours throughout the trapping season. In addition, the spatial distribution of juvenile and adult listed species is not expected to be affected by weir operation in these areas because the weirs are designed to allow juvenile passage, and natural-origin adults are passed upstream when not required for broodstock.

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

The effects of this factor on both listed species are negative, as discussed in greater detail below.

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

Competition may result from direct or indirect interactions between listed natural-origin salmonids and hatchery fish released as part of the proposed action. Direct interactions occur when hatchery-origin fish interfere with accessibility to limited resources by natural-origin fish. For example, hatchery fish may take up residency before naturally produced fry emerge from redds. 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), such as food and rearing sites (NMFS 2012).

Several factors influence the risk of competition posed by hatchery releases: whether competition is intra- or interspecific; the duration of freshwater co-occurrence of hatchery and natural-origin fish; relative body sizes of the two groups; prior residence of shared habitat; environmentally induced developmental differences; and density in shared habitat (Tatara and Berejikian 2012). Intraspecific competition would be expected to be greater than interspecific, and competition would be expected to increase with prolonged freshwater co-occurrence. Hatchery smolts are commonly larger than natural-origin fish, and larger fish usually are superior competitors. However, natural-origin fish have the competitive advantage of prior residence when defending territories and resources in shared natural freshwater habitat. Tatara and Berejikian (2012) further reported that hatchery-influenced developmental differences from co-occurring natural-origin fish are variable and can favor both hatchery- and natural-origin fish. They concluded that of all factors, fish density of the composite population in relation to habitat carrying capacity likely exerts the greatest influence.

Another important possible ecological effect of hatchery releases is predation. Salmon and steelhead are piscivorous and can prey on other salmon and steelhead. Predation, either direct (direct consumption) or indirect (increases in predation by other predator species due to enhanced attraction), can result from hatchery fish released into the wild. In general, the threat from predation is greatest when natural populations of salmon and steelhead are at low abundance, when spatial structure is already reduced, when habitat, particularly refuge habitat, is limited, and when environmental conditions favor high visibility. Our analysis below can only consider the effects of direct predation. Although we acknowledge the possibility of indirect predation, we have no way to assess the effect at this time.

2.5.2.3.1.1. *PCD Risk Model Analysis in Freshwater*

While competition and predation are important factors to consider, they are events which can rarely if ever be observed and directly calculated. However, these behaviors have been established to the point where NMFS can model these potential effects to the species based on known factors that lead to competition or predation occurring. Here, we used the PCD Risk model version 3.1 of Pearsons and Busack (2012), to quantify the potential number of natural-origin Chinook salmon and steelhead juveniles lost to competition and predation from the release of hatchery-origin juveniles. Although model logic is still largely as described in the 2012, the PCD Risk model has undergone considerable modification since then 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. The one modification to the logic was a 2018 elimination of competition equivalents and replacement of the disease function with a delayed mortality parameter. The rationale behind 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).

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 20). We assumed a 100% population overlap between hatchery fish and ESA-listed natural-origin Chinook salmon and steelhead present. We acknowledge that a 100% population overlap in microhabitats is likely an overestimation. We also assumed that habitat complexity was low at only 10% to account for habitat degradation in the Green River Basin. We used habitat segregation estimates of 0.3 for conspecifics, and 0.6 for other species, a dominance mode of 3 and maximum encounters per day of 3, based on what was decided in the HETT (2014) database for hatchery programs of the same life stage and species.

Table 20. Parameters in the PCD Risk model that are the same across all programs.

Parameter	Value
Habitat complexity	0.1
Population overlap	1.0
Habitat segregation	0.3 for conspecifics, 0.6 for all other species
Dominance mode	3
Maximum encounters per day	3
Predator:prey length ratio for predation	0.25[1]

[1] Daly et al. (2014)

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, in this case, we had data to inform the actual number and proportion of natural-origin juveniles of each species present in the Green River Basin (Table 21). For Chinook salmon, this was based on average data from the annual smolt trapping estimates that occurred in the watershed from 2012 to 2016 (Topping and Anderson 2017). For steelhead, we back calculated steelhead smolts from the total adult steelhead spawners in the basin from 2014 to 2018 using a smolt to adult survival rate of 1.5%. We then assumed survival of fry-age-1 smolts of 15% and survival of fry-age-2 smolts of 10% based on (Quinn 2005). We then calculated the number of parr by diving the age-2 smolt value by an assumed 50% survival rate from parr to age-2 smolt. To calculate the number of fry we then divided age-1and age-2 smolts by the aforementioned fry-smolt survival rate. Summing all of the life stage numbers together, we were then able to determine the proportion of each lifestage. For more detail, please see Hurst and Haggerty (2019). We believe this more closely mimics the reality of the Green River system compared to how we have modeled abundance and proportions of natural-origin fish in previous consultations.

We also were able to rule out encounters with natural-origin Chinook salmon and steelhead from the model for some hatchery species. This is because Chinook salmon fry typically have their peak emigration in February (see Section 2.2.1.1), well before most hatchery species are released. Thus, Chinook salmon fry were only included in the model for hatchery chum salmon. Similarly, most hatchery fish releases occur well before steelhead emergence. Thus, we used steelhead redd data to extrapolate fry emergence based on emergence requiring ~1200 accumulated temperature units (ATUs; Haggerty 2019a). This ATU value was suggested by Coccoli (2018a) based on work from Burton (2003). Using this information, and considering the hatchery fish release windows, we were able to include only the proportion of steelhead fry that would have emerged assuming that hatchery fish are all released on the last day of their release window and assuming that all hatchery fish take the full length of travel time to the mouth of the Green River. For example, hatchery coho released on May 15th from the FRF site would take an estimated 22 days to travel to the river mouth (Table 22). This would mean that they would not exit the system until June 6th.

Table 21. Age, size, and occurrence of listed natural-origin salmon and steelhead encountered by juvenile hatchery fish after release.

Species	Abundance	Lifestage	Size in mm (SD)	Lifestage Proportion	Occurrence
Chinook salmon	451,692	fry	41 (4)	0.66	Late-January – early-April
		parr	69 (16)	0.34	Mid-April - June
Steelhead	943,575	fry	60 (19)	0.8	June - October
		parr	96 (17)	0.1	October - mid-May
		smolt	170 (23)	0.1	April - May

Sources: (Beamer et al. 2005; Shapovalov and Taft 1954; Topping and Anderson 2017)

For the hatchery-origin juveniles releases, a number of release groups are not anticipated to have effects on ESA-listed natural-origin Chinook salmon and steelhead because of their release location. The Marine Technology Center coho are released into "North Creek," and the Soos Creek coho that are released into Miller, Walker, and Des Moines Creeks are released into streams that are 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. We assumed 100% survival for all hatchery fish from release until the mouth of the Green River; this is likely an overestimate due to habitat conditions in the Green River, and could be modified with additional data.

Table 22. Hatchery fish parameter values and release information for the PCD Risk model; SCH = Soos Creek Hatchery, IC = Icy Creek Rearing Ponds, FGP = Flaming Geyser Ponds, KCC = Keta Creek Complex, FRF = Fish Restoration Facility; CV = coefficient of variation. Fish released only in phase 1 are bolded; fish released only in phase 2 are italicized.

Program	Release number[1]	Release size (mm)	Release size CV	Release timing	Release temperature (°C)	Release location	Piscivory rate	Travel rate (miles/day)[3]	Travel time to river mouth (days)
SCH Fall Chinook	3,520,000	80	0.08	Early-May-June	12.7	SCH	0.002	3.5	10
	3,300,000	106	0.10	June-July 4	14.4	Palmer Ponds	0.002	3.5	16
	330,000	181	0.10	April	8.3	IC	0.002	9.6	5
FRF Fall Chinook	*3,960,000*	94	0.10	June	12.7	FRF	0.002	3.5	17
FRF Coho	*660,000*	150	0.10	April-May15	9.8	FRF	0.0189	2.7	22
KCC Coho	1,100,000	150	0.10	April-May10	9.8	KCC	0.0189	2.7	15
	55,000	150	0.10	April-May15	9.8	FRF site	0.0189	2.7	22
SCH Coho	660,000	140	0.07	April-May10	9.8	SCH	0.0189	2.7	13
KCC Fall Chum	5,500,000	54	0.10	March-May15	10.4	KCC	0.0000	5.4	8
FRF steelhead	*275,000*	193	0.10	mid-April-June 30	10.8	FRF	0.0023	4.7	13
Green River Native Winter Steelhead	25,300	193	0.10	May	10.3	IC	0.0023	4.7	10
	16,500	193	0.10	May	10.3	FGP	0.0023	4.7	9
	18,700	193	0.10	May	10.3	Palmer Ponds	0.0023	4.7	12
Green River Summer Steelhead[2]	110,000	211	0.08	mid-April-May	10.3	IC	0.0023	4.7	10

Source: (Hurst and Haggerty 2019)

[1] Our analysis includes an extra 10% added to the proposed production goal to account for variability in release numbers.

[2] We assumed release of all fish from this program at the site furthest upstream in the event that co-managers decide to release all fish at that location.

[3] The Chinook subyearling rate was based on data from the Puyallup/White River, other travel rate estimates were based upon the WDFW smolt trap data collected on the mainstem Green River at RM 34.5 (Topping and Anderson 2017).

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 natural-origin juveniles.

Based on the parameter inputs above, our model results show that the release of hatchery juveniles are likely to have the largest effect on natural-origin steelhead, followed by Chinook salmon. The maximum numbers of juvenile fish lost for each species are shown in Table 23. When we convert these to adult equivalents, 52 Chinook salmon adults and 44 steelhead adults would be lost in phase 1. These numbers increased to 73 and 62 respectively for Chinook salmon and steelhead for phase 2, with the addition of the three FRF programs. Using the average number of natural-origin returns for Chinook salmon from 2013-2017 of 1842, this loss would equate to about a maximum potential loss of ~ 2.8% of the potential adult return for Chinook salmon. Using the average number of natural-origin returns for steelhead from 2014-2018 of 1200, this loss would equate to about a maximum potential loss of ~ 3.7% of the potential adult return for steelhead during phase 1. These percentages would increase to 4.0 and 5.2% for Chinook salmon and steelhead respectively in phase 2.

Travel time[9] of juvenile hatchery fish can have a substantial ecological effect. This is because the slower fish travel, the more time available for preying and competing on the natural-origin juveniles in the area. Thus, NMFS recommends the applicants monitor the average number of days required for each release to migrate to the mouth of the River as compared to the values in Table 22. If the value increases by more than 5 days over the course of a 5-year running average, this could increase the potential for ecological effects[10].

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[9] Travel rates were calculated by assuming 12 hours for day 1, and 24 hours for each proceeding day, fish were summed over the entire emigration period and day where 50% of fish were trapped at the Green River screw trap was then determined. Typically this included additional fish for which a fractional day was calculated. For example, 5200 marked fish represented 50% of the fish captured. Assume a cumulative catch on day 4 of 5000, and on day 5 a cumulative catch of 5500, then day 5 would be (5200-5000)/(5500-5000)=0.4 days, day 2-4=3 days, and day 1=0.5 days, for a total time period 4.1 days. Then travel rate is simply distance/time.

[10] NMFS recognizes that this metric can be influenced by factors other than hatchery operation (i.e., environmental variables, hydrosystem operation).

Table 23. 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.

Phase	Hatchery Species	Chinook		Steelhead	
		Predation	Delayed Mortality	Predation	Delayed Mortality
1	Fall Chinook salmon	398	5011	580	8290
	Coho salmon	3789	3664	5922	907
	Chum Salmon	0	1584	0	3
	Steelhead	416	1095	2866	284
	Total Juveniles Lost	15957		18852	
	Adult Equivalents[1]	52		44	
2	Fall Chinook salmon	448	5430	530	8680
	Coho salmon	4469	5056	6878	1128
	Chum Salmon	0	1584	0	3
	Steelhead	2171	2987	8728	711
	Total Juveniles Lost	22145		26660	
	Adult Equivalents[1]	73		62	

[1] Adult equivalents for Chinook salmon were calculated using an assumed fry-to-smolt rate of 50% and a smolt-to-adult escapement rate of 0.34%. Survival rates for steelhead were a fry-to-smolt rate of 12% and a smolt-to-adult rate of 1.5% (Hurst and Haggerty 2019).

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 (Campbell et al. 2017; Kerwin 1999). For coho salmon, Green River screw trap data from 2010-2015 demonstrate an average size at emigration of 107mm (Topping and Anderson 2016). For steelhead, Newaukum Creek screw trap data from 2014 to 2018 indicated that steelhead with no signs of smolting are less than 118 mm. We also used the current hatchery releases to determine the proportion of subyearling Chinook and coho salmon that were below the emigration thresholds identified above for the 2016-2018 releases. For the steelhead proportion, Berejikian et al. (2012) found that the rate of precocity averaged 10% (range of 2% - 20%) for three hatchery conservation programs operated in Hood Canal. Gary Marston (WDFW, personal communication) estimated that 7.5% of the smolts released from a hatchery conservation program residualized in the Duckabush River. Based on this information, the co-managers proposed that 15% is a reasonable proportion below the emigration size threshold of a steelhead release that could residualize.

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 (Table 24). For KCC chum salmon, no metric is proposed as these fish are released as fry, and their life history is to emigrate soon after emergence. Thus, they are unlikely to delay emigration because they have no need to reach a certain size.

Table 24. Proportion of the release below an emigration size threshold

Program	Lifestage	Emigration size threshold (mm)	Proportion below emigration threshold
Fall Chinook	Subyearling	65	0.07
Coho	Yearling	107	0.03
Steelhead	Smolt	118	0.15

2.5.2.3.2. Competition and predation in the estuary and ocean

2.5.2.3.2.1. *Spatial and Temporal Overlap*

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 [FL]), entering natal deltas between December and April (Beamer et al. 2010; Brennan et al. 2004; Duffy 2003; Duffy 2009; Duffy et al. 2005; Simenstad et al. 1982). 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. (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 (Chamberlin et al. 2011; O'Neill and West 2009).

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 (Hartt and Dell 1986; Pearcy and Masuda 1982). 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.

Chum Salmon

Most chum salmon fry begin their downstream migration to saltwater within one or two days of emergence, which can occur as early as December, but usually occurs from February through May. Timing of entry into salt water is correlated with the warming of the nearshore waters and the accompanying plankton blooms (Salo 1991). Chum salmon juveniles of early-returning adults tend to enter estuaries before juveniles of late-returning fish (Koski 1975 in NMFS 2002).

Some chum salmon fry remain near the mouth of their natal river when they enter an estuary, but most disperse within a few hours into tidal creeks and sloughs up to several kilometers from the mouth of their natal river. In Hood Canal, initial distribution in salt water of the juveniles is widespread, and then becomes more shoreline oriented (Bax 1983a; Schreiner 1977 in NMFS 2002). Migration rates of chum salmon in nearshore areas depend upon such factors as fish size, foraging success and environmental conditions (currents). Habitat use appears to be strongly size dependent (Fresh 2006). Observed residence times in estuaries range from 4 to 32 days, with a period of about 24 days being the most common (Johnson et al. 1997).

Small chum salmon fry (< 50-60 mm) tend to migrate along the shoreline in shallow water, less than two meters in depth. As chum salmon fry increase in size to more than 60 mm, they expand the habitats they use to include nearshore surface waters. Chum salmon abundance in nearshore areas peaks in May and June. Abundance after June declines markedly as chum salmon move farther offshore and migrate out of Puget Sound, although some are still found in nearshore areas through October (Fresh 2006).

From the discussion above, it is clear that there is a high likelihood of spatial and temporal overlap of juvenile salmonids (hatchery- and natural-origin) in the estuaries and nearshore environments of Puget Sound (Table 25). However, it appears that juvenile Chinook and chum salmon use estuaries and nearshore environments to a larger degree than other species, and therefore may be potentially more affected by ecological interactions with other juveniles of the same species, hatchery fish, and other species. Thus, the next section focuses on these two species.

Table 25. Periodicity of juvenile salmon and steelhead entry and residence time in Puget Sound estuaries.

Species	Life Stage/ history	Dec	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov
Chinook salmon	Fry			**Entry**				**Residence**					
	Parr						**Entry**			**Residence**			
	Yearling						**Entry**			**Residence**			
Sockeye	Yearling						**Entry**			**Residence**			
Steelhead	Yearling						**Entry**		**Res.**				
Coho	Yearling						**Entry**		**Res.**				
Chum	Subyearling					**Entry**				**Residence**			

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 (Goetz et al. 2015; Moore et al. 2015; Moore et al. 2010). 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 (Duffy 2003; Pearcy and McKinnell 2007; Rensel et al. 1984). 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 (Brodeur 1991; Holt et al. 2008; Rensel et al. 1984). 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.

Most of the hatchery-origin Chinook salmon released from hatcheries being evaluated in this Opinion are subyearlings released in May and June (Table 5). 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. Stable isotope signatures from muscle and liver tissues corroborated this finding, showing 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 (Bradford 1995; Emlen et al. 1990; Lichatowich et al. 1993), and/or is associated with cyclic ocean productivity (Beamish and Bouillon 1993; Beamish et al. 1997; Nickelson et al. 1986). Naish et al. (2008) 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 (Francis 2002; Mahnken et al. 1998).

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. 2011; 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 (Beamish and Bouillon 1993; Beamish et al. 1997; Mahnken et al. 1998; Nickelson et al. 1986). 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 are confounded by 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 chum salmon and 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, steelhead, and the hatchery chum salmon (fed fry) (Duffy 2003; Fresh 2006; Rensel et al. 1984), size differences at release, and partitioning of available food resources in marine areas (Duffy 2003) limit the risk of any substantial competition effects. For example, juvenile chum salmon fry released into Hood Canal in early February and March moved offshore within a few weeks, but fish released in April and early May tended to remain inshore initially, moving offshore in summer (Bax 1983b) . Chum salmon fry also seem to inhabit shallow surface waters (Schreiner 1977), likely leading to different food resources than the larger and more deep water dwelling steelhead and Chinook salmon.

2.5.2.3.2.3. *Predation*

Newly released hatchery-origin yearling salmon and steelhead 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. (2004) 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.

Low predation rates have been reported for released steelhead juveniles (Hawkins and Tipping 1999; Naman and Sharpe 2012). Hatchery steelhead release timing and protocols used widely in the Pacific Northwest were shown to be associated with negligible predation by migrating hatchery steelhead on fall Chinook fry, which had already emigrated or had grown large enough to reduce or eliminate their susceptibility to predation when hatchery steelhead entered the rivers (Sharpe et al. 2008).

Chum salmon fry released through hatchery programs are physically too small in individual size to consume Chinook salmon and steelhead present in marine areas where chum salmon may interact with those species. Hatchery-origin salmon and steelhead predation on natural-origin steelhead in estuaries is unlikely, due to the large size of natural-origin steelhead smolts relative to the co-occurring hatchery salmon. In addition, low predation rates have been reported for released steelhead juveniles (Hawkins and Tipping 1999; Naman and Sharpe 2012).

2.5.2.3.2.4. *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 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				
	Yearling Chinook	Subyearling Chinook	Coho	Chum	Steelhead
Yearling Chinook	High: same habitat, timing and body size	Low: different habitat and timing	Low: different habitat, timing, body size	Low: different habitat and timing	Medium: different habitat and body size, same timing
Subyearling Chinook	Low: different habitat and timing	High: same habitat, timing and body size	Medium: different habitat and body size, same timing	Medium: different habitat and body size, same timing	Low: different timing and body size
Sockeye	Low: different habitat	Low: different habitat	Low: different habitat	Low: different habitat and timing	Low: different timing and body size
Chum	Low: different habitat and timing	Medium: different habitat and body size, same timing	Medium: different habitat and body size, same timing	High: same habitat, timing and body size	Low: different timing and body size
Steelhead	Medium: different habitat and body size, same timing	Low: different timing and body size	Low: different timing and body size	Low: different timing and body size	High: same habitat, 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. The same is true for estuaries. At best, during years of limited food supply, juvenile fish survival and size may be reduced. Hatchery enhancement of salmon and steelhead 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 and steelhead are likely to be less efficient at reproduction than their natural-origin counterparts (Christie et al. 2014), 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 both listed Chinook salmon and steelhead may increase in the future if the Chinook salmon and steelhead populations grow.

Because fall Chinook, coho, and fall chum 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 and steelhead production is limiting natural production of listed salmon species, recovery planners would have to prioritize species. NMFS expects that the monitoring efforts via juvenile screw trapping would detect negative impacts before they reach problematic levels.

2.5.2.3.4. Disease

The risk of pathogen transmission and subsequent disease outbreaks in natural-origin salmon and steelhead is low for the programs included in this proposed action. This is because the water treatment system at the Keta Creek Complex was recently upgraded in 2015 to include sand filtration and UV light. This has eliminated many of the historical fish health issues seen here such as external parasites, and erythrocytic inclusion body syndrome (EIBS). Both the Palmer and Icy Creek rearing ponds are supplied with spring water, which is known to be pathogen free, and eliminates the risk of pathogen infection once fish are moved to these locations for final rearing. In addition, there have been no detections of any exotic pathogens for any of the programs included in the Proposed Action. It is known that *Vibrio spp.* can pose a problem for coho held in net pens, but neither the Elliott Bay nor the Des Moines net pens have a history of vibriosis. Stewart (2018) did note that an epizootic occurs annually in the summer months at the Keta Creek Hatchery when temperatures are warm and flows are low. Overall mortality can be as high as 10% of the coho production, but no infectious agents have been connected to this condition despite an intensive search using conventional culture assays and histopathology. Coho that survive do not seem to have any long lasting negative effects.

Furthermore, treatments for the pathogens responsible for outbreaks in Table 28 usually are effective within hours-14 days after treatment begins depending on the pathogen. Medicated feeds are feeds mixed with an antibiotic such as Florfenicol for *F. psychrophilum*, which causes Coldwater Disease. Formalin is usually administered as a drip into rearing containers to achive a certain concentration. For *Ichthyobodo spp*. (i.e., Costia), treatment last for about one hour (Bryan Quinton, WDFW, personal communication, October 28, 2018). Thus, the amount of time available over which shedding of pathogens could occur is limited.

There are a few 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 (NWIFC and WDFW 2006). These control measures have proven effective in controlling pathogens as indicated by the low number of outbreaks.

Table 27. Pathogen detections in hatchery juveniles that are part of the proposed action.

Program	Pathogen Detected			
	2015	2016	2017	2018
Keta Creek Complex coho	NA	*Flavobacterium psychrophilum*[1], *Renibacterium salmoninarum; Loma salmonae; Myxsoma squamilis*		
Keta Creek Complex fall chum	NA	None		

Soos Creek fall Chinook salmon	*Ichthyobodo sp., A. salmonicida, N. salminicola, Renibacterium salmoninarum*	*Ichthyobodo sp., N. salminicola, R. salmoninarum*	*N. salminicola R. salmoninarum,*	NA
Soos Creek coho	*Ichthyobodo sp., F. psychrophilum, N. salminicola*			NA
Green River Native Winter Steelhead	*Icthyopthirius miltifiliis, F. psychrophilum, N. salminicola, A. salmonicida*	*N. salminicola*	*N. salminicola*	NA
Green River Summer Steelhead				

Sources: (Bryan Quinton, WDFW, Personal Communication, October 28, 2018; Stewart 2018)
[1] After detection coho are fed medicated feed to prevent an outbreak 1-2 times from March-April.

Table 28. Disease outbreaks in program juveniles that are part of the proposed action.

Program	Pathogen	Date(s)	Treatment/control
Soos Creek Coho	*F. psychrophilum*	March 2015 and 2016	medicated feed
Soos Creek Coho	*Ichthyobodo sp.*	February-March 2015, 2016	formalin
Soos Creek coho and fall Chinook, Green River summer steelhead, Green River native winter steelhead	*N. salmincola*	2015, 2016, 2017	none
Soos Creek fall Chinook	*Ichthyobodo sp.*	March-April 2015, 2016	formalin
Soos Creek fall Chinook	*R. salmoninarum*	December 2015; November 2016, 2017	medicated feed
Soos Creek coho and fall Chinook, Green River summer steelhead	*A. salmonicida*	May 2015	medicated feed
Green River summer steelhead	*F. psychropilum*	April 2015	medicated feed
Green River summer steelhead	*Icthyopthirius multifilliis*	June 2015	formalin

Sources: (Bryan Quinton, WDFW, personal communication, October 28, 2018)

2.5.2.4. Factor 4. Research, monitoring, and evaluation

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)
- Holding the fish in captivity, sampling (e.g., the removal of scales and tissues)
- Tagging and fin-clipping

Observing/Harassing

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

Capturing/handling

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

Fin clipping and tagging

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

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

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.

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

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

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.

Screening

A number of facilities are not anticipated to have any effects on ESA-listed salmon and steelhead. Intake screens on Big Soos Creek were rebuilt in the summer of 2018, to bring the screens into compliance with current NMFS criteria (NMFS 2011a). The intakes for the Icy Creek Hatchery and the Marine Technology Center are located below an area of extremely steep stream gradient, which precludes natural-origin salmonids from using Icy Creek and "North Creek" for spawning or rearing (WDFW 2013; WDFW 2014b; WDFW 2014c). Anadromous fish are not present upstream of the water intakes for Palmer Ponds, the Miller Creek Hatchery, and the Keta Creek Complex (Muckleshoot Indian Tribe 2014; Muckleshoot Indian Tribe and Suquamish Indian Tribe 2017). Screening at the Flaming Geyser intake was replaced in 2012 and meets current NMFS Anadromous Salmonid Passage Facility Design Criteria (NMFS 2011a). The Des Moines Marina Net Pen and the Elliott Bay Net Pen programs would operate using mesh sizes on the net-pens containing hatchery-origin coho salmon smolts (Muckleshoot Indian Tribe and Suquamish Indian Tribe 2017) that are unlikely to pose any measurable risks of entrainment and mortality to listed fish in marine waters because of the passive flow of sea water.

Water Withdrawals

Facilities that withdraw a relatively large proportion of water over a relatively large diversion distance may present risks to the migration and survival of listed salmon and steelhead. For the facilities analyzed in this Proposed Action, there are no facilities that NMFS believes are a risk for several reasons; (1) no listed fish are upstream, (2) diversion distance is relatively short, (3) water use is non-consumptive, (4) the proportion of water withdrawn is relatively low, and (5) the water source is groundwater.

For the Icy Creek Rearing Ponds, Palmer Ponds, the Marine Technology Center, and the Keta Creek complex, no listed fish occur upstream of the intakes. In addition, water is diverted only a short distance for most of these facilities (≤ 0.3 km) and use is non-consumptive. Furthermore, withdrawal estimates are from June when facilities are most likely to be using the maximum water right because fish are on hand just before release. Water withdrawals at facilities that only use groundwater, are unlikely to affect anadromous fish (i.e., Miller Creek Hatchery). The two net pen programs only use passively supplied marine water, which is not diverted and is non-consumptive, and thus have no effect on salmon and steelhead (Table 29). For the above reasons, withdrawal of water up to permitted levels from these facilities is unlikely to lead to a lowering of stream flow that would affect listed fish migration and survival.

Table 29. Water source, use, and discharge by salmon and steelhead hatchery facilities.

Facilities	Surface Water (cfs)	Water Diversion Distance (km)	Water source	Discharge Location	Mean Monthly Discharge (cfs)	Maximum Percent Surface Water Diverted[1]
Soos Creek Hatchery	37.64	0.02	Big Soos Creek	Big Soos Creek	90[2]	42
Icy Creek Rearing Ponds	20.0	<0.03	Icy Creek	Icy Creek	2.2/13[3]	100
Palmer Rearing Ponds	NA	NA	NA	Green River	NA	NA

Flaming Geyser Ponds	1.5	0.05	Cristy Creek	Cristy Creek	NM	100
Fish Restoration Facility	Up to 27.0	1.6	Green River	Green River	877[4]	3
Marine Technology Center	Up to 5.0	0.05	North Creek	Puget Sound	NM	100
Keta Creek Complex	10.55	0.3	Crisp Creek	Crisp Creek	6.5[5]	
Miller Creek Hatchery	NA	NA	Miller Creek	Miller Creek	NA	NA
Elliott Bay Net Pens	NM[5]	NA	Puget Sound	NA	NA	NA
Des Moines Net Pens	NM[5]	NA	Puget Sound	NA	NA	NA

[1] Maximum percentage withdrawals derived assuming hatchery use of available surface water up to the maximum permitted surface water withdrawal levels.
[2] USGS June (when the most fish are on hand) mean monthly discharge for Big Soos Creek streamflow monitoring station #12112600 for water years 2007-2017. The gage is located just upstream of the Soos Creek Hatchery.
[3] Spring and stream system is not gaged, estimates of annual minimum and maximum flow (WDFW 2013).
[4] USGS June (when the most fish are on hand) mean monthly discharge for Green River streamflow monitoring station #12106700 for water years 2007-2017.
[5] King County gage 40D for water years 1995-2015.

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

All hatchery effluent at Soos Creek Hatchery, Icy Creek Hatchery, and Palmer Ponds would be passed through a cleaning and treatment system. Funding is being sought to construct a new two-bay pollution abatement pond system at Soos Creek Hatchery, which should further reduce potential affects to water quality and listed fish (WDFW 2015). The following water quality parameters, selected by EPA and WDOE as important for determining hatchery-related water quality effects, are monitored (WDFW 2013; WDFW 2014c).

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

Though compliance with NPDES permit conditions is not an assurance that effects on ESA-listed salmonids will not occur, the facilities use the water specifically for the purposes of rearing steelhead, which have a low mortality during hatchery residence compared to survival in the natural-environment (~ 55% compared to 7%; Bradford 1995). Because the same water used for rearing (where survival is high compared to the natural environment) is then discharged into the surrounding habitat and then further diluted once it is combined with the river water, we believe effluent will have a minimal impact on ESA-listed salmonids in the area.

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

2.5.2.6. Factor 6. Fisheries

Fisheries in the action area not part of this proposed action, but rather are subject to separate consultation on an annual or multi-year basis, depending on the duration of the Puget Sound fishery management plan submitted by the co-managers (NMFS 2016a; Grayum 2016; Bowhay 2016; Unsworth and Bowhay 2016; Warren and Bowhay 2016). As described in Section 2.4.4, Environmental Baseline, the effects of all fisheries on ESA-listed species are expected to continue at similar levels to those described in the Environmental Baseline. NMFS (2016a); NMFS (2017a) found that the fisheries will not appreciably reduce the likelihood of survival and recovery for the listed species.

2.5.3. Effects of the Action on Critical Habitat

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. With the exception of temporary, seasonally operated weirs on Big Soos Creek, and the marine net pens, all hatchery facilities are not located in Green River Basin waters where designated critical habitat for listed Chinook salmon and steelhead would be affected.

Proposed surface water diversion for rearing juvenile salmon and steelhead would not affect the spatial distribution of adult or juvenile ESA protected Green River Basin Chinook salmon or steelhead. Permitted water withdrawal levels for fish rearing are usually a small fraction of average annual flows in freshwater areas where listed fish may be present, and water withdrawn for hatchery use is returned near the points of withdrawal. Hatchery diversion screens protect listed juvenile Chinook salmon and steelhead from entrainment and injury, and meet current

NMFS screen criteria, or are proposed for retrofitting to meet those criteria as needed (See Section 2.5.2.5).

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. Effluent discharge for the hatchery operations is not expected to degrade water quality. Consistent with effluent discharge permit requirements developed by the Environmental Protection Agency and the Washington Department of Ecology for upland fish hatcheries, water used for fish production at Soos Creek, Icy Creek, Palmer Ponds, and Keta 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.

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

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

2.6. Cumulative Effects

"Cumulative effects" are those effects of future state or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 CFR 402.02). 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 2.3. 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 (SSPS 2007), and the Green River Basin Salmon Habitat Plan (Watershed Resource Inventory Area 9 Steering Committee 2005) 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 Green River Basin. Future tribal, state, and local government actions will likely be in the form of legislation, administrative rules, policy initiatives, and land use and other types of permits. Government and private actions may include changes in land and water uses, including ownership and intensity, which could affect listed species or their habitat. Government actions are subject to political, legislative, and fiscal uncertainties.

Non-Federal actions are likely to continue affecting listed species. State, tribal, and local governments have developed plans and initiatives to benefit listed species (SSPS 2007; Watershed Resource Inventory Area 9 Steering Committee 2005). The cumulative effects of non-Federal actions in the action area are difficult to analyze because of the political variation in the action area, and the uncertainties associated with funding and implementation of government and private actions. However, we expect the activities identified in the baseline to continue at similar magnitudes and intensities as in the recent past.

On-going State, tribal, and local government salmon restoration and recovery actions implemented through plans such as the recovery plans (NMFS 2018c; SSPS 2007) would likely continue to help lessen the effects of non-Federal land and water use activities on the status of listed fish species. The temporal pace of 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.

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 (2.4) and to cumulative effects (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) reduce the value of designated or proposed critical habitat. This assessment is made in full consideration of the status of the species and critical habitat and the status and role of the affected population(s) in recovery (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 population diversity, spatial structure, and productivity are also below levels required for the Green River population to recover to a self-sustaining condition (Section 2.2.1.1). The Green River population currently does not assume a primary role for recovery of the Puget Sound ESU (NMFS 2010a). Our environmental baseline considers the effects of dams, habitat condition, fisheries, and hatcheries on Puget Sound Chinook Salmon. Although all may have contributed to the listing, all factors have also seen improvements in the way they are managed/operated. As we continue to deal with a changing climate, management of these factors may also alleviate some of the potential adverse effects (e.g., hatcheries serving as a genetic reserve for natural populations).

The majority of the effects of the Proposed Action on this ESU are genetic and ecological in nature, with small, localized effects from facility operation. Effects from RM&E have been covered previously (NMFS 2017c; NMFS 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 Green River Chinook salmon population are limited by the use of natural-origin broodstock, and an expected PNI of 0.5 on average is a reasonable long-term target for a population targeted for tier 2 in a recovery scenario. This PNI value is a substantial improvement from the current PNI of 0.09. However, the reality of the degraded habitat in the lower Green River, the lack of downstream fish passage at HHD, and the intention to produce more fish to expand the prey base for resident ESA-listed killer whales make achieving this goal within the first two phases extremely difficult. However, through some major modifications to the current fall Chinook salmon program, the population could achieve a PNI of 0.4 in years where natural-origin abundance is at least similar to the current value in phases 1 and 2. This PNI goal is more likely to be achieved by phase 4, once passage at HHD is possible and successful enough to allow for a self-sustaining natural-origin population component above the dam. Because the Green River population is one of 22 populations in the ESU, most populations are above critical thresholds, and the Proposed Action substantially improves the Green River population's PNI, the Proposed Action is unlikely to have an adverse effect at the ESU level.

Our dispersion analysis concluded that Chinook salmon from the Green River Basin contribute about 6.9% of the Chinook salmon spawning naturally in the Snoqualmie River. This could increase to 10% with the increased releases sizes described in the Proposed Action. NMFS anticipates that the co-managers will continue to monitor the contribution of fish from the Green River into the Snoqualmie, and revise our analysis of pHOS in the context of the management changes to be implemented in the Chinook program, such as differential marking, to gather more information on the Palmer Pond releases. In the near term, we anticipate this level of pHOS to have only a small adverse effect on the Snoqualmie population diversity because: it is proposed to be a tier 3 population (NMFS 2010a); we recognize that pHOS is likely an overestimate of genetic effects; and we have yet to have data on a full brood year of Chinook salmon releases from Palmer Ponds.

Ecological effects on natural-origin juvenile Chinook salmon associated with hatchery program releases are equivalent to loss of about 2.8% in phase 1 and 4.0% in phase 2 from the adult return to the Green River. 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 Green River, and many of those populations are situated in Basins that have substantially better habitat than the Green 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. For the adult life stage, we conclude that coho and chum salmon are most likely to superimpose on Chinook salmon redds, although it is unlikely to occur to a great degree. Furthermore, as we move through the four phases, more habitat is likely to become available, decreasing the risk of redd superimposition even further.

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

The Green River Basin is severely degraded with very limited spawning and rearing habitat for anadromous species, including a decrease in the estuary's suitable habitat of ~ 99%. Development in the area, which is right outside of Seattle, WA is only likely to increase as the human population continues to grow. Despite these realities, the Chinook salmon population is still likely to achieve vast improvements in PNI under the Proposed Action; an increase in PNI from 0.1 currently to ~ 0.4 in phase 1, and potentially above 0.5 under improved habitat conditions, including fish passage at HHD. In addition, the existence of the hatchery programs ensures that fish will still exist in the Green River if natural-origin returns decrease to low levels

(< 500). Furthermore, the ecological effects of releasing hatchery fish of many species into the Green River Basin is estimated to result in a loss of no more than 4.0% of the adult equivalents. This estimate is also likely to decrease as targeted monitoring to improve model parameter estimates continues. Because the proposed action is likely to lead to improvements in the current genetics of the population, and considering the status of the Green as a tier 2 population in NMFS Population Recovery Approach out of 22 total populations in the ESU, the Proposed Action will not appreciably reduce the likelihood of survival and recovery of the Puget Sound Chinook Salmon ESU.

2.7.2. Puget Sound Steelhead

Best available information indicates that the Puget Sound Steelhead DPS remains threatened (NWFSC 2015). Spawner abundance is currently depressed, and population diversity, spatial structure, and productivity are also below desired levels required for the Green River population to recover to a self-sustaining condition (Section 2.2.1.3). Our Environmental Baseline considers the effects of hydropower, habitat, fisheries, and hatcheries. Although all may have contributed to the listing of the DPS, all factors have also seen improvements in the way they are managed/operated. As we continue to deal with a changing climate, management of these factors may also alleviate some of the potential adverse effects (e.g., hatcheries serving as a genetic reserve for natural populations).

The majority of the effects of the Proposed Action on this DPS are genetic and ecological in nature, with small, localized effects from facility operation. Effects from RM&E has been covered previously (NMFS 2017c; NMFS 2018b) and included in the baseline, and the information gained from conducting the work is essential for understanding the effects of the hatchery programs on natural-origin steelhead populations.

The ecological and genetic effects on the adult life stage are limited by the proportion of hatchery-origin fish spawning naturally and the incorporation of natural-origin fish into the broodstock for integrated programs. Currently in phase 1, PNI exceeds 0.67, and, even with the addition of the FRF program in phase 2, we still anticipate PNI to meet or exceed the 0.67 value. NMFS believes this PNI target is sufficient to ensure natural selection outweighs hatchery selection. Our analysis of the ESS program, based on the present level of empirical and theoretical information currently available, suggests that gene flow levels of < 2% from the segregated summer steelhead program into natural-origin Puget Sound steelhead populations will pose only minor genetic risk potentially resulting in small reductions in fitness. Furthermore, the program will transition to the use of a more local Puget Sound stock within 12 years to minimize the genetic effects on the winter steelhead population. We believe the DPS can handle this level of risk because the Green River population is one of 32 populations in three MPGs over a large geographic area.

Ecological effects on natural-origin juvenile steelhead associated with releases from the hatchery program are equivalent to loss of about 3.7% from the adult return to the Green River in phase 1 and 5.2% in phase 2. 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 of little overall importance to the DPS, which is composed of 32 populations, because at least a few populations in each MPG have a low probability of extinction over the coming decades. Also, while these programs may result in some steelhead loss due to juvenile competition and predation, they also are designed to help supplement steelhead abundance. In addition, as we continue to improve the model, these estimates will become more refined in the future, and will likely demonstrate a decrease in the percentage of adults that are lost. Furthermore, the loss of these potential adults may be offset by the benefits of releasing hundreds of thousands smolts to return to spawn naturally the following generation, especially when habitat may very well be limiting productivity.

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

Habitat conditions for steelhead are the same as for Chinook salmon above; the Green River Basin is severely degraded with very limited spawning and rearing habitat for anadromous species, including a decrease in the estuary's suitable habitat of ~ 99%. Development in the area, which is right outside of Seattle, Washington, is only likely to increase as the human population continues to grow. Despite these realities, the winter steelhead population is still likely to maintain a PNI $\geq$ 0.67 under the Proposed Action. In addition, the existence of the hatchery programs ensures that fish will still exist in the Green River if natural-origin returns decline further. Furthermore, the ecological effects of releasing hatchery fish of many species into the Green River Basin is estimated to result in a loss of no more than 5.2% of the adult equivalents. This estimate is likely to decrease as targeted monitoring to improve model parameter estimates continues. Because no recovery scenario has been developed for Puget Sound steelhead, NMFS considers all populations as primary at this time. Thus, maintenance of PNI $\geq$ 0.67 preserves recovery options for the Green River. In addition, this population is one of 32 in the DPS, and 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, our analysis leads NMFS to conclude, after considering all factors, that the Proposed Action will not appreciably reduce the likelihood of survival and recovery of the Puget Sound Steelhead DPS.

2.7.3. Critical Habitat

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

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 Green River Basin may be adversely affected by climate change (see section 2.4). A decrease in winter snow pack resulting from predicted rapid changes over a geological scale in climate conditions in the Cascade Mountains would be expected to reduce spring and summer flows, impairing water quantity and water quality in primary fish rearing habitat located in the mainstem Green River. Predicted increases in rain-on-snow events would increase the frequency and intensity of floods in mainstem river areas, leading to scouring flows that would threaten the survival and productivity of natural- and hatchery-origin ESA-listed fish species. However, minimum flow maintenance and flood control operation of HHD could help reduce the risk and effects on listed fish, especially during the winter and spring months when the hatchery programs are withdrawing the most water. The proposed Chinook salmon and winter steelhead 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.

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 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 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 and steelhead 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. For these two take pathways, NMFS will therefore rely on a single common set of surrogate take indicators: the number of hatchery-origin steelhead on the spawning grounds as defined here:

- A minimum annual PNI value for the Green River fall Chinook salmon population that corresponds with the natural-origin return for that year depicted in Figure 7 for phases 1 and 2. When natural-origin returns are < 500, PNI will drop below 0.2, as demographic concerns outweigh genetic concerns.
- A 5-year running average PNI value of ≥ 0.67 for the Green River winter steelhead population across both phases.
- Gene flow < 2.0% attributable to the ESS program for the natural winter steelhead population in the Green River measured as a 4-year running average (a full steelhead generation).
- No more than 10% of the escapement into the Snoqualmie will be from the Green River hatchery programs in phases 1 and 2 measured as a 5-year running average.

This set of take surrogate measurements is logically related to the genetic and ecological take pathways through assessment of intraspecific hatchery-origin Chinook salmon and steelhead on the spawning grounds. If these fish spawn, they can cause both ecological and genetic effects on natural-origin spawners. Each of these take surrogates represents a significant limitation on the ability for genetic effects to exceed the amount of take that is expected to occur under the Proposed Action.

For the ecological effects of redd superimposition and spawning site competition associated with the coho salmon hatchery programs, take is expected to occur at the number of hatchery fish spawning naturally compared to the baseline numbers in Table 17. The number of hatchery-origin fish on the spawning grounds shall not increase by more than 50% based on a 5-year running average beginning in 2019 (average of 2015-2019), which equates to an additional 535 spawners. 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 19.

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 steelhead smolts 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 (particularly precocial males largely associated with steelhead). However, it is difficult to quantify this take because ecological interactions cannot be directly measured and/or observed. Thus, we will have two take surrogates, one to address the effects of migrating hatchery juveniles, and a second to address the effects of non-migrating hatchery juveniles

We will quantify the extent of take of migrating fish using travel time of juvenile hatchery fish. This is a reasonable surrogate for the take that occurs because the slower fish travel, the more time available for preying and competing on ESA-listed natural-origin juveniles in the area. Thus, take is exceeded if the average number of days required for each release group identified in Table 22 to migrate to the mouth of the river increases by more than 5 days based on a 5-year running average beginning in 2019 (years 2015-2019). In this case, the expected take from interactions will have likely been exceeded as a result of a longer average period of overlap between hatchery and natural-origin fish. This surrogate will be monitored using emigration estimates from screw traps, or other juvenile monitoring techniques developed by the operators and approved by NMFS.

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 exceeds the proportion in Table 24, it is a sign that more fish may have longer freshwater residence times. Therefore, the expected take from interactions will have likely been exceeded as a result of a longer period of overlap between hatchery and natural-origin fish. This threshold will be monitored using emigration estimates from screw traps, proportion of fish below the emigration size threshold prior to release, or other juvenile monitoring techniques developed by the operators and approved by NMFS.

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 nondiscretionary measures to minimize the amount or extent of incidental take (50 CFR 402.02). NMFS concludes that the following reasonable and prudent measures are necessary and appropriate to minimize incidental take. NMFS shall ensure that:

1. The applicants follow all conditions specified in each authorization issued as well as guidelines specified in this opinion for their respective programs.
2. A workgroup—comprised of co-managers, NMFS, and the Army Corps of Engineers—is being developed, to be coordinated by NOAA, to plan for fish passage and the reintroduction of fish above HHD with discussions beginning in the summer of 2019.
3. The applicants provide reports to SFD annually for all hatchery programs and associated RM&E.

2.9.4. Terms and Conditions

The terms and conditions described below are non-discretionary, and the Action Agencies must comply with them in order to implement the reasonable and prudent measures (50 CFR 402.14). The 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 following terms and conditions are not complied with, the protective coverage of section 7(o)(2) will lapse. NMFS shall ensure that:

1. The applicants follow all conditions specified in each authorization issued 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. Finalize a plan to phase out use of out-of-basin steelhead broodstock. As a measure to eliminate genetic effects of out of Puget Sound ESS production on the Green River winter steelhead population, the co-managers have proposed to transition the Soos Creek Hatchery ESS program, but still maintain a release size of up to 100,000 smolts throughout the transition, to a within Puget Sound summer steelhead stock within 12 spawn years of opinion signature. A transition plan will be discussed and submitted to NMFS within one year of opinion signature. The working assumption in developing the transition plan is that an integrated hatchery program using steelhead collected from the South Fork Skykomish will be the source of broodstock for the new program.

d. No ESS collected at the hatcheries shall be released back into the natural environment as a measure to reduce straying and gene flow risks to the natural-origin steelhead population.

e. Development and submission of a steelhead sampling plan in the Green River to verify PEHC values within four months of Opinion signature.

f. Remove surplus hatchery-origin fish as needed to meet pHOS/PNI metrics for the Green River fall Chinook salmon and winter steelhead populations.

g. The co-managers contribute to studies on assessing hatchery-origin influence on the Snoqualmie population that addresses the genetic effects of strays from the Green River Chinook salmon hatchery programs.

    i. Re-evaluate the contribution of fish released from Palmer Ponds once data for an entire brood year is obtained

    ii. Provide otolith samples to the Tulalip Tribe for subyearling Chinook salmon released from Palmer Ponds

2. A workgroup—comprising co-managers, NMFS, and the Army Corps of Engineers—is developed to plan for fish passage and the reintroduction of fish above HHD with discussions beginning in the summer of 2019.

3. 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 Charlene Hurst (503-230-5409, charlene.n.hurst@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 2017, report due April 2018), 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

- Proportion of release below the emigration size threshold in Table 24
- Survival rates of green egg-to-smolt, and smolt-to-adult
- 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 and their distribution within the Green River Basin
- The number and species of listed fish encountered at each adult collection location, and the number that die
- The contribution of Chinook salmon and steelhead from these programs into all ESA-listed populations where feasible with existing stock assessment methods
- Distribution of arrival times at smolt traps for each juvenile hatchery-origin fish release
- Mean length, coefficient of variation, number, and age of natural-origin juveniles during RM&E activities
- Estimates of ESS program-related PEHC for the natural steelhead population in the Green River watershed

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 three conservation recommendations appropriate to the Proposed Action:

1. Currently, there is limited ability to collect adults at Palmer Ponds due to a lack of infrastructure. The ability to collect returning hatchery-origin adults at Palmer Ponds would further reduce the genetic effects of hatchery-origin Chinook salmon by removing those fish from the naturally-spawning population. Thus, NMFS recommends improvements to Palmer Ponds to allow for adult collection.
2. The co-managers will work with NMFS to continue refining the methods for the dispersion analysis.
3. NMFS will work with the co-managers to continue to refine the estimates of non-migrating juveniles from the hatchery programs.

2.10. Re-initiation of Consultation

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

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 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 the Green River. Thus, NMFS believes that our Proposed Action is likely to only have discountable effects on HCS chum salmon.

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 (Washington Department of Fisheries and Washington Department of Wildlife 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 anticipated effects on Lake Ozette sockeye salmon are likely to be 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 Green River 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 our Proposed Action is likely to have discountable effects on Lake Ozette sockeye salmon.

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

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

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

3.1. Essential Fish Habitat Affected by the Project

The 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

The biological opinion describes in considerable detail the impacts hatchery programs might have on natural-origin salmon and steelhead populations (Section 2.5.2). Naturally spawning adult salmon produced by the proposed hatchery programs may lead to effects on natural-origin salmon EFH through spawning ground competition and redd superimposition. The biological opinion describes impacts the hatchery programs might have on naturally spawning salmon populations (Section 2.5.2). The intent of the hatchery Chinook and coho salmon programs is to produce native fish that will return to marine and freshwater commercial and recreational fishing areas to augment harvests. 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. Further, any naturally spawning hatchery coho and fall chum salmon would not overlap temporally and/or spatially to a substantial degree with natural-origin Chinook, coho, or pink salmon in natural spawning areas, limiting effects of competition or red superimposition.

The release of salmon and steelhead through the proposed hatchery programs may lead to effects on EFH through predation on and competition with juvenile Chinook, coho, and pink salmon. Coho salmon yearlings from the Elliott Bay Net-Pens and the Des Moines Marina Net Pen programs would be released directly into seawater, and there would be no effects on freshwater salmon EFH. Hatchery-origin predation on and competition with natural-origin juvenile Chinook salmon was ~4% of the natural-origin adult equivalents. It is likely to be less than this for pink salmon because pinks emigrate soon after emergence around February-March, before hatchery fish are released. Both pink and coho salmon also have greater natural-origin abundances; meaning that even if the adult equivalents are similar among species, the proportional effect would be less on those species that have larger populations. Predation on and competition with natural-origin salmon in the marine environment is possible, but is likely limited by the release of hatchery fish that are ready to emigrate to the ocean quickly and the lack of a usable estuary for rearing outside of the Green River

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).

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 groundfish. Of the potential adverse effects listed in (PFMC 2016b), effects 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.

In summary, the proposed action is expected to have adverse effects on EFH for Chinook, coho and pink salmon, but not for coastal pelagic species and groundfish.

3.3. Essential Fish Habitat Conservation Recommendations

For each of the potential adverse effects by the Proposed Action on EFH for Chinook, coho, and pink salmon, NMFS believes that the Proposed Action, as described in the HGMPs and the ITS (Section 2.9), includes the best approaches to avoid or minimize those adverse effects. The Reasonable and Prudent Measures and Terms and Conditions included in the ITS associated with ecological interactions constitute NMFS recommendations to address potential EFH effects. NMFS and BIA shall ensure that the ITS, including Reasonable and Prudent Measures and implementing Terms and Conditions, are carried out.

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. Therefore, we ask that, in your statutory reply to the EFH portion of this consultation, you clearly identify the number of conservation recommendations accepted.

3.5. Supplemental Consultation

The NMFS and BIA 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 the10 Green River Basin hatchery programs as proposed will not jeopardize ESA-listed species and will not destroy or adversely modify designated critical habitat. Therefore, NMFS can issue an ITS. The intended users of this opinion are the Muckleshoot and Suquamish Tribes and WDFW (operators); NMFS (regulatory agency), and BIA (indirect funding entity). The scientific community, resource managers, and stakeholders benefit from the consultation through adult returns of program-origin salmon and steelhead to the Green River Basin 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 and steelhead 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: FACTORS CONSIDERED WHEN ANALYZING HATCHERY EFFECTS

NMFS' analysis of the Proposed Action is in terms of effects the Proposed Action would be expected to have on ESA-listed species and on designated critical habitat, based on the best scientific information available. Generally speaking, effects range from beneficial to negative when programs use local fish[11] for hatchery broodstock, and from negligible to negative when programs do not use local fish for broodstock[12]. Hatchery programs can benefit population viability, but only if they use genetic resources that represent the ecological and genetic diversity of the target or affected natural population(s). When hatchery programs use genetic resources that do not represent the ecological and genetic diversity of the target or affected natural population(s), NMFS is particularly interested in how effective the program will be at isolating hatchery fish and at avoiding co-occurrence and effects that potentially disadvantage fish from natural populations. 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. Analysis of a 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, 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 exist because of the hatchery program, including terminal fisheries intended to reduce the escapement of hatchery-origin fish to spawning grounds.

The effects of hatchery fish on ESU/DPS status will depend on which of the four VSP criteria are currently limiting the ESU/DPS and how the hatchery program affects each of the criteria (NMFS 2005b). The category of effect assigned to a factor is based on an analysis of each factor weighed against each affected population's current risk level for abundance, productivity, spatial structure, and diversity, the role or importance of the affected natural population(s) in ESU or

[11] The term "local fish" is defined to mean fish with a level of genetic divergence relative to the local natural population(s) that is no more than what occurs within the ESU or steelhead DPS (70 FR 37215, June 28, 2005).
[12] Exceptions include restoring extirpated populations and gene banks.

steelhead DPS recovery, the target viability for the affected natural population(s), and the environmental baseline including the factors currently limiting population viability.

Table 30. An overview of the range of effects on natural population viability parameters from the two categories of hatchery programs.

Natural population viability parameter	Hatchery broodstock originate from the local population and are included in the ESU or DPS	Hatchery broodstock originate from a non-local population or from fish that are not included in the same ESU or DPS
Productivity	**Positive to negative effect** Hatcheries are unlikely to benefit productivity except in cases where the natural population's small size is, in itself, a predominant factor limiting population growth (i.e., productivity) (NMFS 2004c).	**Negligible to negative effect** Productivity is dependent on differences between hatchery fish and the local natural population (i.e., the more distant the origin of the hatchery fish, the greater the threat), the duration and strength of selection in the hatchery, and the level of isolation achieved by the hatchery program (i.e., the greater the isolation, the closer to a negligible effect).
Diversity	**Positive to negative effect** Hatcheries can temporarily support natural populations that might otherwise be extirpated or suffer severe bottlenecks and have the potential to increase the effective size of small natural populations. On the other hand, broodstock collection that homogenizes population structure is a threat to population diversity.	**Negligible to negative effect** Diversity is dependent on the differences between hatchery fish and the local natural population (i.e., the more distant the origin of the hatchery fish, the greater the threat) and the level of isolation achieved by the hatchery program (i.e., the greater the isolation, the closer to a negligible effect).
Abundance	**Positive to negative effect** Hatchery-origin fish can positively affect the status of an ESU by contributing to the abundance of the natural populations in the ESU (70 FR 37204, June 28, 2005, at 37215). Increased abundance can also increase density dependent effects.	**Negligible to negative effect** Abundance is dependent on the level of isolation achieved by the hatchery program (i.e., the greater the isolation, the closer to a negligible effect), handling, RM&E, and facility operation, maintenance and construction effects.
Spatial Structure	**Positive to negative effect** Hatcheries can accelerate re-colonization and increase population spatial structure, but only in conjunction with remediation of the factor(s) that limited spatial structure in the first place. "Any benefits to spatial structure over the long term depend on the degree to which the hatchery stock(s) add to (rather than replace) natural populations" (70 FR 37204, June 28, 2005 at 37213).	**Negligible to negative effect** Spatial structure is dependent on facility operation, maintenance, and construction effects and the level of isolation achieved by the hatchery program (i.e., the greater the isolation, the closer to a negligible effect).

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

This factor considers the risk to a natural population from the removal of natural-origin fish for hatchery broodstock. The level of effect for this factor ranges from neutral or negligible to negative.

A primary consideration in analyzing and assigning effects for broodstock collection is the origin and number of fish collected. The analysis considers whether broodstock are of local origin and the biological pros and cons 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 tapped to provide hatchery broodstock. “Mining” a natural population to supply hatchery broodstock can reduce population abundance and spatial structure. Also considered here is whether the program “backfills” with fish from outside the local or immediate area. The physical process of collecting hatchery broodstock and the effect of the process on ESA-listed species is considered under Factor 2.

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

NMFS also analyzes the effects of hatchery fish and the progeny of naturally spawning hatchery fish on the spawning grounds. The level of effect for this factor ranges from positive to negative.

There are two aspects to this part of the analysis: genetic effects and ecological effects. NMFS generally views genetic effects as detrimental because we believe that artificial breeding and rearing is likely to result in some degree of genetic change and fitness reduction in hatchery fish and in the progeny of naturally spawning hatchery fish relative to desired levels of diversity and productivity for natural populations based on the weight of available scientific information at this time. Hatchery fish can thus pose a risk to diversity and to natural population rebuilding and recovery when they interbreed with fish from natural populations.

However, NMFS recognizes that beneficial effects exist as well, and that the risks just mentioned may be outweighed under circumstances where demographic or short-term extinction risk to the population is greater than risks to population diversity and productivity. Conservation hatchery programs may accelerate recovery of a target population by increasing abundance faster than may occur naturally (Waples 1999). Hatchery programs can also be used to create genetic reserves for a population to prevent the loss of its unique traits due to catastrophes (Ford et al. 2011).

NMFS also recognizes there is considerable debate regarding genetic risk. The extent and duration of genetic change and fitness loss and the short- and long-term implications and consequences for different species (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, NMFS believes that hatchery intervention is a legitimate and useful tool to alleviate short-term extinction risk, but otherwise managers should seek to limit interactions between hatchery and natural-origin fish and implement hatchery practices that harmonize conservation with the implementation of treaty Indian fishing rights and other applicable laws and policies (NMFS 2011d).

5.2.1. Genetic effects

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

First, within-population genetic diversity is a general term for the quantity, variety, and combinations of genetic material in a population (Busack and Currens 1995). Within-population diversity is gained through mutations or gene flow from other populations (described below under outbreeding effects) and is lost primarily due to genetic drift, a random loss of diversity due to population size. The rate of loss is determined by the population's effective population size (N_e), which can be considerably smaller than its census size. For a population to maintain genetic diversity reasonably well, the effective size should be in the hundreds (e.g., Lande 1987), and diversity loss can be severe if N_e drops to a few dozen.

Hatchery programs, simply by virtue of creating more fish, can increase N_e. 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_e by two principal methods. One is by the simple removal of fish from the population so that they can be used in the 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). Two is when N_e 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 semen is especially problematic because when semen of several males is mixed and applied to eggs, a large portion of the eggs may be fertilized by a single male (Gharrett and Shirley 1985; Withler 1988). An extreme form of N_e reduction is the Ryman-Laikre effect (Ryman et al. 1995; Ryman and Laikre 1991), when N_e is reduced through the return to the spawning grounds of large numbers of hatchery fish from very few parents. On the other hand, factorial mating schemes, in which fish are systematically mated multiple times, can be used to increase N_e (Busack and Knudsen 2007; Fiumera et al. 2004).

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

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

Gene flow from other populations can have two effects. It can increase genetic diversity (e.g., Ayllon et al. 2006), which can be a benefit in small populations, but it can also alter established allele frequencies (and co-adapted gene complexes) and reduce the population's level of adaptation, a phenomenon called outbreeding depression (Edmands 2007; McClelland and Naish 2007). In general, the greater the geographic separation between the source or origin of hatchery fish and the recipient natural population, the greater the genetic difference between the two populations (ICTRT 2007), and the greater potential for outbreeding depression. For this reason, NMFS advises hatchery action agencies to develop locally derived hatchery broodstock. Additionally, unusual rates of straying into other populations within or beyond the population's MPG, salmon ESU, or a steelhead DPS can have an homogenizing effect, decreasing intra-population genetic variability (e.g., Vasemagi et al. 2005), and increasing risk to population diversity, one of the four attributes measured to determine population viability. Reduction of within-population and among-population diversity can reduce adaptive potential.

The proportion of hatchery fish (pHOS)[13] among natural spawners 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). Caution must also be taken in assuming that strays contribute genetically in proportion to their abundance. Several studies demonstrate little genetic impact from straying despite a considerable presence of strays in the spawning population (Blankenship et al. 2007; Saisa et al. 2003). The causative factors for poorer breeding success of strays are likely similar to those identified as responsible for reduced productivity of hatchery-origin fish in general, e.g., differences in run and spawn timing, spawning in less productive habitats, and

[13] It is important to reiterate that as NMFS analyzes them, outbreeding effects are a risk only when the hatchery fish are from a different population than the naturally produced fish. If they are from the same population, then the risk is from hatchery-influenced selection.

reduced survival of their progeny (Leider et al. 1990; Reisenbichler and McIntyre 1977; Williamson et al. 2010).

Hatchery-influenced selection (often called domestication), the third major area of genetic effects of hatchery programs, occurs when selection pressures imposed by hatchery spawning and rearing differ greatly from those imposed by the natural environment and causes genetic change that is passed on to natural populations through interbreeding with hatchery-origin fish. These differing selection pressures can be a result of differences in environments or a consequence of protocols and practices used by a hatchery program. Hatchery-influenced selection can range from relaxation of selection that would normally occur in nature, to selection for different characteristics in the hatchery and natural environments, to intentional selection for desired characteristics (Waples 1999).

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

Most of the empirical evidence of fitness depression due to hatchery-influenced selection comes from studies of species that are reared in the hatchery environment for an extended period – one to two years – prior to release (Berejikian and Ford 2004). Exposure time in the hatchery for fall and summer Chinook salmon and Chum salmon is much shorter, just a few months. One especially well-publicized steelhead study (Araki et al. 2007; Araki et al. 2008), showed dramatic fitness declines in the progeny of naturally spawning Hood River hatchery steelhead. Researchers and managers alike have wondered if these results could be considered a potential outcome applicable to all salmonid species, life-history types, and hatchery rearing strategies, but researchers have not reached a definitive conclusion.

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

Critical information for analysis of hatchery-induced selection includes the number, location, and timing of naturally spawning hatchery fish, the estimated level of gene flow between hatchery-origin and natural-origin fish, the origin of the hatchery stock (the more distant the origin compared to the affected natural population, the greater the threat), the level and intensity of hatchery selection and the number of years the operation has been run in this way. Efforts to control and evaluate the risk of hatchery-influenced selection are currently largely focused on gene flow between natural-origin and hatchery-origin fish[14]. The Interior Columbia Technical Recovery Team (ICTRT) developed guidelines based on the proportion of spawners in the wild consisting of hatchery-origin fish (pHOS) (Figure 9).

More recently, the Hatchery Scientific Review Group (HSRG) developed gene-flow guidelines based on mathematical models developed by (Ford 2002) and by (Lynch and O'Hely 2001). Guidelines for isolated programs are based on pHOS, but guidelines for integrated programs are based also on a metric called proportionate natural influence (PNI), which is a function of pHOS and the proportion of natural-origin fish in the broodstock (pNOB)[15]. PNI is, in theory, a reflection of the relative strength of selection in the hatchery and natural environments; a PNI value greater than 0.5 indicates dominance of natural selective forces. The HSRG guidelines vary according to type of program and conservation importance of the population. When the underlying natural population is of high conservation importance, the guidelines are a pHOS of no greater than 5% for isolated programs. For integrated programs, the guidelines are a pHOS no greater than 30% and PNI of at least 67% for integrated programs (HSRG 2009b). Higher levels of hatchery influence are acceptable, however, when a population is at high risk or very high risk of extinction due to low abundance and the hatchery program is being used to conserve the population and reduce extinction risk in the short-term. (HSRG 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. The HSRG recently produced an update report (HSRG 2014) that stated that the guidelines for isolated programs may not provide as much protection from fitness loss as the corresponding guidelines for integrated programs.

[14] Gene flow between natural-origin and hatchery-origin fish is often interpreted as meaning actual matings between natural-origin and hatchery-origin fish. In some contexts, it can mean that. However, in this document, unless otherwise specified, gene flow means contributing to the same progeny population. For example, hatchery-origin spawners in the wild will either spawn with other hatchery-origin fish or with natural-origin fish. Natural-origin spawners in the wild will either spawn with other natural-origin fish or with hatchery-origin fish. But all these matings, to the extent they are successful, will generate the next generation of natural-origin fish. In other words, all will contribute to the natural-origin gene pool.

[15] PNI is computed as pNOB/(pNOB+pHOS). This statistic is really an approximation of the true proportionate natural influence, but operationally the distinction is unimportant.

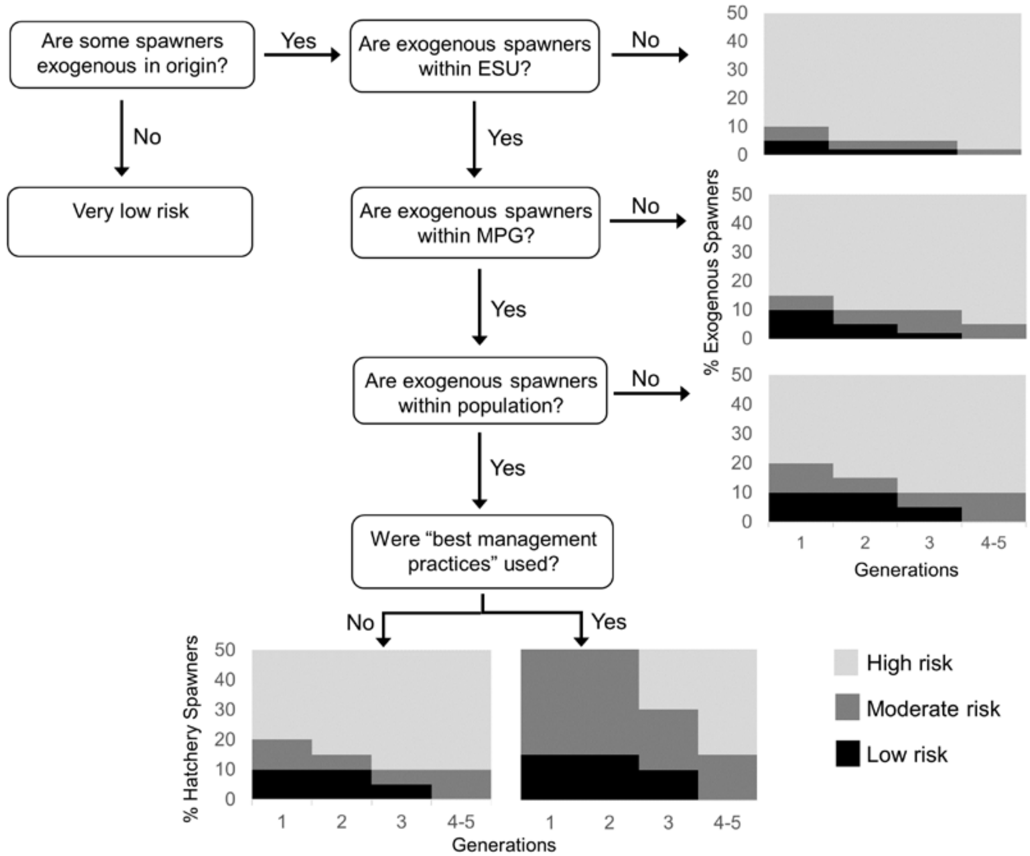

Figure 9. ICTRT (2007b) risk criteria associated with spawner composition for viability assessment of exogenous spawners on maintaining natural patterns of gene flow. Exogenous fish are considered to be all fish hatchery origin, and non-normative strays of natural origin

Another HSRG team recently reviewed California hatchery programs and developed guidelines that differed considerably from those developed by the earlier group (California HSRG 2012). The California HSRG felt that truly isolated programs in which no hatchery-origin returnees interact genetically with natural populations were impossible in California, and was "generally unsupportive" of the concept. However, if programs were to be managed as isolated, they recommend a pHOS of less than 5%. They rejected development of overall pHOS guidelines for integrated programs because the optimal pHOS will depend upon multiple factors, such as "the amount of spawning by natural-origin fish in areas integrated with the hatchery, the value of pNOB, the importance of the integrated population to the larger stock, the fitness differences between hatchery- and natural-origin fish, and societal values, such as angling opportunity." They recommended that program-specific plans be developed with corresponding population-specific targets and thresholds for pHOS, pNOB, and PNI that reflect these factors. However, they did state that PNI should exceed 50% in most cases, although in supplementation or reintroduction programs the acceptable pHOS could be much higher than 5%, even approaching 100% at times. They also recommended for conservation programs that pNOB approach 100%, but pNOB levels should not be so high they pose demographic risk to the natural population.

Discussions involving pHOS can be problematic due to variation in its definition. Most commonly, the term pHOS refers to the proportion of the total natural spawning population consisting of hatchery fish, and the term has been used in this way in all NMFS documents. However, the HSRG has defined pHOS inconsistently in its Columbia Basin system report, equating it with "the proportion of the natural spawning population that is made up of hatchery fish" in the Conclusion, Principles and Recommendations section (HSRG 2009b), but with "the proportion of *effective* hatchery origin spawners" in their gene-flow criteria. In addition, in their Analytical Methods and Information Sources section (appendix C in HSRG 2009b) they introduce a new term, *effective pHOS* ($pHOS_{eff)}$ defined as the effective proportion of hatchery fish in the naturally spawning population. This confusion was cleared up in the 2014 update document, where it is clearly stated that the metric of interest is effective pHOS (HSRG 2014).

The HSRG recognized that hatchery fish spawning naturally may on average produce fewer adult progeny than natural-origin spawners, as described above. To account for this difference the HSRG defined *effective* pHOS as:

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

where $pHOS_{census}$ is the proportion of the naturally spawning population that is composed of hatchery-origin adults (HSRG 2014). In the 2014 report, the HSRG explicitly addressed the differences between *census* pHOS and *effective* pHOS, by defining PNI as:

$$PNI = \frac{pNOB}{(pNOB + pHOS_{eff})}$$

NMFS feels that adjustment of census pHOS by RRS should be done very cautiously, 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, however, 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 natural-origin and hatchery-origin spawners differs, and the hatchery-origin 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 natural-origin broodstock tend to mature early and residualize (due to non-genetic effects of rearing), as has been documented in some spring Chinook salmon and steelhead programs, the "effective" pNOB might be much lower than the census pNOB.

It is also 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 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, NMFS feels that census pHOS, rather than effective pHOS, is the appropriate metric to use for genetic risk evaluation.

Additional perspective on pHOS that is independent of HSRG modelling is provided by a simple analysis of the expected proportions of mating types. Figure 10 shows the expected proportion of mating types in a mixed population of natural-origin (N) and hatchery-origin (H) fish as a function of the census pHOS, assuming that N and H adults mate randomly[16]. For example, at a census pHOS level of 10%, 81% of the matings will be NxN, 18% will be NxH, and 1% will be HxH. This diagram can also be interpreted as probability of parentage of naturally produced progeny, assuming random mating and equal reproductive success of all mating types. Under this interpretation, progeny produced by a parental group with a pHOS level of 10% will have an 81% chance of having two natural-origin parents, etc.

Random mating assumes that the natural-origin and hatchery-origin spawners overlap completely spatially and temporally. As overlap decreases, the proportion of NxH matings decreases; with no overlap, the proportion of NxN matings is 1 minus pHOS and the proportion of HxH matings equals pHOS. RRS does not affect the mating type proportions directly but changes their effective proportions. Overlap and RRS can be related. For example, in the Wenatchee River, hatchery spring Chinook salmon tend to spawn lower in the system than natural-origin fish, and this accounts for a considerable amount of their lowered reproductive success (Williamson et al. 2010). In that particular situation the hatchery-origin fish were spawning in inferior habitat.

[16] These computations are purely theoretical, based on a simple mathematical binomial expansion ($(a+b)^2=a^2 + 2ab + b^2$).

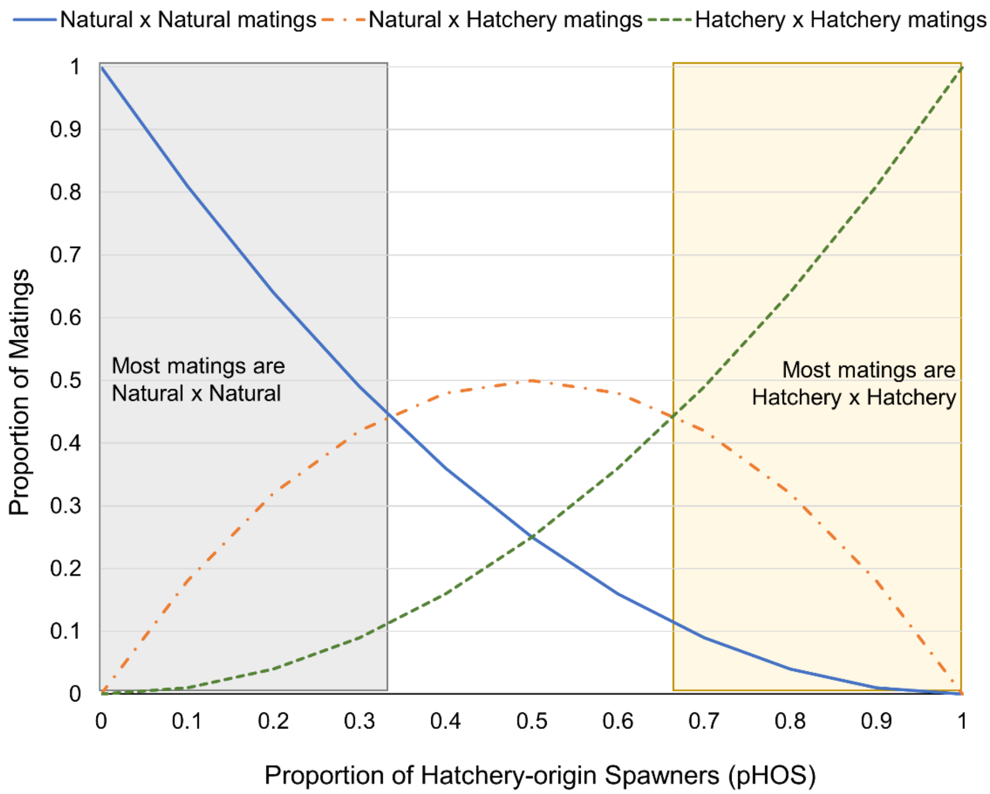

Figure 10. Relative proportions of types of matings as a function of proportion of hatchery-origin fish on the spawning grounds (pHOS).

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 (Gresh et al. 2000; Kline et al. 1990; Larkin and Slaney 1996; Murota 2003; Piorkowski 1995; Quamme and Slaney 2003; Wipfli et al. 2003). As a result, the growth and survival of juvenile salmonids may increase (Bell 2001; Bilton et al. 1982; Bradford et al. 2000; Brakensiek 2002; Hager and Noble 1976; Hartman and Scrivener 1990; Holtby 1988; Johnston et al. 1990; Larkin and Slaney 1996; Quinn and Peterson 1996; Ward and Slaney 1988).

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

The added spawner density resulting from hatchery-origin fish spawning in the wild can have negative consequences at times. In particular, the potential exists for hatchery-derived fish to superimpose or destroy the eggs and embryos of ESA-listed species when there is spatial overlap between hatchery and natural spawners. 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. Generally speaking, 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

NMFS also analyzes the potential for competition and predation when the progeny of naturally spawning hatchery fish and hatchery releases share juvenile rearing areas. The level of effect for this factor ranges from negligible to negative.

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 naturally produced 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).

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

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

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 (California HSRG 2012; Steward and Bjornn 1990)
- 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

Critical to analyzing competition risk is information on the quality and quantity of spawning and rearing habitat in the action area,[17] including the distribution of spawning and rearing habitat by

[17] "Action area" 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.

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

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

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

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

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 no history of occurrence within state boundaries. For example, *Oncorhynchus masou virus* (OMV) would be considered an exotic pathogen if identified anywhere in Washington state. Endemic pathogens are native to a state, but may not be present in all watersheds.

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

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

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

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

In addition to the state, federal and tribal fish health policies, disease risks can be further minimized by preventing pathogens from entering the hatchery facility through the treatment of incoming water (e.g., by using ozone) or by leaving the hatchery through hatchery effluent (Naish et al. 2008). Although preventing the exposure of fish to any pathogens prior to their release into the natural environment may make the hatchery fish more susceptible to infection after release into the natural environment, reduced fish densities in the natural environment compared to hatcheries likely reduces the risk of fish encountering pathogens at infectious levels (Naish et al. 2008). Treating the hatchery effluent would also minimize amplification, but would not reduce disease outbreaks within the hatchery itself caused by pathogens present in the incoming water supply. Another challenge with treating hatchery effluent is the lack of reliable, standardized guidelines for testing or a consistent practice of controlling pathogens in effluent (LaPatra 2003). However, hatchery facilities located near marine waters likely limit freshwater pathogen amplification downstream of the hatchery without human intervention because the pathogens are killed before transmission to fish when the effluent mixes with saltwater.

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. Acclimation

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

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

Having 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. By having 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 homing include:

- The timing of the 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. The level of effect for this factor ranges from positive to negative. 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)
- Holding the fish in captivity, sampling (e.g., the removal of scales and tissues)
- Tagging and fin-clipping, and observing the fish (in-water or from the bank)

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

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.

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

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. The level of effect for this factor ranges from neutral or negligible to negative.

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 of the Proposed Action in a section 7 consultation. One is where there are fisheries that exist because of the HGMP that describes the Proposed Action (i.e., the fishery is an interrelated and interdependent action), and listed species are inadvertently and incidentally taken in those fisheries. The other is when fisheries 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. The level of effect for this factor ranges from neutral or negligible to negative.

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

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