DRAFT ENVIRONMENTAL ASSESSMENT

Environmental Assessment to Analyze Impacts of a NOAA's National Marine Fisheries Service Proposed 4(d) Determination under Limit 6 for Three Early Winter Steelhead Programs in the Dungeness, Nooksack, and Stillaguamish River Basins

Prepared by the
National Marine Fisheries Service, West Coast Region

March 2015

Cover Sheet
March 2015

Title of Environmental Review:	Environmental Assessment to Analyze Impacts of a NOAA's National Marine Fisheries Service Proposed 4(d) Determination under Limit 6 for Three Early Winter Steelhead Programs in the Dungeness, Nooksack, and Stillaguamish River Basins
Evolutionarily Significant Units/ Distinct Population Segments:	Puget Sound Steelhead
Responsible Agency and Official:	William Stelle, Jr. Regional Administrator National Marine Fisheries Service West Coast Region 7600 Sand Point Way N.E., Building 1 Seattle, WA 98115
Contacts:	Allyson Purcell Sustainable Fisheries Division National Marine Fisheries Service West Coast Region 1201 NE Lloyd Blvd. Portland, OR
Legal Mandate:	Endangered Species Act (ESA) of 1973, as amended and implemented – 50 CFR Part 223
Location of Proposed Activities:	Dungeness, Nooksack, and Stillaguamish River Basins in Washington
Activity Considered:	Operation of three hatchery programs for the augmentation of steelhead fisheries. The operator is the Washington Department of Fish and Wildlife. The Federal action considered in this environmental assessment is the National Marine Fisheries Service's proposed 4(d) determination under Limit 6 for these three hatchery programs.

Table of Contents

List of Tables

List of Figures

1. PURPOSE OF AND NEED FOR THE PROPOSED ACTION

1.1. Background

NOAA's National Marine Fisheries Service (NMFS) is the lead agency responsible for administering the Endangered Species Act (ESA) as it relates to listed salmon and steelhead. Actions that may affect listed species are reviewed by NMFS under section 7 or section 10 of the ESA or under section 4(d), which can be used to limit the application of take prohibitions described in section 9. NMFS issued a final rule pursuant to ESA section 4(d) (4(d) Rule), adopting regulations necessary and advisable to conserve threatened species (50 CFR 223.203). The 4(d) Rule applies the take prohibitions in section 9(a)(1) of the ESA to salmon and steelhead listed as threatened, and also sets forth specific circumstances when the prohibitions will not apply, known as 4(d) limits. With regard to hatchery programs described in Hatchery and Genetic Management Plans (HGMPs), NMFS declared under limit 6 of the 4(d) Rule that section 9 take prohibitions would not apply to activities carried out under those HGMPs when NMFS determines that the HGMPs meet the requirements of limit 6.

The Washington Department of Fish and Wildlife (WDFW) and Jamestown S'Klallam Tribe, Lummi Nation, Nooksack Tribe, Stillaguamish Tribe, and Tulalip Tribes as co-managers of the fisheries resource under *United States v. Washington* (1974) (hereafter referred to as "the co-managers"), have provided NMFS with three Hatchery and Genetic Management Plans (HGMP) for hatchery programs and associated monitoring and evaluation actions in the Dungeness, Nooksack, and Stillaguamish River watersheds that will affect ESA-listed Puget Sound Chinook salmon, Hood Canal summer chum salmon, and Puget Sound steelhead (Scott 2014). The HGMPs provide the framework through which the Washington State and Tribal jurisdictions can jointly manage hatchery operations, monitoring, and evaluation activities, while meeting requirements specified under the ESA. The co-managers developed the plans jointly, and have provided the HGMPs for review and determination by NMFS as to whether they address the criteria of limit 6 of the 4(d) Rule. For the purposes of the proposed recommendation, NMFS considers the three joint HGMPs, submitted for consideration under limit 6, to be an RMP.

Table 1. Permit applications for Dungeness River, Nooksack River, and Stillaguamish River winter steelhead hatchery programs.

Hatchery Program	Location	Operator	HGMP Last Updated
Dungeness River Early Winter Steelhead Hatchery Program	Dungeness River Basin	WDFW	26-Jul-14
Kendall Creek Winter Steelhead Hatchery Program	Nooksack River Basin	WDFW	26-Jul-14
Whitehorse Ponds Winter Steelhead Hatchery Program	Stillaguamish River Basin	WDFW	26-Jul-14

1.2. Description of the Proposed Action

WDFW and Jamestown S'Klallam Tribe, Lummi Nation, Nooksack Tribe, Stillaguamish Tribe, and Tulalip Tribes as co-managers of the fisheries resource under *United States v. Washington* (1974) (hereafter referred to as "the co-managers"), have provided NMFS with three Hatchery and Genetic Management Plans (HGMP) for hatchery programs and associated monitoring and evaluation actions in the Dungeness, Nooksack, and Stillaguamish River watersheds that will affect ESA-listed Puget Sound Chinook salmon, Hood Canal summer chum salmon (Dungeness), and Puget Sound steelhead (Scott 2014). The co-managers developed the plans jointly, and have provided the HGMPs for review and determination by NMFS as to whether they address the criteria of limit 6 of the 4(d) Rule. For the purposes of the proposed recommendation, the NMFS consider the three joint HGMPs, submitted for consideration under limit 6, to be a RMP. All of the hatchery programs release non-ESA-listed early-winter steelhead of Chambers Creek origin. All of the programs are currently operating, and all propagated fish are derived from locally-returning broodstock collected at each of the associated hatchery facilities.

Under the Proposed Action, NMFS would make a determination that the submitted HGMPs meet the requirements of limit 6 of the 4(d) Rule. Activities included in the HGMPs are as follows:

- Broodstock collection through operation of weirs, fish traps, and collection ponds (Table 2)
- Transport of broodstock from Dungeness River Hatchery to Hurd Creek Hatchery
- Holding, identification, and spawning of adult fish at Dungeness, Hurd Creek, Kendall Creek, and Whitehorse Ponds Hatcheries (Table 2)
- Egg incubation at Dungeness, Hurd Creek, Kendall Creek, and Whitehorse Ponds Hatcheries (Table 2)
- Fish rearing at Dungeness, Hurd Creek, Kendall Creek, and Whitehorse Ponds Hatcheries and at McKinnon Pond (Table 2)
- Clipping the adipose fin of 100 percent of the hatchery-origin juveniles prior to release

- Release of up to 10,000 steelhead yearlings into the Dungeness River Basin, 150,000 steelhead yearlings into the Nooksack River Basin, and 130,000 steelhead yearlings into the Stillaguamish River Basin
- Removal of adult hatchery-origin steelhead returning to the Dungeness, Nooksack, and Stillaguamish River Basins at weirs, fish traps, and other collection facilities
- Monitoring and evaluation activities to assess the performance of the programs in meeting conservation, harvest augmentation, and listed fish risk minimization objectives (Table 2)

Table 2. Hatchery facilities associated with the proposed Dungeness, Nooksack, and Stillaguamish River Basin early-winter steelhead programs

Activity	Facility	Location[†]	Does Facility Exist under Baseline Conditions?	Is Facility Operated under Baseline Conditions?
Broodstock collection	Dungeness River Hatchery	RM 10.5 on the Dungeness River	Yes	Yes
	Kendall Creek Hatchery	Located at the mouth of Kendall Creek (WRIA 01.0406), tributary to the NF Nooksack River (WRIA 01.0120) at RM 46	Yes	Yes
	Whitehorse Ponds Hatchery	Located at RM 1.5 of Whitehorse Springs Creek (WRIA 05.0254A), tributary to the NF Stillaguamish River (WRIA 05.0135) at RM 28	Yes	Yes
Spawning	Dungeness River Hatchery	RM 10.5 on the Dungeness River	Yes	Yes
	Kendall Creek Hatchery	Located at the mouth of Kendall Creek (WRIA 01.0406), tributary to the North Fork Nooksack River (WRIA 01.0120) at RM 46	Yes	Yes
	Whitehorse Ponds Hatchery	Located at RM 1.5 of Whitehorse Springs Creek (WRIA 05.0254A), tributary to the North Fork Stillaguamish River (WRIA 05.0135) at RM 28	Yes	Yes
Incubation	Dungeness River Hatchery	RM 10.5 on the Dungeness River	Yes	Yes
	Hurd Creek Hatchery	RM 0.2 on Hurd Creek, tributary to the Dungeness River at RM 2.7	Yes	Yes

Activity	Facility	Location†	Does Facility Exist under Baseline Conditions?	Is Facility Operated under Baseline Conditions?
	Kendall Creek Hatchery	Located at the mouth of Kendall Creek (WRIA 01.0406), tributary to the North Fork Nooksack River (WRIA 01.0120) at RM 46	Yes	Yes
	Whitehorse Ponds Hatchery	Located at RM 1.5 of Whitehorse Springs Creek (WRIA 05.0254A), tributary to the NF Stillaguamish River (WRIA 05.0135) at RM 28	Yes	Yes
Rearing	Dungeness River Hatchery	RM 10.5 on the Dungeness River	Yes	Yes
	Hurd Creek Hatchery	RM 0.2 on Hurd Creek, tributary to the Dungeness River at RM 2.7	Yes	Yes
	Kendall Creek Hatchery	Located at the mouth of Kendall Creek (WRIA 01.0406), tributary to the North Fork Nooksack River (WRIA 01.0120) at RM 46	Yes	Yes
	McKinnon Pond	Located just downstream from the Mosquito Lake Road Bridge on the left bank of the Middle Fork Nooksack River with water from and outlet to a creek (WRIA 01.0352, known locally as "Peat Bog Creek"), which emanates from Peat Bog, tributary to Middle Fork Nooksack River (WRIA 01.0339) at RM 4.4.	Yes	Yes
	Whitehorse Ponds Hatchery	Located at RM 1.5 of Whitehorse Springs Creek (WRIA 05.0254A), tributary to the North Fork Stillaguamish River (WRIA 05.0135) at RM 28	Yes	Yes
Juvenile Fish Release	Dungeness River Hatchery	RM 10.5 on the Dungeness River	Yes	Yes
	Kendall Creek Hatchery	Located at the mouth of Kendall Creek (WRIA 01.0406), tributary to the NF Nooksack River (WRIA 01.0120) at RM 46	Yes	Yes

Activity	Facility	Location[†]	Does Facility Exist under Baseline Conditions?	Is Facility Operated under Baseline Conditions?
	Whitehorse Ponds Hatchery	Located at RM 1.5 of Whitehorse Springs Creek (WRIA 05.0254A), tributary to the NF Stillaguamish River (WRIA 05.0135) at RM 28	Yes	Yes
	Whitehorse fish in excess of release goals are released into various King and Snohomish County lakes for harvest.	Various lakes that are functionally isolated from anadromous-accessible freshwater	Yes	Yes
Monitoring and evaluation	Dungeness River Hatchery	RM 10.5 on the Dungeness River	Yes	Yes
	Hurd Creek Hatchery	RM 0.2 on Hurd Creek, tributary to the Dungeness River at RM 2.7	Yes	Yes
	Kendall Creek Hatchery	Located at the mouth of Kendall Creek (WRIA 01.0406), tributary to the NF Nooksack River (WRIA 01.0120) at RM 46	Yes	Yes
	Whitehorse Ponds Hatchery	Located at RM 1.5 of Whitehorse Springs Creek (WRIA 05.0254A), tributary to the NF Stillaguamish River (WRIA 05.0135) at RM 28	Yes	Yes
	Watershed areas accessible to natural salmon and steelhead migration, spawning and rearing	Dungeness, Nooksack, and Stillaguamish River basin areas, including tributaries, extending from the river mouth through the upstream extent of anadromous fish access.	N/A	N/A

RM: River mile, measured from the farthest downstream point on the stream in question.
WRIA: Water Resources Inventory Area, typically defining geographic areas where surface-water run-off drains into a common surface-water body, such as a lake, section of a stream, or a bay.

1.3. Purpose of and Need for the Proposed Action

NMFS's purpose and need for the Proposed Action is three-fold:

- Ensure the proposed hatchery programs comply with requirements of the ESA
- Meet NMFS's tribal treaty rights trust and fiduciary responsibilities
- Work collaboratively with WDFW and tribal co-managers to protect and conserve listed species

WDFW and the tribal co-managers' purpose and need for the Proposed Action is two-fold:

- Comply with requirements of the ESA
- Continue operation of on-going hatchery programs to provide tribal and recreational harvest opportunity for steelhead in the Dungeness, Nooksack, and Stillaguamish River Basins

1.4. Action Area

The action area (or project area) is the geographic area where the Proposed Action would take place. It includes the places where the proposed steelhead hatchery programs would (1) collect broodstock; (2) spawn, incubate, and rear fish; (3) release fish; or (4) remove surplus hatchery-origin adult steelhead that return to hatchery facilities; and (5) conduct monitoring and evaluation activities. The action area includes the Dungeness, Nooksack, and Stillaguamish River Basins, as well as the following hatchery and satellite facilities and their immediate surroundings:

- Dungeness River Hatchery
- Hurd Creek Hatchery
- Kendall Creek Hatchery
- McKinnon Ponds
- Whitehorse Ponds

The analysis area is the geographic extent that is being evaluated for a particular resource. For some resources, the analysis area may be larger than the action area, since some of the effects of the alternatives may occur outside the action area.

1.5. Relationship to Other Plans and Policies

In addition to NEPA and ESA, other plans, regulations, agreements, treaties, laws, and Secretarial and Executive Orders also affect hatchery operations in the Dungeness, Nooksack, and Stillaguamish River Basins. They are summarized below to provide additional context for the hatchery programs and their proposed HGMPs.

1.5.1. Clean Water Act

The Clean Water Act (33 USC 1251, 1977, as amended in 1987), administered by the U.S. Environmental Protection Agency and state water quality agencies, is the principal Federal legislation directed at protecting water quality. Each state implements and carries forth Federal provisions, as well as approves and reviews National Pollutant Discharge Elimination System (NPDES) applications, and establishes total maximum daily loads for rivers, lakes, and streams. The states are responsible for setting the water quality standards needed to support all beneficial uses, including protection of public health, recreational activities, aquatic life, and water supplies.

The Washington State Water Pollution Control Act, codified as Revised Code of Washington Chapter 90.48, designates the Washington Department of Ecology (Ecology) as the agency responsible for carrying out the provisions of the Federal Clean Water Act within Washington State. The agency is responsible for establishing water quality standards, making and enforcing water quality rules, and operating waste discharge permit programs. These regulations are described in Washington Administrative Code (WAC) 173. Hatchery operations are required to comply with the Clean Water Act.

1.5.2. Bald Eagle and Golden Eagle Protection Act

The Bald Eagle and Golden Eagle Protection Act (16 USC. 668-668c), enacted in 1940, and amended several times since then, prohibits the taking of bald eagles, including their parts, nests, or eggs. The act defines “take” as "pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest or disturb." The U.S. Fish and Wildlife Service, who is responsible for carrying out provisions of this Act, defines “disturb” to include “injury to an eagle; a decrease in its productivity, by substantially interfering with normal breeding, feeding, or sheltering behavior; or nest abandonment, by substantially interfering with normal breeding, feeding, or sheltering behavior.” Changes in hatchery production have the potential to affect eagle productivity through changes in its salmon and steelhead prey sources.

1.5.3. Marine Mammal Protection Act

The Marine Mammal Protection Act of 1972 (16 USC 1361) as amended, establishes a national policy designated to protect and conserve wild marine mammals and their habitats. This policy was established so as not to diminish such species or populations beyond the point at which they cease to be a significant functioning element in the ecosystem, nor to diminish such species below their optimum sustainable population. All marine mammals are protected under the Marine Mammal Protection Act.

The Marine Mammal Protection Act prohibits, with certain exceptions, the take of marine mammals in United States waters and by United States citizens on the high seas, and the importation of marine mammals and marine mammal products into the United States. The term "take," as defined by the Marine Mammal Protection Act, means to "harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal." The Marine Mammal Protection Act further defines harassment as "any act of pursuit, torment, or annoyance, which (i) has the potential to injure a marine mammal or marine mammal stock in the wild; or (ii) has the potential to disturb a marine mammal or marine mammal stock in the wild by causing a disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering but which does not have the potential to injure a marine mammal or marine mammal stock in the wild."

NMFS is responsible for reviewing Federal actions for compliance with the Marine Mammal Protection Act. Changes in fish production can indirectly affect marine mammals by altering the number of available salmon and steelhead prey sources.

1.5.4. Executive Order 12898

In 1994, the President issued Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority and Low-income Populations*. The objectives of the Executive Order include developing Federal agency implementation strategies, identifying minority and low-income populations where proposed Federal actions could have disproportionately high and adverse human health and environmental effects, and encouraging the participation of minority and low-income populations in the NEPA process. Changes in hatchery production have the potential to affect the extent of harvest available for minority and low-income populations.

1.5.5. Treaties of Point Elliot, Medicine Creek, and Point No Point

Beginning in the mid-1850s, the United States entered into a series of treaties with tribes in Puget Sound. The treaties were completed to secure the rights of the tribes to land and the use of natural resources in their historically inhabited areas, in exchange for the ceding of land to the United States for settlement by its citizens. These treaties secured the rights of tribes for taking fish at usual and accustomed grounds and stations in common with all citizens of the United States. Marine and freshwater areas of Puget Sound were affirmed as the usual and accustomed fishing areas for treaty tribes under *U.S. v. Washington* (1974).

The Lummi Nation, Nooksack Tribe, Stillaguamish Tribe, and Tulalip Tribes are signatory to the Treaty of Point Elliot, the lands settlement treaty between the United States government and the Native American tribes of the North Puget Sound and Strait of Georgia regions, in the recently-formed Washington Territory. The Treaty of Point Elliot was signed on January 22, 1855, at Muckl-te-oh or Point Elliott, now Mukilteo, Washington.

The Jamestown S’Klallam Tribe is signatory to the Treaty of Point No Point, the lands settlement treaty between the United States government and the Native American tribes of the Strait of Juan de Fuca and Hood Canal regions (then, the S'Klallam, the Chimakum, and the Skokomish Tribes), also in the recently-formed Washington Territory. The Treaty of Point No Point was signed on January 26, 1855, at Hahdskus – the Salish dialect name for Point No Point – on the northern tip of the Kitsap Peninsula.

1.5.6. *U.S. v. Washington*

U.S. v. Washington (1974) is the Federal court proceeding that enforces and implements reserved treaty fishing rights with regards to salmon and steelhead returning to Puget Sound. Hatcheries in Puget Sound provide salmon and steelhead for these fisheries. Without many of these hatcheries, there would be few, if any, fish for the tribes to harvest. These fishing rights and attendant access were established by treaties that the Federal government signed with the tribes in the 1850s. In those treaties, the tribes agreed to allow the peaceful settlement of Indian lands in western Washington in exchange for their continued right to fish, gather shellfish, hunt, and exercise other sovereign rights. Under Phase II of *U.S. v. Washington*, the Federal District Court ensured tribes the rights to the protection of fish habitat subject to treaty catch and a right to the fish that are produced by hatcheries. In 1974, Judge George Boldt decided in *U.S. v. Washington* that the tribes’ fair and equitable share was 50 percent of all of the harvestable fish destined for the tribes’ traditional fishing places.

1.5.7. Secretarial Order 3206

Secretarial Order 3206 (*American Indian Tribal Rights, Federal-Tribal Trust Responsibilities and the ESA*) issued by the secretaries of the Departments of Interior and Commerce, clarifies the responsibilities of the agencies, bureaus, and offices of the departments when actions taken under the ESA and its implementing regulations affect, or may affect, Indian lands, tribal trust resources, or the exercise of American Indian tribal rights as they are defined in the Order. Secretarial Order 3206 acknowledges the trust responsibility and treaty obligations of the United States toward tribes and tribal members, as well as its government-to-government relationship when corresponding with tribes. Under the Order, NMFS and the U.S. Fish and Wildlife Service (Services) “will carry out their responsibilities under the [ESA] in a manner that harmonizes the Federal trust responsibility to tribes, tribal sovereignty, and statutory missions of the [Services], and that strives to ensure that Indian tribes do not bear a disproportionate burden for the conservation of listed species, so as to avoid or minimize the potential for conflict and confrontation.”

More specifically, the Services shall, among other things, do the following:

- Work directly with Indian tribes on a government-to-government basis to promote healthy ecosystems (Sec. 5, Principle 1)
- Recognize that Indian lands are not subject to the same controls as Federal public lands (Sect. 5, Principle 2)
- Assist Indian tribes in developing and expanding tribal programs so that healthy ecosystems are promoted and conservation restrictions are unnecessary (Sec. 5, Principle 3)
- Be sensitive to Indian culture, religion, and spirituality (Sec. 5, Principle 4)

1.5.8. The Federal Trust Responsibility

The United States government has a trust or special relationship with Indian tribes. The unique and distinctive political relationship between the United States and Indian Tribes is defined by statutes, executive orders, judicial decisions, and agreements and differentiates tribes from other entities that deal with, or are affected by the Federal government. Executive Order 13175, *Consultation and Coordination with Indian Tribal Governments*, states that the United States has recognized Indian tribes as domestic dependent nations under its protection. The Federal government has enacted numerous statutes and promulgated numerous regulations that establish and define a trust relationship with Indian tribes. The relationship has been compared to one existing under common law trust, with the United States as trustee, the Indian tribes or individuals as beneficiaries, and the property and natural resources of the United States as the trust corpus (Cohen 2005; Newton et al. 2005). The trust responsibility has been interpreted to require Federal agencies to carry out their activities in a manner that is protective of Indian treaty rights. This policy is also reflected in the March 30, 1995, document, *Department of Commerce – American Indian and Alaska Native Policy* (U. S. Department of Commerce 1995).

1.5.9. Washington State Endangered, Threatened, and Sensitive Species Act

This EA will consider the effects of hatchery programs and harvest actions on state endangered, threatened, and sensitive species. The State of Washington has species of concern listings (Washington Administrative Code Chapters 232-12-014 and 232-12-011) that include all state endangered, threatened, sensitive, and candidate species. These species are managed by WDFW, as needed, to prevent them from becoming endangered, threatened, or sensitive. The state-listed species are identified on WDFW's website (*http://wdfw.wa.gov/conservation/endangered/*); the most recent update occurred in June 2008. The criteria for listing and de-listing, and the requirements for recovery and management plans for these species are provided in Washington Administrative Code Chapter 232-12-297. The state list is separate from the Federal ESA list; the state list includes species status relative to Washington state jurisdiction only. Critical wildlife habitats associated with state or federally listed species are identified in Washington Administrative Code Chapter 222-16-080. Species listed under the state endangered, threatened, and sensitive species list are reviewed in this EA.

1.5.10. Hatchery and Fishery Reform Policy

WDFW's Hatchery and Fishery Reform Policy (Policy C-3619) was adopted by the Washington Fish and Wildlife Commission in 2009 (WFWC 2009). It supersedes WDFW's Wild Salmonid Policy, which was adopted in 1997. Its purpose is to advance the conservation and recovery of wild salmon and steelhead by promoting and guiding the implementation of hatchery reform. The policy applies to state hatcheries and its intent is to improve hatchery effectiveness, ensure compatibility between hatchery production and salmon recovery plans and rebuilding programs, and support sustainable fisheries.

1.5.11. Recovery Plans for Puget Sound Salmon

Federal recovery plans are in place for the ESA-listed Puget Sound Chinook Salmon (SSPS 2007) and Hood Canal Summer Chum Salmon ESUs (Hood Canal Coordinating Council 2005). Broad partnerships of Federal, state, local, and tribal governments and community organizations collaborated in the development of the two completed salmon recovery plans under Washington's Salmon Recovery Act. The comprehensive recovery plans include conservation goals and proposed habitat, hatchery, and harvest actions needed to achieve the conservation goals for each watershed within the geographic boundaries of the two listed ESUs. Although listed in 2007, a recovery plan for the Puget Sound Steelhead DPS has not yet been completed, but is currently in the process of assembly.

1.5.12. Wilderness Act

The 1964 Wilderness Act directs Federal agencies to manage wilderness so as to preserve its wilderness character. Lands classified as wilderness through the Wilderness Act may be under the jurisdiction of the U.S. Forest Service, National Park Service, U.S. Fish and Wildlife Service, or the U.S. Bureau of Land Management. With some exceptions, the Wilderness Act prohibits motorized and mechanized vehicles, timber harvest, new grazing and mining activity, or any kind of development. In 1988, Congress designated 95 percent of the Olympic National Park as wilderness under the Wilderness Act. The Olympic Wilderness Area is under the jurisdiction of the National Park Service. Some of the Dungeness River Basin is within the Olympic Wilderness Area. All three forks of the Nooksack River originate in the Mount Baker Wilderness. One tributary of the Stillaguamish River – Boulder River – originates in the Boulder River Wilderness Area.

2. ALTERNATIVES INCLUDING THE PROPOSED ACTION

Four alternatives are considered in this EA: (1) NMFS would not make a determination under the 4(d) Rule (No Action); (2) NMFS would make a determination that the submitted HGMPs meet the requirements of the 4(d) Rule (Proposed Action); (3) NMFS would make a determination that revised HGMPs with reduced production levels would meet the requirements of the 4(d) Rule; (4) NMFS would make a determination that revised HGMPs that replace Chambers Creek stock with a native broodstock meet the requirements of the 4(d) Rule. These alternatives are described below.

2.1. Alternative 1 (No Action) – Do Not Make a Determination under the 4(d) Rule

Under this alternative, NMFS would not make a determination under the 4(d) Rule, and WDFW would discontinue its early winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins. All steelhead currently being raised within the proposed hatchery programs would be killed, and no additional broodstock would be collected. This no-action alternative represents NMFS's best estimate of what would happen in the absence of the proposed Federal action – a determination that the submitted plans meet requirements of the 4(d) Rule.

2.2. Alternative 2 (Proposed Action) – Make a Determination that the Submitted HGMPs Meet the Requirements of the 4(d) Rule

Under this alternative, NMFS would make a determination that the submitted HGMPs meet the requirements of the 4(d) Rule, and the early winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins would be implemented as described in the three submitted HGMPs (WDFW 2014a, WDFW 2014b, and WDFW 2014c).

Under Alternative 2, the annual maximum release levels would be as follows:

- Dungeness River Basin: up to 10,000 steelhead yearlings
- Nooksack River Basin: up to 150,000 steelhead yearlings
- Stillaguamish River Basin: up to 130,000 steelhead yearlings

2.3. Alternative 3 (Reduced Production Alternative) – Make a Determination that Revised HGMPs with Released Production Levels Meet the Requirements of the 4(d) Rule

Under this alternative, WDFW would reduce the number of fish released from each of the three proposed hatchery programs. Revised HGMPs would be submitted reflecting these reduced production levels, and NMFS would make a determination that the revised HGMPs meet the requirements of the 4(d) Rule.

For the purposes of analysis, NMFS will evaluate a 50 percent reduction from the proposed hatchery program because it represents a mid-point between the Proposed Action (Alternative 2) and the No-action Alternative (Alternative 1). Note that NMFS's 4(d) regulations do not provide NMFS with the authority to order changes of this magnitude as a condition of approval of the HGMPs. NMFS's 4(d) regulations require NMFS to make a determination that the HGMPs *as proposed* either meet or do not meet the standards prescribed in the rule. Nonetheless, NMFS supports analysis of this alternative to assist with a full understanding of potential effects on the human environment under various management scenarios.

2.4. Alternative 4 (Transition to Native Broodstock) - Make a Determination that Revised HGMPs that Replace Chambers Creek Stock with a Native Broodstock Meet the Requirements of the 4(d) Rule

Under this alternative, WDFW would change its program management to transition the programs from the current non-native Chambers Creek stock to broodstock derived from fish native to the watersheds in the action area. While this could be done in multiple ways, involving different periods of time and various objectives, for the purpose of this analysis NMFS assumes that use of Chambers Creek stock fish in the broodstock would be terminated immediately. Fish taken for broodstock would then only be those determined to be native to the given watershed.

Broodstock collection would be contingent upon availability of natural-origin fish, ensuring first that an appropriate minimum number of fish would be able to spawn naturally; after that critical threshold is ensured, then a proportion of additional returns would be taken into the hatchery facilities. Broodstock collection would occur through fish volunteering to the hatcheries, but might also require additional collection methods, including at weirs, via hook and line, or through seining. The Proportionate Natural Influence (PNI, described in section 3.3.1) would be 0.67 or higher, and no more than 10 percent of the naturally spawning fish in the river would be hatchery-origin spawners.

Note that NMFS's 4(d) regulations do not provide NMFS with the authority to order changes of this magnitude as a condition of approval of the HGMPs. NMFS's 4(d) regulations require NMFS to make a determination that the HGMPs *as proposed* either meet or do not meet the standards prescribed in the rule. Nonetheless, NMFS supports analysis of this alternative to assist with a full understanding of potential effects on the human environment under various management scenarios.

2.5. Alternatives Considered But Not Analyzed in Detail

The following alternatives were considered, but NMFS determined that they would not be measurably different from the alternatives already being considered, would likely have increased environmental effects relative to the Proposed Action, or would not meet the purpose and need for action (Subsection 1.3, Purpose of and Need for the Proposed Action):

- Hatchery programs with additional best management practices – Under this alternative, WDFW would revise their HGMPs to incorporate additional best management practices to further reduce the risk of adverse impacts of the hatchery programs on natural-origin salmon and steelhead populations, and NMFS would determine the revised HGMPs meet the requirements of the 4(d) Rule. However, because the HGMPs have already incorporated best management practices identified by independent reviewers, and because the HGMPs allow for the incorporation of additional best management practices in the future as a result of monitoring and evaluation activities, this alternative would not be meaningfully different from the Proposed Action and will not be evaluated in detail.

- Hatchery programs with greater levels of hatchery production than those proposed – Under this alternative, WDFW would revise their HGMPs to incorporate higher production levels than those proposed. This alternative will not be analyzed in detail because higher productions would be expected to have incrementally higher environmental impacts than production levels under the Proposed Action, and exceed threshold levels of impact consistent with ESA requirements.

- Hatchery programs with a sunset date – Under this alternative, WDFW would revise their HGMPs to include a sunset date (i.e., a date that the programs would be terminated). This alternative will not be considered in detail because the proposed hatchery programs are designed for harvest augmentation. Without them, there would not be hatchery-origin steelhead in the Dungeness, Nooksack, or Stillaguamish River Basins for harvest, which would not meet the purpose and need for action (Subsection 1.3, Purpose of and Need for the Proposed Action). In addition, an alternative that terminates the hatchery programs is already being evaluated as Alterative 1 (No Action).

3. AFFECTED ENVIRONMENT

Chapter 3, Affected Environment, describes baseline conditions for eight resources that may be affected by implementation of the EA alternatives:

- Water quantity (Subsection 3.1)
- Water quality (Subsection 3.2)
- Salmon and steelhead (Subsection 3.3)
- Other fish species (Subsection 3.4)
- Wildlife and marine mammals (Subsection 3.5)
- Socioeconomics (Subsection 3.6)
- Environmental justice (Subsection 3.7)

No other resources were identified during internal scoping that would have the potential to be significantly impacted by the Proposed Action or alternatives. Baseline conditions include effects of the past and present operation of the early-winter steelhead programs in the Dungeness, Nooksack, and Stillaguamish River Basins. Under baseline conditions, the early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basin produce the following number of smolts:

- Dungeness River Basin: Up to 10,000 yearlings
- Nooksack River Basin: Up to 150,000 yearlings
- Stillaguamish River Basin: Up to 130,000 yearlings

The action area (or project area) is the geographic area where the Proposed Action would take place. It includes the places where early-winter steelhead would be spawned, incubated, reared, acclimated, released, or harvested in the Dungeness, Nooksack, and Stillaguamish River Basins (Subsection 1.4, Action Area). Each resource's analysis area includes the action area as a minimum area, but may include locations beyond the action area if some of the effects of the EA's alternatives on that resource would be expected to occur outside the action area (Subsection 1.4, Action Area).

3.1. Water Quantity

Hatchery programs can affect water quantity when they take water from a well (groundwater) or a neighboring river or tributary stream (surface water) to use in the hatchery facility for broodstock holding, egg incubation, juvenile rearing, and juvenile acclimation. All water, minus evaporation, that is diverted from a river or taken from a well is discharged into the water course adjacent to the hatchery rearing location after it circulates through the hatchery facility (non-consumptive use). When hatchery programs use groundwater (i.e., from wells), they may reduce the amount of water for other users in the same aquifer. When hatchery programs use surface water, they may lead to dewatering of the stream between the water intake and discharge structures (called the "bypass reach"), which may impact fish and wildlife if migration is impeded or dewatering leads to increased water temperatures. Generally, water intake and discharge structures are located as closely together as possible to minimize the area of the stream that may be impacted by a water withdrawal.

Five hatchery facilities are currently used to support the three proposed early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins (Subsection 1.4, Action Area). Two of the hatchery facilities use surface water exclusively (Dungeness River Hatchery and McKinnon Rearing Pond), and three of the hatchery facilities use both groundwater and surface water (Kendall Creek Hatchery, Hurd Creek Hatchery, and Whitehorse Ponds Hatchery).

A water right permit is required for all groundwater withdrawals except those supporting single-family homes. All wells used by hatchery facilities supporting the proposed early winter steelhead hatchery programs are permitted by the Washington Department of Ecology.

Surface flows fluctuate seasonally, based on rainfall levels and snowmelt with flows generally highest in winter and spring. Surface water withdrawal needs for the hatchery programs also fluctuate seasonally, with the highest hatchery water withdrawal needs occurring in the late winter and spring months because that is when fish are at their largest size and need high rearing flows for fish health maintenance. Hatchery water withdrawal needs for fish rearing are lowest in the late summer months when river flows are at their lowest level.

The following sections summarize water withdrawals at the facilities that support the early-winter steelhead programs in the Dungeness, Nooksack, and Stillaguamish River Basins. These data can also be found in Table 3.

Dungeness River Basin: The Dungeness River Hatchery uses surface water exclusively, withdrawn through three water intakes on the Dungeness River and one on Canyon Creek, an adjacent tributary. The Hurd Creek Hatchery facility uses a combination of groundwater withdrawn from five wells, and surface water withdrawn from Hurd Creek as an emergency back-up source.

The Dungeness River Hatchery withdraws up to 2.0 cubic feet per second (cfs) of water from the Dungeness River and up to 0.4 cfs from Canyon Creek to support the Dungeness River early-winter steelhead program (Table 3). All water is returned to the river after circulating through the hatchery. Water quantity is only affected between the water intake and discharge structures. Water flows in the Dungeness River average 397 cfs with minimum flows of 55.5 cfs. Because the early-winter steelhead hatchery program diverts up to 2 cfs of water from the Dungeness River, which is 3.6 percent of the water in the Dungeness River during low flow conditions, the effects of the water withdrawal are considered negligible under baseline conditions. Water flows in the Canyon Creek average 8 cfs with minimum flows of 2 cfs. Because the early-winter steelhead hatchery program diverts up to 0.26 cfs of water, which is 20.0 percent of the water in Canyon Creek during low flow conditions, the effects of the water withdrawal are considered moderate under baseline conditions.

The Hurd Creek Hatchery withdraws up to 0.26 cfs from Hurd Creek and 0.95 cfs from wells to support the Dungeness River early-winter steelhead program (Table 3). All water is returned to the creek after circulating through the hatchery. Water quantity is only affected between the water intake and discharge structures. Water flows in Hurd Creek average 5 cfs with minimum flows of 2 cfs. Because the early-winter steelhead hatchery program diverts up to 0.26 cfs of water from Hurd Creek, which is 13.0 percent of the water in Hurd Creek during low flow conditions, the effects of the water withdrawal are considered moderate under baseline conditions.

Surface water withdrawal rights are formalized through Washington State water right permits # S2-06221 (25 cfs) & S2-21709 (15 cfs) for the Dungeness River and # S2-00568 (8.5 cfs) for Canyon Creek. Hurd Creek Hatchery water rights are formalized through permit # G2-24026 (6.4 cfs). Monitoring and measurement of water usage are reported in monthly National Pollutant Discharge Elimination System (NPDES) reports to Washington State Department of Ecology.

Nooksack River Basin: The Kendall Creek Hatchery uses well and surface water (when available). The McKinnon Pond uses gravity fed surface water from a stream locally known as "Peat Bog Creek" (WRIA 01.0352).

The Kendall Creek Hatchery withdraws up to 6.7 cfs from Kendall Creek and 7.7 cfs from wells to support the Kendall Creek early-winter steelhead program (Table 3). All water is returned to the creek after circulating through the hatchery. Water quantity is only affected between the water intake and discharge structures. Water flows in Kendall Creek average 3,847 cfs with minimum flows of 522 cfs. Because the early-winter steelhead hatchery program diverts up to 6.7 cfs of water from Hurd Creek, which is 1.3 percent of the water in Kendall Creek during low flow conditions, the effects of the water withdrawal are considered negligible under baseline conditions.

The McKinnon Pond may withdraw up to 2.0 cfs from Peat Bog Creek from December through February to rear early-winter steelhead (Table 3). Steelhead are not reared in McKinnon Pond during the remainder of the year. All water is returned to the creek after circulating through the rearing pond. Water quantity is only affected between the water intake and discharge structures. Water flows in Peat Bog Creek average 520 cfs with minimum flows of 32 cfs. Because the early-winter steelhead hatchery program diverts up to 2 cfs of water from Peat Bog Creek, which is 0.3 percent of the water in Peat Bog Creek during average flow conditions, the effects of the water withdrawal are considered negligible under baseline conditions.

Surface water rights for Kendall Creek Hatchery are formalized through Washington State trust water right permits #G1-10562c, G1-2361c, and S1-00317. Surface water rights for McKinnon Pond are formalized through Washington State trust water right permit #S1-27351. Monitoring and measurement of water usage are reported in monthly NPDES permit reports to Washington Department of Ecology.

Stillaguamish River Basin: Whitehorse Ponds Hatchery uses well and surface water. The Whitehorse Ponds Hatchery withdraws up to 2.4 cfs from Whitehorse Springs Creek and up to 0.5 cfs from wells to support the early-winter steelhead hatchery program (Table 3). All water is returned to the creek after circulating through the hatchery. Water quantity is only affected between the water intake and discharge structures. Water flows in Whitehorse Springs Creek average 1,908 cfs with minimum flows of 123 cfs. Because the early-winter steelhead hatchery program diverts up to 2.4 cfs of water from Whitehorse Springs Creek, which is 1.2 percent of the water in Whitehorse Springs Creek during low flow conditions, the effects of the water withdrawal are considered negligible under baseline conditions.

Surface and well water rights are formalized through Washington State trust water right permits #S1-00825 (up to 5.6 cfs) and G1-28153P (1.1 cfs).

Table 3. Water use at hatchery facilities that support the early-winter steelhead programs in the Dungeness, Nooksack, and Stillaguamish River Basins.

Hatchery Facility	Max Ground Water Use (cfs)	Max Surface Water Use (cfs)	Percent of Hatchery Facility Used to Rear Steelhead (%)	Max Use of Water to Support Steelhead Programs (cfs)	Surface Water Source	Annual Surface Water Flow (min/mean/max) (cfs) [1]	Max Percentage of Water Flow Diverted During Low Flow Conditions (%)
Dungeness River Hatchery	N/A	40	5	Surface: 2	Dungeness River	Min: 55.5 Mean: 397 Max: 3,310	3.6
	N/A	8.5		Surface: 0.4	Canyon Creek	Min: 2 Mean: 8 Max: 2,025	20.0
Hurd Creek Hatchery	5	1.4	19[2]	Surface: 0.26 Ground: 0.95	Hurd Creek	Min: 2 Mean: 5 Max: 2,007	13.0
Kendall Creek Hatchery	27.2	23.8	28.3	Ground: 7.7 Surface: 6.7	Kendall Creek	Min: 522 Mean: 3,847 Max: 43,700	1.3
McKinnon Pond	N/A	2.0	100 from December through February; 0 from March through November	Surface: 2.0	Peat Bog Creek	Min: 32 Mean: 520 Max: 8,650	0.3 (note that steelhead are not reared in McKinnon Pond during low flow conditions so this is the proportion used during average flow conditions)
Whitehorse Ponds Hatchery	1.1	5.6	42	Ground: 0.5 Surface: 2.4	Whitehorse Spring Creek	Min: 123 Mean: 1,908 Max: 36,800	1.2

Source: HGMPs Table 4.1.1

[1] October through September 5-year (2006-2011) mean, minimum, and maximum flow data for the lower Dungeness River from Washington Department of Ecology (WDOE 2012a) Dungeness River Stream Flow Monitoring Station 18A050, accessible at: https://fortress.wa.gov/ecy/wrx/wrx/flows/station.asp?wria=18#block2_Flow data collection reach is downstream of five irrigation withdrawal points on the river. Additional source of flow data is Elwha Dungeness Planning Unit (EDPU 2005) available at: http://www.clallam.net/environment/elwhadungenesswria.html. Flows presented for the upper Dungeness River are the estimated incremental average annual flows from EDPU (2005). The Dungeness River Management Team recommended minimum instream flows for the lower Dungeness River at seasonal flow levels recommended by the Dungeness Instream Flow

Group (Wampler and Hiss 1991; Hiss 1993): November through March: 575 cfs; April through July: 475 cfs; and August through October: 180 cfs. These minimum flows are not based on seasonal, historical Dungeness River flows, but represent flows required to maintain optimal potential fish habitat area (EDPU 2005). Nooksack and Stillaguamish flows are measured at Nooksack RM 30.9, MF Nooksack RM 5.6, and NF Stillaguamish RM 6.5. Source is USGS gauges; mean of mean daily flow, min of mean daily flow, max of mean daily flow for all months. These are the closest gauges (USGS or Ecology) reporting discharge for a period of record greater than 5 years. Gallons-per-minute to cubic-feet-per-second conversion factor: cfs = gpm/7.48/60.

[2] The Hurd Creek Hatchery Facility produces about 8,850 pounds of Chinook, coho, steelhead and pink salmon each year (including fingerlings for transfer, smolts for release), of which 1,700 pounds are steelhead (19% of annual production).

3.2. Water Quality

Hatchery programs could affect several water quality parameters in the aquatic system. Concentrating large numbers of fish within hatcheries could produce effluent with ammonia, organic nitrogen, total phosphorus, biological oxygen demand, pH, and suspended solids (Sparrow 1981; Ecology 1989; Kendra 1991; Cripps 1995; Bergheim and Åsgård 1996; Michael 2003). Chemical use within hatcheries could result in the release of antibiotics, fungicides, and disinfectants into receiving waters (Boxall et al. 2004; Pouliquen et al. 2008; Martinez Bueno et al. 2009). Other chemicals and organisms that could potentially be released by hatchery operations are polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT) and its metabolites (Missildine 2005; HSRG 2009), fish disease pathogens (HSRG 2005; HSRG 2009), steroid hormones (Kolodziej et al. 2004), anesthetics, pesticides, and herbicides.

The direct discharge of hatchery facility effluent is regulated by the Environmental Protection Agency under the Clean Water Act through NPDES permits (Table 4). 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, and the Washington Department of Ecology provides regulatory oversight. NPDES permits are not needed for hatchery 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 facilities used by the early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins are compliant with NPDES permit requirements, or do not require a NPDES permit (WDFW 2014a; WDFW 2014b; WDFW 2014c). All hatchery effluent is passed through pollution abatement ponds to settle out uneaten food and fish waste before being discharged into receiving waters.

As part of administering elements of the Clean Water Act, Washington Department of Ecology is required to assess water quality in streams, rivers, and lakes. These assessments are published in what are referred to as the 305(d) report and the 303(d) list (the numbers referring to the relevant sections of the original Clean Water Act text). The 305(d) report reviews the quality of all waters of the state, while the 303(d) list identifies specific water bodies considered impaired (based on a specific number of exceedances of state water quality criteria in a specific segment of a water body). The Environmental Protection Agency reviewed and approved Washington Department of Ecology's 2008 303(d) list on January 29, 2009. A "category 5" assignment in the 303(d) list means that Washington Department of Ecology has data showing that the water quality standards have been violated for the pollutant, and there is no "Total Maximum Daily Load" (TMDL) or pollution control plan established it. For pollutants assigned as "category 5," a TMDL process is required to establish limits on pollutant levels that can be discharged to a water body that will ensure that state water quality standards are met. The Hurd Creek Hatchery, Kendell Creek Hatchery, and McKinnon Pond discharge into 303(d) listed water bodies (Table 4).

Table 4. NPDES permit status by hatchery facility and applicable "Category 5" 303(d) listing.

Hatchery Facility	NPDES Permit Number	NPDES Permit Compliant	Discharges Effluent into a 303(d) Listed Water Body	Impaired Parameters (Category)	Cause of Impairment
Dungeness River Hatchery	WAG 13-1037	Yes	No	N/A	N/A
Hurd Creek Hatchery	N/A[1]	N/A [1]	Yes	Bacteria (5)	Agriculture and other human developmental activities
Kendall Creek Hatchery	WAG 13-3007	Yes	Yes	Temperature (5)	Low stream flows, high air temperature, possible loss of vegetation
McKinnon Pond	N/A[1]	N/A[1]	Yes	pH (1) Temperature (5)	As above
Whitehorse Pond	WAG 13-3008	Yes	No	None	N/A

Source: Washington Department of Ecology Water Quality Assessments and TMDL data for the Dungeness River watershed (Ecology 2014), accessed November 6-10, 2014 at: http://www.ecy.wa.gov/programs/wq/303d/currentassessmt.html

[1]Not applicable because an NPDES permit is not required for hatchery or net-pen facilities that release less than 20,000 pounds of fish per year or apply less than 5,000 pounds of fish feed per year. The Hurd Creek Hatchery produces a relatively small amount of fish each year and well under the 20,000 pounds per year criteria set by Washington Department of Ecology as the limit for concern regarding hatchery effluent discharge effects and for the requirement for an NPDES permit. Funds were designated in 2012 to construct a new two-bay pollution abatement pond at Hurd Creek, scheduled to begin by spring 2014.

3.3. Salmon and Steelhead

Since 1991, NMFS has identified two salmon ESUs (Puget Sound Chinook Salmon and Hood Canal Summer Chum Salmon) and one steelhead DPS (Puget Sound Steelhead) in the analysis area that require protection under the ESA (64 FR 14308, March 24, 1999; 72 FR 26722, May 11, 2007; 76 FR 50488, August 5, 2011)[1]. There are four additional non-listed salmon species in the analysis area (fall chum salmon, pink salmon, sockeye salmon, and coho salmon). Table 5 summarizes which salmon and steelhead species are found in the analysis area.

[1] The analysis area for salmon and steelhead effects is the Dungeness, Nooksack, and Stillaguamish River Basins where WDFW would operate their three proposed early winter steelhead programs. The analysis area for salmon and steelhead also includes the Puget Sound where the steelhead released by the proposed hatchery programs could interact with salmon and steelhead populations from other Puget Sound tributaries.

Table 5. A summary of salmon and steelhead populations in the analysis area.

	Listing Status under ESA	Dungeness River Basins	Nooksack River Basins	Stillaguamish River Basins	Puget Sound
Spring/Summer Chinook Salmon	Threatened	X	X	X	X
Fall Chinook Salmon	Threatened			X	X
Summer Chum Salmon	Threatened	X			X
Winter Steelhead[1]	Threatened	X	X	X	X
Summer Steelhead	Threatened		X	X	X
Fall Chum Salmon	Not listed		X	X	X
Pink Salmon	Not listed	X	X	X	X
Coho Salmon	Not listed	X	X	X	X
Sockeye Salmon	Not listed	X	X[2]	X[2]	X

[1] Although populations of steelhead in the Puget Sound ESU include both summer and winter run life history types, the ESU is composed primarily of winter run populations.
[2] It is unknown whether the sockeye salmon is the Nooksack and Stillaguamish Basins are self-sustaining riverine stocks or if they represent strays from adjacent watersheds where self-sustaining sockeye populations are present.

Critical habitat has been designated for Puget Sound Chinook salmon (70 FR 52630, September 2, 2005) and Hood Canal summer chum salmon (70 FR 52630). NMFS has proposed designation of critical habitat for Puget Sound steelhead (78 FR 2726, January 14, 2013). Critical habitat has not been designated for fall chum, pink salmon, and coho salmon because these species are not listed under the ESA. The analysis area includes critical habitat for Puget Sound Chinook salmon and Hood Canal summer chum salmon and proposed critical habitat for Puget Sound steelhead.

Steelhead hatchery programs in Puget Sound were initiated in the early 1900s to augment harvest opportunity. 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 Nooksack (Kendall Creek Hatchery beginning in 1998), Stillaguamish (Whitehorse Ponds Hatchery in 1964), and Dungeness River Basins (Dungeness River Hatchery in 1995) (WDFW 2014a; WDFW 2014b; WDFW 2014c). Advances in cultural techniques in the 1960s led to further development of the Chambers Creek hatchery-origin stock (also known as the early-winter steelhead stock) through broodstock selection and accelerated rearing (Crawford 1979).

The early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins are segregated hatchery programs that seek to minimize interactions between hatchery-origin and natural-origin fish. The programs are not designed to augment the abundance of natural spawners; they are designed to contribute to recreational fisheries while minimizing adverse impact on natural-origin populations. Since Puget Sound steelhead were listed under the ESA, several risk reduction measures have been implemented in early winter steelhead hatchery programs in Puget Sound (WDFW 2014a; WDFW 2014b; WDFW 2014c):

- Greater than 50 percent reduction in total number of early-winter steelhead released in the Puget Sound tributaries
- Greater than 65 percent reduction in the number of early-winter steelhead release locations
- Elimination of cross-basin transfers, off-station releases, and adult recycling
- Volitional smolt releases to ensure the fish are ready to migrate out of the freshwater system, thus minimizing the amount of time for ecological interactions between hatchery-origin and natural-origin fish
- Hatchery broodstock collection by January 31 to enhance separation between hatchery-origin steelhead and the later-returning, native natural-origin steelhead populations
- Genetic monitoring of steelhead
- Hatchery traps now remain open through March 15 (or later as conditions allow) to provide the opportunity for all adult hatchery-origin fish to return to the hatcheries to reduced straying
- Eggs are only collected from fish that return to the hatchery to promote fidelity of homing to the hatcheries

Hatchery programs have the potential to adversely affect natural-origin salmon and steelhead and their habitat through genetic risks, competition and predation, hatchery facility effects, incidental fishing effects, and disease transfer. The general mechanisms through which segregated hatchery programs can affect natural-origin salmon and steelhead populations are described in Table 6. The Final Environmental Impact Statement to Inform Columbia River Basin Hatchery Operations and the Funding of Mitchell Act Hatchery Programs (NMFS 2014a) and the Draft Environmental Impact Statement on Two Joint State and Tribal Resource Management Plans for Puget Sound Salmon and Steelhead Hatchery Programs (NMFS 2014b) describe in more detail these general mechanisms and are hereby incorporated by reference. The baseline effects of the past and current operation of the early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins are discussed in more detail in Subsection 3.3.1, Genetic Risk, through Subsection 3.3.5, Disease Transfer.

Table 6. General mechanisms through which segregated hatchery programs can affect natural-origin salmon and steelhead populations.

Effect Category	Description of Effect
Genetic Risks	• Interbreeding with hatchery-origin fish can change the genetic character of the local salmon or steelhead populations. • Interbreeding with hatchery-origin fish may reduce the reproductive performance of the local salmon or steelhead populations.
Competition and Predation	• Hatchery-origin fish can increase competition for food and space. • Hatchery-origin fish can increase predation on natural-origin salmon and steelhead.
Hatchery Facility Effects	• Hatchery facilities can reduce water quantity or quality in adjacent streams through water withdrawal and discharge. • Weirs for broodstock collection or to control the number of hatchery-origin fish on the spawning grounds can have the following unintentional consequences: o Isolation of formerly connected populations o Limiting or slowing movement of migrating fish species, which may enable poaching or increase predation o Alteration of stream flow o Alteration of streambed and riparian habitat o Alteration of the distribution of spawning within a population o Increased mortality or stress due to capture and handling o Impingement of downstream migrating fish o Forced downstream spawning by fish that do not pass through the weir o Increased straying due to either trapping adults that were not intending to spawn above the weir, or displacing adults into other tributaries
Incidental Fishing Effects	• Fisheries targeting hatchery-origin fish have incidental impacts on natural-origin fish.
Disease Transfer	• Concentrating salmon and steelhead for rearing in a hatchery facility can lead to an increased risk of carrying fish disease pathogens. When hatchery-origin fish are released from the hatchery facilities, they may increase the disease risk to natural-origin salmon and steelhead.

Although this subsection is focused on the effects of the early-winter steelhead hatchery programs on listed and non-listed salmon and steelhead in Puget Sound, it is important to recognize that these hatchery programs are but one of a variety of natural and human-caused changes that have and will continue to affect these species. Some of these changes are briefly described below. These changes are described in more detail in NMFS's Draft Environmental Impact Statement on Two Joint State and Tribal Resource Management Plans for Puget Sound Salmon and Steelhead Hatchery Programs (NMFS 2014b).

Habitat: Freshwater habitat has been modified from development and land use practices related to agriculture, forestry, industry, and residential use. These modifications have altered steam hydrology and natural stream channels, reduced riparian cover and large woody debris in streams, and increased sedimentation and flooding.

Dams and Diversions: Construction of dams, water diversion structures, and hydroelectric operations can block salmon and steelhead migration routes, entrain migrating juveniles, change stream flow patterns, and alter natural water temperature regimes.

Predation: Direct predation by aquatic, terrestrial, and avian species result in salmon and steelhead mortality.

Oceanic Conditions: Broad-scale, cyclic changes in climatic and ocean conditions drive salmon productivity (e.g., El Niño events), and are important to how and where populations of salmon are sustained over the short and long term.

Climate Change: Changes in the climate can alter the abundance, productivity, and distribution of salmon and steelhead through changes in water temperatures and seasonal stream flow regimes, which then affect the type and extent of aquatic habitat that is suitable for viable salmon and steelhead.

The co-managers currently release a total about 147 million juvenile salmon and steelhead through into Puget Sound freshwater and marine areas each year. This total includes 46.1 million Chinook salmon; 14.6 million coho salmon; 44.5 million fall chum salmon; 4.5 million pink salmon; 35.1 million sockeye salmon; and 1.8 million steelhead (NMFS 2014b). In Puget Sound, run size and escapement monitoring indicate that for recent years, hatchery-origin fish make up 76% of total adult returns of Chinook salmon, 47% of coho salmon, 29% of fall chum salmon, 30% of sockeye salmon, 2% of pink salmon, and an unknown proportion of total steelhead returns (NMFS 2014b). In addition to the three early-winter steelhead programs that are the subject of this EA, WDFW and three Puget Sound treaty tribes operate 17 additional hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins.

Nooksack River Basin Hatchery Programs: There are nine additional hatchery programs operating in the Nooksack River basin, of which two are operated cooperatively by WDFW and the Lummi Nation for stock conservation purposes, with the remainder implemented by WDFW (four programs) and the Lummi Nation (three programs) to provide fish for harvest. All of the Nooksack River basin hatchery programs operate to partially offset natural-origin salmon and steelhead population reductions resulting from past and on-going land-use practices, including forestry and agriculture (SSPS 2005).

Stillaguamish River Basin Hatchery Programs: In the Stillaguamish River basin, WDFW operates two additional salmon and steelhead hatchery programs (one jointly with the Stillaguamish Tribe for conservation purposes and one for harvest augmentation), and the Stillaguamish Tribe operates an additional three programs (one for stock conservation and two for harvest augmentation. These hatchery programs operate in the Stillaguamish River basin to offset existing severe constraints on natural-origin fish production due to poor freshwater habitat conditions (Stillaguamish 2007).

Dungeness River Basin: WDFW, with some funding assistance from the Jamestown S'Klallam Tribe, operates three salmon hatchery programs in the Dungeness River basin. Two programs operate for conservation-directed supplementation purposes, and one program produces coho salmon largely to provide fish for harvest. The Dungeness River hatchery programs are operated to conserve at-risk native salmon populations (Chinook and pink salmon) and partially mitigate for lost natural-origin fish production largely resulting from past and on-going loss and degradation of natural fish habitat, and impending climate change (WDFW 2013).

3.3.1. Genetic Risks

As described in Subsection 3.3 (Salmon and Steelhead), the Dungeness, Nooksack, and Stillaguamish early-winter steelhead programs operate as segregated hatchery programs and produce fish that are derived from Chambers Creek steelhead, a non-local stock whose time of return and spawning has been advanced through fish culture practices (i.e., hatchery-induced selection, sometimes called domestication). Although the hatchery-origin steelhead from these segregated hatchery programs spawn earlier than the natural-origin steelhead in the Dungeness, Nooksack, and Stillaguamish River Basins, and, thus, not at the optimal time for successful reproduction, they may have some success spawning in the wild. In addition, there may be overlap in timing between the latest spawning early-winter hatchery-origin steelhead and the earliest spawning winter-run steelhead (Figure 1). This potential overlap creates the potential for interbreeding between early-winter hatchery-origin steelhead from the proposed hatchery programs and natural-origin steelhead found in the Dungeness, Nooksack, and Stillaguamish River Basins. The traits that are intentionally and inadvertently selected for in the hatchery environment (e.g., early run timing) make early-winter hatchery-origin steelhead ill-suited for survival and productivity in the natural environment. Therefore, any successful reproduction of early winter steelhead, especially interbreeding between early-winter hatchery-origin steelhead and natural-origin steelhead, may have affected the genetic integrity and productivity of natural-origin steelhead populations in the Dungeness, Nooksack, and Stillaguamish River Basins.

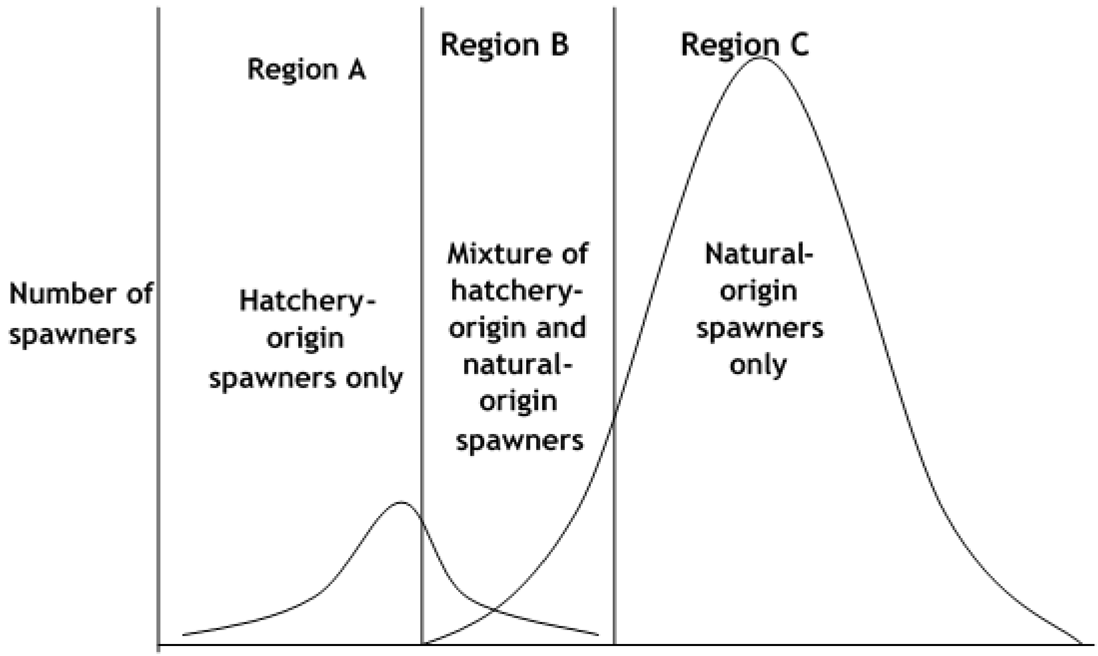

Figure 1. Schematic of temporal spawning overlap between early winter hatchery steelhead and natural-origin winter steelhead. Shape, sizes and placement of curves is conceptual and is not meant to represent any specific situation (Scott and Gill 2008, Fig. 4-7).

In 2004, the Hatchery Scientific Review Group (HSRG) released its recommendations for hatchery reform (HSRG 2014). While not addressing the early-winter steelhead hatchery programs specifically in their guidelines, the HSRG discussed risks posed by highly diverged hatchery stocks and concluded that ". . . if non-harvested fish spawn naturally, then these segregated programs can impose significant genetic risks to naturally spawning populations. Indeed, any natural spawning by fish from these broodstocks may be considered unacceptable because of the potential genetic impacts on natural populations . . . to minimize these risks, segregated hatchery programs need to be located in areas where virtually all returning adults can be harvested or recaptured, or where natural spawning or ecological interactions with natural-origin fish are considered minimal or inconsequential" (HSRG 2004). In 2009, the HSRG recommended that primary populations (those of high conservation concern) affected by segregated hatchery programs have a proportion of hatchery-origin spawners (pHOS) of no more than 5 percent (HSRG 2009)[2]. The HSRG recommended that integrated hatchery programs affecting primary populations have a Proportionate Natural Influence (PNI) of 0.67 (HSRG 2009). More recently, the HSRG suggested that perhaps pHOS levels should be lower than 5 percent for segregated programs and suggested that 2 percent would be more appropriate for

[2] pHOS is the proportion of natural spawners that consist of hatchery-origin fish, and is a surrogate measure for gene flow. WDFW has developed two additional methods for directly measuring for gene flow: (1) the Warheit method, which uses genetic data to estimate proportionate effective hatchery contribution (PEHC) (Warheit 2014a) and (2) a demographic method, referred to as the Scott-Gill method (Scott and Gill 2008).

some programs based on their modeling (HSRG 2014). As a result, and for the purposes of this analysis, NMFS will assume that segregated programs with a pHOS of less than 2 percent and integrated programs with a PNI of greater than 0.67 pose a low genetic risk to natural-origin populations. WDFW's current statewide steelhead management plan is consistent with the HSRG's recommendations for segregated hatchery programs and states that segregated programs will result in average gene flow levels of less than 2 percent (WDFW 2008) (note that pHOS is a surrogate metric for gene flow). This conclusion was based on analysis of early winter programs that used the Ford (2002) model, the same model used to establish the HSRG guidelines.

Assessments of steelhead spawning (and pHOS) are difficult because high spring flows and associated turbidity hamper detection of redds. Available genetic information has documented introgression from hatchery-origin to natural-origin steelhead populations in Puget Sound in the past (e.g., Phelps et al. 1997; Winans et al. 2008; Pflug et al. 2013). However, currently it appears, based on genetic data, that gene flow into the Nooksack and Stillaguamish Basins is under 2%. Using another method, based on demographic information, gene flow into these two basins and the Dungeness Basin is also estimated to be under 2% (Table 7; Appendix A). Therefore, NMFS assumes for the purposes of this analysis that the early-winter steelhead programs in the Dungeness, Nooksack, and Stillaguamish River Basins pose a low genetic risk to natural-origin populations.

Table 7. Summary of analyses of gene flow from early-winter hatchery steelhead into listed Nooksack, Stillaguamish, and Dungeness River steelhead populations

Basin	Listed Population	Warheit Method (PEHC)	Scott Gill Method (Gene_Flow) (%)
Nooksack	Nooksack (W)	0.00 (0.00-0.02)	0.57
	SF Nooksack (S)	0.00 (0.00-0.02)	-
Stillaguamish	Stillaguamish (W)	0.00 (0.00-0.07)	1.05
	Deer Cr. (S)	0.00 (0.00-0.01)	-
	Canyon Cr. (S)	0.00 (0.00-0.02)	-
Dungeness	Dungeness (S/W)	-	0.50

Source: Appendix A; Warheit 2014a; Warheit 2014b; Scott and Gill 2008; Hoffman 2015a; Hoffman 2015b

Hatchery-origin steelhead do not interbreed with salmon species and, therefore, do not pose a genetic risk to natural-origin salmon populations. Therefore, genetic risks to salmon species will not be further discussed in this EA.

3.3.2. Competition and Predation

The Dungeness, Nooksack, and Stillaguamish River Basin early-winter steelhead hatchery programs release steelhead at the yearling stage, and they have the potential to compete with or predate on other salmon and steelhead (Table 8).

Table 8. Ecological relationship between hatchery-origin steelhead and natural-origin salmon and steelhead in the analysis area.

	Ecological Relationship with Hatchery-origin Steelhead			**Location of Ecological Interaction**		
Species	**Predator of Hatchery-Origin Steelhead**	**Competitor with Hatchery-Origin Steelhead**	**Prey of Hatchery-Origin Steelhead**	**Freshwater**	**Estuary**	**Marine**
Spring Chinook Salmon		X		X	X	
Fall Chinook Salmon			X	X	X	Unknown
Summer Chum Salmon[1]						
Winter Steelhead		X		X	X	
Summer Steelhead		X		X	X	
Fall Chum Salmon			X	X	X	Unknown
Pink Salmon			X	X	X	Unknown
Coho Salmon		X		X	X	
Sockeye Salmon			X	X	X	Unknown

[1] Dungeness hatchery steelhead are released after any summer chum have emigrated seaward. Summer chum are not present in the Nooksack and Stillaguamish River Basins.

Hatchery-origin steelhead smolts likely compete with natural-origin steelhead, Chinook salmon, and coho salmon smolts in the freshwater and estuary areas because they are a similar size and would likely eat similar prey (Table 7). Competition between hatchery-origin steelhead smolts and natural-origin salmon and steelhead smolts is not expected to occur in the marine areas because, once steelhead smolts enter the marine environment, the fish tend to move directly offshore into areas where steelhead are dispersed and not present in numbers that would contribute to density-dependent effects (Hartt and Dell 1986; Light et al. 1989)

Hatchery-origin steelhead smolts may prey upon juvenile natural-origin salmonids at several stages of their life history. Newly released hatchery smolts have the potential to consume naturally produced fry and fingerlings that are encountered in freshwater during downstream migration. Some reports suggest that hatchery fish can prey on fish that are up to 1/2 their length (Pearsons and Fritts 1999; HSRG 2004), but other studies have concluded that salmonid predators prey on fish 1/3 or less their length (Horner 1978; Hillman and Mullan 1989; Beauchamp 1990; Cannamela 1992; CBFWA (CBFWA 1996). Hatchery steelhead that do not emigrate and instead take upstream residence near the point of release (residuals) have the potential to prey on rearing natural-origin juvenile fish over a more prolonged period.

Therefore, the risk of hatchery-origin steelhead predation on natural-origin juvenile fish in freshwater and the estuary is dependent upon three factors: (1) the hatchery fish and their potential natural-origin prey must overlap temporally; (2) the hatchery fish and their prey must overlap spatially; and (3) the prey should be less than 1/3 the length of the predatory fish. Based on comparative fish sizes and timings, early winter steelhead smolts that would be released through the hatchery programs would have spatial and temporal overlap in freshwater and the estuary with smaller subyearling Chinook salmon, fall chum salmon fry, pink salmon fry, and potentially sockeye salmon fry. When combined with occurrence overlap, the large average size of the early-winter steelhead smolts poses a risk for predator-prey interactions in freshwater and the estuary for these species and life stages. It is unknown whether these predation risks continue after the species have emigrated and dispersed in marine areas. The few diet studies that have been conducted in Puget Sound indicate that the predation risk posed by larger hatchery-origin fish to juvenile salmon is low (Buckley 1999; WDFW 2013a). Predation may be low for the following reasons: (1) due to rapid growth, natural-origin salmon are better able to elude predators and are accessible to a smaller proportion of predators due to size alone; (2) because juvenile salmon disperse soon after entering seawater, they are present in low densities relative to other fish species (e.g., herring); and (3) there has either been learning or selection for some predator avoidance (Cardwell and Fresh 1979).

3.3.3. Hatchery Facility Risks

Operating hatchery facilities can impact instream fish habitat in the following ways: (1) reduction in available fish habitat from water withdrawals, (2) operation of instream structures (e.g., water intake structures, fish ladders, and weirs), or (3) maintenance of instream structures (e.g., protecting banks from erosion or clearing debris from water intake structures).

Water withdrawals may affect instream fish habitat if they reduce the amount of water in a river between the hatchery's water intake and discharge structures. A full discussion of the effects of water withdrawal can be found in Subsection 3.1, Water Quantity.

The early winter steelhead programs in the Dungeness, Nooksack, and Stillaguamish River Basins use hatchery facilities that have several instream structures such as water intakes, fish ladders, and weirs. All hatchery intakes on salmon and steelhead streams are screened to prevent fish injury from impingement or permanent removal from streams. NMFS's screening criteria for water withdrawal devices set forth conservative standards that help minimize the biological risk of harming naturally produced salmonids and other aquatic fauna (NMFS 2011). NMFS periodically updates its screening criteria based on best available science and technology. Consequently, some hatcheries have water intake screens that do not meet NMFS's most current screening criteria, although they meet the screening criteria that were in place when the water intake was installed. Hatchery facilities upgrade their water intake screens as funding becomes available.

McKinnon Pond is screened consistent with NMFS's 2011 screening criteria (Table 9). Hurd Creek Hatchery, Kendall Creek Hatchery, and Whitehorse Ponds Hatchery are screened consistent with older NMFS screening criteria. Screening for the Dungeness River Hatchery's water intake structures (one on the Dungeness River and one on Canyon Creek) are in compliance with NMFS's 2011 screening criteria, but are not in compliance with NMFS's fish passage criteria. The Canyon Creek water intake to the Dungeness River Hatchery is adjacent to a small dam that until recently completely blocked access to upstream salmon spawning habitat. WDFW is in the process of correcting fish passage problems at the location of the Dungeness River structure, with plans to complete work in 2017. The current three structures used to withdraw water from the Dungeness River will be reduced to one structure, which will be passable to upstream and downstream migrating fish (WDFW 2013a). The water intakes at Dungeness River hatchery and Hurd Creek hatchery will be screened and made passable to fish consistent with NMFS's 2011 criteria by the summer of 2017. The Kendall Creek Hatchery screens have been identified for replacement but are a lower priority than at other hatcheries, as listed fish do not utilize habitat upstream of the rack on Kendall Creek (WDFW 2014b). The Whitehorse Ponds Hatchery screen has not been identified for replacement. However, listed fish do not utilize habitat upstream of the water intake structure (WDFW 2014c).

The early winter steelhead programs in the Dungeness, Nooksack, and Stillaguamish River use several weirs to collect broodstock and/or manage adult returns. All weirs are compliant with NMFS's 2011 criteria for fish passage (Table 9). A weir is a barrier to fish movement. The biological risks associated with weirs include the following:

- Isolation of formerly connected populations
- Limiting or slowing movement of non-target fish species
- Alteration of stream flow
- Alteration of streambed and riparian habitat
- Alteration of the distribution of spawning within a population
- Increased mortality or stress due to capture and handling
- Impingement of downstream migrating fish
- Forced downstream spawning by fish that do not pass through the weir
- Increased straying due to either trapping adults that were not intending to spawn above the weir, or displacing adults into other tributaries

By blocking migration and concentrating salmon into a confined area, weirs may also increase predation efficiency of mammalian predators (RIST 2009). The following sections summarize the use of weirs at hatchery facilities that rear early-winter steelhead in the Dungeness, Nooksack, and Stillaguamish River Basins.

Dungeness River Hatchery: The weir and trap used to collect early winter steelhead as broodstock for the Dungeness River Hatchery program does not present any biological risks to natural fish populations. Steelhead broodstock are collected as volunteers to Dungeness River Hatchery. The facility is located away from listed natural-origin salmon and steelhead migration and rearing areas.

Hurd Creek Hatchery: No weir operates in conjunction with the early-winter steelhead programs.

Kendall Creek Hatchery: The weirs and trap for adult steelhead broodstock collection at Kendall Creek Hatchery does not affect migration or spatial distribution of natural-origin juvenile and adult Chinook salmon, steelhead, fall chum salmon, and pink salmon because the weirs are removed from migration and rearing areas for these fish species. Natural-origin coho salmon and sea-run cutthroat trout are encountered at the Kendall Creek weirs. Measures are applied to ensure that any coho and cutthroat trout reaching the first weir and entering the adult collection pond are passed upstream above the second weir without delay to allow the fish to spawn naturally. Due to large picket spacing that allows unimpeded passage for juvenile fish, the Kendall Creek Hatchery weirs pose no risks to downstream migrating juvenile coho salmon or cutthroat.

McKinnon Pond: No weir operates in conjunction with the early-winter steelhead programs.

Whitehorse Ponds Hatchery: The weir for adult steelhead broodstock collection at Whitehorse Ponds Hatchery does not affect any natural-origin juvenile and adult salmon and steelhead because it is located in a small, off-channel creek, which is located away from natural-origin salmon and steelhead migration and rearing areas.

Instream maintenance may include clearing of debris and bedload from hatchery intake screens and fish ladders or protecting banks from erosion. Instream maintenance such as clearing of debris and bedload from hatchery intake screens and fish ladders or protecting banks from erosion may increase stream sedimentation, but maintenance activities are usually small in scale and duration, and return conditions to what they were when structures were first constructed.

Table 9. Compliance of instream structures with NMFS's screening and fish passage criteria

	Dungeness River Hatchery	**Hurd Creek Hatchery**	**Kendall Creek Hatchery**	**McKinnon Pond**	**Whitehorse Ponds Hatchery**
Do water intake screens meet NMFS' current screening criteria? (NMFS 2011)	Yes	No	No	Yes	No
Do water intake screens meet older NMFS' screening criteria?	No[1]	Yes	Yes	Yes	Yes
Does the hatchery facility operate any weirs?	Yes	No	Yes	No	Yes
Are weirs complaint with NMFS' current fish passage criteria? (NMFS 2011)	Yes	N/A	Yes	N/A	Yes
Are all water intake structures compliant with NMFS' fish passage criteria? (NMFS 2011)	No	No	No	Yes	No

Source: WDFW 2013a; WDFW 2014a; WDFW 2014b; WDFW 2014c

3.3.4. Incidental Fishing Effects

Implementation of mark-selective fishing rules for steelhead began in Puget Sound in the 1990s. Under selective fishing rules, anglers have only been able to retain steelhead with a clipped adipose fin. One hundred percent of the early-winter hatchery-origin fish are "adipose clipped." The fisheries targeting early-winter hatchery-origin steelhead generally start in November and end by late February. Cool water temperatures during those months minimize incidental mortality on listed natural-origin steelhead that are caught and released[3]. In addition, because the

[3] Direct studies on hook and releases mortality of steelhead have not been done in the Dungeness, Nooksack, and Stillaguamish River Basins. Nelson et al. (2005) showed catch and release mortalities of 1.4% to 5.8% in 1999 and 2000 respectively on steelhead caught in recreational fisheries on the Chilliwack River in British Columbia. This study also showed no indication of increased mortality on fish that had been caught and released multiple times. A hook-and-line mortality study conducted in the Samish River on winter-run steelhead also showed similar results, although it indicated that there may be a negative relationship between a fish being caught in a sport fishery and their survival to out-migration as kelts (Ashbrook et al. in press). Taylor and Barnhart (1999) determined that summer steelhead caught and released in the Mad and Trinity Rivers of California had a 9.5% mortality rate, with 83% of the mortalities occurring at water temperatures of 21°C or greater. Based on best available information, hooking mortality associated with recreational harvest is generally believed to be less than 10% of fish hooked and released.

steelhead fisheries targeting early-winter hatchery-origin steelhead close before most of the natural-origin steelhead arrive, the number of natural-origin steelhead that are caught and released would be low. Because of their earlier freshwater migration timing, natural-origin summer steelhead in the Nooksack and Stillaguamish Rivers may be subject to catch and release effects to a greater extent than winter run steelhead[4]. Effects would remain low, however, because of the tendency for summer steelhead to migrate into and hold in upstream areas and tributaries of the watershed where they would be less susceptible to harvest in fisheries targeting early-winter steelhead.

Prior to the 1990s, hatchery-origin steelhead were not mass-marked with an adipose fin clip. Therefore, anglers could not easily differentiate between natural-origin and hatchery-origin steelhead. Fish managers tried to minimize harvest impacts on natural-origin steelhead by closing the fisheries that targeted earlier arriving hatchery-origin steelhead before the natural-origin winter-run populations arrived. However, fishermen may have inadvertently harvested the earliest-returning natural-origin steelhead, which may have changed the overall run timing of the population [i.e., evidence suggests that, historically, the natural-origin winter population had a larger proportion of adult fish returning prior to February (Myers et al. 2014)].

3.3.5. Risk of Disease Transfer

Interactions between hatchery-origin fish and natural-origin fish in the environment may result in the transmission of pathogens if either the hatchery-origin or the natural-origin fish are harboring fish disease (Table 10). This impact may occur in tributary areas where hatchery-origin fish are released and throughout the migration corridor where hatchery-origin and natural-origin fish may interact. As the pathogens responsible for fish diseases are present in both hatchery-origin and natural-origin populations, there is some uncertainty associated with determining the source of the pathogen (Williams and Amend 1976; Hastein and Lindstad 1991). Hatchery-origin fish may have an increased risk of carrying fish disease pathogens because of relatively high rearing densities that increase stress and can lead to greater manifestation and spread of disease within the hatchery-origin population. Consequently, it is possible that the release of hatchery-origin salmon and steelhead may lead to an increase of disease in natural-origin salmon and steelhead populations.

WDFW's hatchery facilities are operated in compliance with all applicable fish health guidelines (Pacific Northwest Fish Health Protection Committee 1989; IHOT 1995; WDFW and WWTIT 1998, updated 2006). These fish health guidelines ensure that fish health is monitored, sanitation practices are applied, and hatchery-origin fish are reared and released in healthy conditions. Pathologists from WDFW's Fish Health Section monitor hatchery programs monthly (WDFW

[4] Adults from extant populations of winter steelhead return from December to May, and peak spawning occurs in March through May. Summer steelhead adults return from May through October and peak spawning occurs the following January to May (Hard et al. 2007).

2014a; WDFW 2014b; WDFW 2014c). Exams performed at each life stage may include tests for virus, bacteria, parasites, or pathological changes.

Table 10. Common fish pathogen found in hatchery facilities.

Pathogen	Disease	Species Affected
Renibacterium salmoninarum	Bacterial Kidney Disease (BKD)	Chinook salmon, chum salmon, coho salmon, steelhead, and sockeye salmon
Ceratomyxa shasta	Ceratomyxosis	Chinook salmon, steelhead, coho salmon, and chum salmon
Flavobacterium psychrophilum	Coldwater Disease	Chinook salmon, chum salmon, coho salmon, steelhead, and sockeye salmon
Flavobacterium columnare	Columnaris	Chinook salmon, chum salmon, coho salmon, steelhead, and sockeye salmon
Yersinia ruckeri	Enteric Redmouth	Chinook salmon, chum salmon, steelhead, and sockeye salmon
Aermonas salmonicida	Furunculosis	Chinook salmon, chum salmon, coho salmon, steelhead, and sockeye salmon
Infectious hematopoetic necrosis	IHN	Chinook salmon, steelhead, chum salmon, and sockeye salmon
Saprolegnia parasitica	Saprolegniasis	Chinook salmon, coho salmon, steelhead, chum salmon, and sockeye salmon

Sources: IHN database http://gis.nacse.org/ihnv/ ; http://www.nwr.noaa.gov/Salmon-HarvestHatcheries/Hatcheries/Hatchery-Genetic-Mngmnt-Plans.cfm.

3.3.6. Risk of "Mining" Natural-Origin Steelhead

Incorporating natural-origin fish into a hatchery broodstock can reduce the abundance and spatial structure of the natural-origin population, which is commonly referred to as "mining." Under baseline conditions, the early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins do not "mine" the natural-origin populations because they do not incorporate natural-origin fish into their broodstock (Table 11).

Table 11. Broodstock needs and abundance information for the early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins.

	Broodstock Needs	Proportion of Natural-origin Steelhead in Broodstock	Proportion of Hatchery-origin Steelhead in Broodstock	Average Abundance of Natural-origin Winter Steelhead Population	TRT Interim Viable Abundance Target
Dungeness River Basin	Up to 30 with a 1:1 sex ratio	0	100	487[a]	1,232
Nooksack River Basin	Up to 100 with a 1:1 sex ratio	0	100	1,760[b]	11,023
Stillaguamish River Basin	Up to 120 adults with a 1:1 sex ratio	0	100	1,852[c]	9,559

Source: WDFW 2014a; WDFW 2014b; WDFW 2014c; Hard et al 2014

[a]Abundance based on average abundance in 2011 and 2013. Surveys in 2010, and particularly in 2012, were cut short due to high water levels associated with spring rain and snow runoff; however escapement estimates can be obtained through the use of timing curves from other comparable river systems. The Jamestown S'Klallam Tribe has completed estimates of spawners for the entire season for 2011 and 2013. An estimated 410 fish spawned in 2011, and an estimated 564 fish spawned in 2013 after March 10. Prior to 2010, the last escapement estimate for Dungeness winter steelhead was in the 2000/2001 season with an estimated escapement of 183 based on index areas.

[b] Average escapement 2004 through 2012

[c] Average abundance 2001 through 2012

3.4. Other Fish Species

Many fish species in the Dungeness, Nooksack, and Stillaguamish River Basins and other adjacent nearshore marine areas have a relationship with steelhead as prey, predators, or competitors (Table 12). All fish species in the analysis area may be prey for or predators of steelhead at some life stage. Additionally, all fish species in the analysis area compete with steelhead for food and space.

The analysis area is not considered as one of the geographical areas occupied by the ESA-listed southern DPS of Pacific eulachon (76 FR 65324, October 20, 2011). Therefore, the species will not be discussed further in this document.

Pacific lamprey and Western brook lamprey are Federal "species of concern" and are Washington State "monitored species" (Table 12). In marine areas, several species of rockfish are listed as threatened under the ESA. Pacific herring (a forage fish for salmon and steelhead) is a Federal species of concern and a State candidate species. All of these species have a range that includes the Dungeness, Nooksack, and Stillaguamish River Basins or nearby marine areas.

However, none of these species is located exclusively in these areas, and in most cases these areas are a very small percentage of their total range.

Table 12. Range and status of other fish species that may be affected by early-winter steelhead hatchery programs.

Species	Federal/State Listing Status	Type of Interaction with salmon and steelhead
Pacific, river, and brook lamprey	Not listed. Pacific lamprey and river lamprey are federal species of concern, river lamprey is a Washington State candidate species,	• Potential prey item for adult salmon and steelhead • May compete with salmon and steelhead for food and space • May be a parasite on salmon and steelhead while in marine waters • May benefit from additional marine-derived nutrients provided by hatchery-origin fish
Bull Trout	Federally listed as threatened	• Freshwater predator on salmon and steelhead eggs and juveniles • May compete with salmon and steelhead for food • May benefit from additional marine-derived nutrients
White sturgeon	Not federally listed	• May compete with salmon and steelhead for food • May benefit from additional marine-derived nutrients provided by hatchery-origin fish
Margined sculpin	WDFW species of concern	• Predator on salmon and steelhead eggs and fry • Potential prey item for adult salmon and steelhead • May compete with salmon and steelhead for food and space • May benefit from additional marine-derived nutrients provided by hatchery-origin fish
Umatilla and leopard dace	Not federally listed, Washington State candidate species	• May compete with salmon and steelhead for food • May benefit from additional marine-derived nutrients provided by hatchery-origin fish
Mountain sucker	Not federally listed, Washington State species of concern	• Occurs in similar freshwater habitats, but is a bottom feeder and has a different ecological niche • May benefit from additional marine-derived nutrients provided by hatchery-origin fish
Northern pikeminnow	Not listed	• Freshwater predator on salmon and steelhead eggs and juveniles • May compete with salmon and steelhead for food • May benefit from additional marine-derived nutrients

Species	Federal/State Listing Status	Type of Interaction with salmon and steelhead
Inland redband trout	Not listed	• Predator of salmon and steelhead eggs and fry • Potential prey item for adult salmon and steelhead • May compete with salmon and steelhead for food and space • May interbreed with steelhead • May benefit from additional marine-derived nutrients provided by hatchery-origin fish
Rockfish	Several species are federally listed as threatened and/or have State Candidate listing status [1]	• Predators of juvenile salmon and steelhead • Juveniles are prey for juvenile and adult salmon • May compete with salmon and steelhead for food
Forage fish	Pacific herring is a federal species of concern and a Washington State candidate species	• Prey for juvenile and adult salmon and steelhead • May compete with salmon and steelhead for food

Sources: Finger 1982; Horner 1978; Krohn 1968; Maret et al 1997; Polacek et al 2006; WDFW 2013b; Beamish 1980

1 Georgia Basin bocaccio DPS (*Sebastes paucispinis*)- Federally listed as endangered and state candidate species; Georgia Basin yelloweye rockfish DPS (*S. ruberrimus*)- Federally listed as threatened and state candidate species; Georgia Basin canary rockfish DPS (*S. pinniger*) -Federally listed as threatened and state candidate species; Black, brown, China, copper, green-striped, quillback, red-stripe, tiger, and widow rockfish are state candidate species.

3.5. Wildlife and Marine Mammals

Hatchery operations have the potential to affect wildlife by changing the total abundance of salmonids in aquatic and marine environments. Changes in the abundance of salmon and steelhead can affect wildlife through predator/prey interactions. Many wildlife species consume salmon and steelhead, which may benefit their survival and productivity through the nourishment provided. Increases or decreases in the abundance of juvenile and adult steelhead in the basins associated with the early winter steelhead hatchery operations may, therefore, affect the viability of wildlife species that prey on fish. In addition, in general, hatcheries could affect wildlife through transfer of toxic contaminants from hatchery-origin fish to wildlife, the operation of weirs (which could block or entrap wildlife, or conversely, make salmon and steelhead easier to catch through their corralling effect), or predator control programs (which may harass or kill wildlife preying on juvenile salmon at hatchery facilities).

The analysis area supports a variety of birds, large and small mammals, amphibians, and invertebrates that may eat or be eaten by steelhead (Table 13). Steelhead eat invertebrates and amphibians, which may include insects and frogs. Steelhead predators include several species of birds, cougars, black bear, river otter, mink, weasels, and some amphibians. Some bird species, including bald eagle and cormorants, scavenge on steelhead carcasses, as do minks, weasels, and several invertebrate species. Other wildlife species compete with steelhead for food or habitat (e.g., gulls). Fish are not the only component of the diets of these species, though salmonids may represent a somewhat larger proportion of the diet during the relatively short period of the year that adult fish, including steelhead return to the analysis area.

Within the analysis area, there are several wildlife species listed under the ESA (Table 13). The marbled murrelet and gray wolf are listed as endangered, and the northern spotted owl and grizzly bear are listed as threatened (USFWS 2012). The Taylor's checkerspot butterfly is proposed for ESA-listing. The Pacific fisher is a Federal candidate wildlife species present within the analysis area. The bald eagle, Brown pelican, Cascades frog, Cassin's auklet, long-eared myotis, long-legged myotis, Makah's copper, (Olympic) Mazama pocket gopher, northern goshawk , northern sea otter, olive-sided flycatcher, Olympic torrent salamander, Oregon vesper sparrow, Pacific Townsend's big-eared bat, peregrine falcon, tailed frog, tufted puffin, valley silverspot, Van Dyke's salamander and western toad are present in the analysis area and are designated by the U.S. Fish and Wildlife Service as "species of concern" (USFWS 2012).

Table 13. Status and habitat associations of wildlife in the analysis area with direct or indirect relationships with hatchery-origin salmon and steelhead.

		Habitat 1			Ecological Relationship with Steelhead			
Species	**Status**	**Fresh-water**	**Estuary**	**Marine**	**Predator**	**Compe-titor**	**Prey**	**Scaven-ger**
Bald eagle	State sensitive	X	X	X	X			X
Golden eagle	State candidate							
Osprey	State monitored							
Northern spotted owl	Federal threatened State endangered	X			X			
Marbled Murrelet	Federal threatened State threatened		X	X	X			
Northern goshawk	Federal species of concern State candidate		X		X			

		Habitat[1]			Ecological Relationship with Steelhead			
Peregrine falcon	Federal species of concern State sensitive	X	X					
Gulls and cormorants	None	X	X	X	X	X		X
Great blue heron	State monitored	X	X		X	X		
Duck (species)	None[6]	X	X	X	X			
Beaver	None	X				X		
Cougar	None	X			X			
Black bear	None	X	X		X			
Grizzly bear	Federal threatened State endangered	X	X		X			
Gray wolf	Federal endangered State endangered	X	X		X			
River otter	None	X	X		X			X
Pacific Fisher	Federal candidate State endangered	X			X			
Other mink and weasels	None	X	X		X			X
Bats	Varies by species[2]	X				X		
Amphibians (e.g., salamanders and frogs)	Varies by species[3]	X			X	X	X	
Aquatic/terrestrial/riparian zone invertebrates (e.g., insects and snails)	Varies by species[4]	X	X				X	X
Southern Resident Killer Whale	Federal Endangered State endangered			X	X			
Harbor seal	Protected under MMPA[5]		X	X	X	X		
Steller sea lion	Protected under MMPA		X	X	X	X		
California sea lion	Protected under MMPA		X	X	X	X		

		Habitat 1			Ecological Relationship with Steelhead			
Northern sea otter	Protected under MMPA Federal species of concern State endangered		X	X	X	X		
Harbor porpoise (Inland Washington & Oregon-Washington Coastal stocks	Protected under MMPA State candidate			X	X	X		
Dall's porpoise (California/Oregon/ Washington stock)	Protected under MMPA			X	X	X		
Pacific white-sided dolphin (California/Oregon/ Washington stock)	Protected under MMPA			X	X	X		
Marine invertebrates (e.g., zooplankton; crab)	None		X	X			X	X

Sources: Listed and Proposed Endangered and Threatened Species And Critical Habitat; Candidate Species; And Species Of Concern In Clallam, Whatcom, and Snohomish Counties. As Prepared By The U.S. Fish And Wildlife Service Washington Fish And Wildlife Office. (Revised December 11, 2012); Washington State Priority Habitats and Species Lists: for WRIAs 18 (Dungeness/Elwha), 1 (Nooksack), 5 (Stillaguamish), and 7 (Snohomish) (Terry Johnson, pers. comm. 11/10/2014) Available at http://wdfw.wa.gov/conservation/endangered/All/

[1] Includes those habitats most relevant for evaluating interactions with salmon and steelhead; does not include all habitats used by each species.

[2] Applicable listed species include fringed myotis (state monitored), Long-eared myotis (*Myotis evotis*) (Federal sensitive, state monitored); Long-legged myotis (*Myotis volans*) (Federal sensitive, state monitored); and Pacific Townsend's big-eared bat (*Corynorhinus townsendii townsendii*) (state and federal candidate species).

[3] Applicable listed species include federally listed sensitive species (Cascades frog (*Rana cascadae*) (State Monitored); Olympic torrent salamander (*Rhyacotriton olympicus*) (state monitored); Oregon spotted frog (federal candidate, state endangered), Tailed frog (*Ascaphus truei*) (State Monitored); Van Dyke's salamander (*Plethodon vandykei*) (state candidate); and Western toad (*Bufo boreas*) (state candidate).

[4] Applicable listed species include federally listed snails (Bliss Rapids snail, *Taylorconcha serpenticola*, (federally threatened), Banbury Springs lanx, *Lanx* sp., (federally endangered), Snake River physa snail, *Physa natricina*, (federally endangered), Utah valvata, *Valvata utahensis*, (federally endangered).

[5] Marine Mammal Protection Act. Enacted by Congress in 1972, the MMPA prohibits, with certain exceptions, the "take" of marine mammals in U.S. waters and by U.S. citizens on the high seas, and the importation of marine mammals and marine mammal products into the U.S.

[6] Common loons are listed as state sensitive.

Harbor seals, southern resident killer whales, sea lions, northern sea otters, harbor porpoises, Dall's porpoises, and Pacific white-sided dolphins are present in marine areas and may intercept early-winter steelhead returning to the tributaries as adults. However, because of the very small numbers of juveniles and adults produced relative to Puget Sound and Pacific Coast-wide production from natural areas and other hatcheries, the early-winter steelhead are not expected to be a substantial component of the diet of any of these species. The southern resident killer whale is listed under the ESA as endangered.

None of the hatchery facilities supporting the early-winter steelhead hatchery programs hazes wildlife to prevent them from eating fish being raised in the hatchery facilities. Instead, the hatchery facilities place nets over raceways to exclude predators. This method of passively excluding potential predators is not thought to adversely affect any wildlife species (WDFW 2014a; WDFW 2014b; WDFW 2014c).

3.6. Socioeconomics

Socioeconomics is defined as the study of the relationship between economics and social interactions with affected regions, communities, and user groups. In addition to providing fish for harvest, hatchery programs directly affect socioeconomic conditions in the economic impact regions where the hatchery facilities operate. Hatchery facilities generate economic activity (personal income and jobs) by providing employment opportunities and through local procurement of goods and services for hatchery operations (e.g., fish food).

The five hatchery facilities that are used by the early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins directly employ 11 full-time employees and 3 seasonal employees (WDFW 2014a; WDFW 2014b; WDFW 2014c).

Fisheries supported by hatchery programs contribute to local economies through the purchase of supplies such as fishing gear, camping equipment, consumables, and fuel at local businesses. All of these expenditures would be expected to support local businesses, but it is unknown how dependent these businesses are on fishing-related expenditures. Anglers would also be expected to contribute to the economy through outfitter/guide/charter fees.

Scott and Gill (2008) completed an economic analysis of recreational harvest of steelhead in Puget Sound and Strait of Juan de Fuca regions between the 1995/1996 and 2003/2004 seasons. They estimated that recreational anglers spent $14.0 million annually to go steelhead fishing, which generated an economic output of $26.5 million[5]. As described in Subsection 3.3, Salmon and Steelhead, production levels for hatchery-origin steelhead have been reduced by around 50 percent in the last 10 years. Since the early 1990s, fishing regulations have only allowed retention of hatchery-origin steelhead. Therefore, for the purposes of this EA, NMFS assumes the current steelhead hatchery programs in the Puget Sound result in $7.0 million in annual angler expenditures and $13.25 million in economic output.

[5] Economic output was estimated by multiplying expenditures per steelhead caught by an economic output multiplier. The economic multiplier estimated the ripple effect of how each dollar was spent by an angler increases another person's income, enabling the person (or business) to spend more, which in turn increases income for someone else (Scott and Gill 2008).

The hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins produce 27 percent of the total hatchery-origin winter and summer steelhead released in Puget Sound annually for the purposes of augmenting fisheries harvests[6]. Therefore, for the purposes of this analysis, NMFS assumes that these hatchery programs result in $1.89 million of annual angler expenditure and $3.58 million in economic output.

Salmon fishing has been a focus for tribal economies, cultures, lifestyles, and identities for over 1,000 years (Gunther 1950; Stein 2000). Beyond generating jobs and income for contemporary commercial tribal fishers, salmon are regularly eaten by individuals and families, and are served at gatherings of elders at traditional dinners and other ceremonies. To Native American tribes, salmon are a core symbol of tribal and individual identity. The survival and well-being of salmon are seen as extricable linked to the survival and well-being of Indian people and their cultures (Meyer Resources Inc. 1999). Salmon evoke sharing, gifts from nature, responsibility to the resource, and connection to land and water. Puget Sound treaty tribes use salmon in various ways, including personal and family consumption, informal and formal distribution and community sharing, and ceremonial uses (Amoss 1987).

3.7. Environmental Justice

This section was prepared in compliance with Presidential Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations* (EO 12898), dated February 11, 1994, and Title VI of the Civil Rights Act of 1964.

Executive Order 12898 (see 59 FR 7629, February 16, 1994) states that Federal agencies shall identify and address, as appropriate "…disproportionately high and adverse human health or environmental effects of [their] programs, policies and activities on minority populations and low-income populations…." While there are many economic, social, and cultural elements that influence the viability and location of such populations and their communities, certainly the development, implementation and enforcement of environmental laws, regulations and policies can have impacts. Therefore, federal agencies, including NMFS, must ensure fair treatment, equal protection, and meaningful involvement for minority populations and low-income populations as they develop and apply the laws under their jurisdiction.

Both EO 12898 and Title VI address persons belonging to the following target populations:

- Minority – all people of the following origins: Black, Asian, American Indian and Alaskan Native, Native Hawaiian or Other Pacific Islander, and Hispanic[7]

[6] The early-winter steelhead programs in the Dungeness, Nooksack, and Stillaguamish River Basins produce up to 290,000 fish annually. The total number of steelhead for harvest augmentation in Puget Sound tributaries is 1,075,000.

[7] Hispanic is an ethnic and cultural identity and is not the same as race.

- Low income – persons whose household income is at or below the U.S. Department of Health and Human Services poverty guidelines.

Definitions of minority and low income areas were established on the basis of the Council on Environmental Quality's (CEQ's) *Environmental Justice Guidance under the National Environmental Policy Act* of December 10, 1997. CEQ's *Guidance* states that "minority populations should be identified where either (a) the minority population of the affected area exceeds 50 percent or (b) the population percentage of the affected area is meaningfully greater than the minority population percentage in the general population or other appropriate unit of geographical analysis." The CEQ further adds that "[t]he selection of the appropriate unit of geographical analysis may be a governing body's jurisdiction, a neighborhood, a census tract, or other similar unit that is chosen so as not to artificially dilute or inflate the affected minority population."

The CEQ guidelines do not specifically state the percentage considered meaningful in the case of low-income populations. For this EA, the assumptions set forth in the CEQ guidelines for identifying and evaluating impacts on minority populations are used to identify and evaluate impacts on low-income populations. More specifically, potential environmental justice impacts are assumed to occur in an area if the percentage of minority, per capita income, and percentage below poverty level are markedly greater than the percentage of minority, per capita income, and percentage below poverty level in their state as a whole (i.e., Washington).

The early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basis raise and release fish in Clallam, Whatcom, and Snohomish Counties. These are also the counties that are primarily affected by the fisheries targeting early-winter steelhead produced in these hatchery programs. Clallam and Snohomish Counties are environmental justice communities of concern because 5.46 percent of Clallam County and 3.2 percent of Snohomish County is American Indian/Alaskan Native compared to 1.82 percent for the state as a whole (Table 14). Snohomish County's poverty level (15.80 percent of the population) also meaningfully exceeds the poverty level of the state as a whole (12.90 percent of the population) (Table 14).

Table 14. Percentage minority, per capita income, and percentage below poverty level in Clallam, Whatcom, and Snohomish Counties and Washington State.

Indicator	Clallam County	Whatcom County	Snohomish County	Washington State
Population (2013)	72,350	730,500	205,800	6,882,400
Percent American Indian/Alaskan Native (%)	5.46	1.55	3.12	1.82
Percent Other Races (%)	6.34	16.79	8.63	16.28
Percent Hispanic (%)	5.33	9.33	8.15	11.67
Persons below Poverty lLevel, 2008-2012 (%)	13.50	9.80	15.80	12.90

Shading of cells represents values that meaningfully exceeded (greater than 10 percent) those of the reference population, making them an environmental justice community of concern.
Sources: Population statistics: Washington State Data Book. Washington Office of Financial Management. 2013. Available at : http://www.ofm.wa.gov/localdata/default.asp
Economic statistics: U.S. Bureau of Census. 2013. State/County QuickFacts. Available at: http://quickfacts.census.gov/qfd/states/53/53009.html
Both accessed November 6, 2014/

The EPA guidance regarding environmental justice extends beyond statistical threshold analyses to consider explicit environmental justice effects on Native American tribes (EPA 1998). Federal duties under the Environmental Justice Executive Order, the presidential directive on government-to-government relations, and the trust responsibility to Indian tribes may merge when the action proposed by another federal agency or the EPA potentially affects the natural or physical environment of a tribe. The natural or physical environment of a tribe may include resources reserved by treaty or lands held in trust; sites of special cultural, religious, or archaeological importance, such as sites protected under the National Historic Preservation Act or the Native American Graves Protection and Repatriation Act; and other areas reserved for hunting, fishing, and gathering (*usual and accustomed* areas, which may include “ceded” lands that are not within reservation boundaries). Potential effects of concern may include ecological, cultural, human health, economic, or social impacts when those impacts are interrelated to impacts on the natural or physical environment (EPA 1998).

As described in Subsection 3.6 (Socioeconomics), salmon fishing has been a focus for tribal economies, cultures, lifestyles, and identities for over 1,000 years. These activities continue to be important today, both economically and for subsistence and ceremonial purposes. Returning early winter steelhead adults provide for limited tribal commercial and subsistence use. The following tribes or their representatives work with WDFW to develop fishing plans that target early-winter hatchery-origin steelhead in the Dungeness, Nooksack, and Stillaguamish River

Basins: Lummi Nation, Nooksack Tribe, Stillaguamish Indian Tribe, Tulalip Tribes, Port Gamble S'Klallam Tribe, Jamestown S'Klallam Tribe, and Lower Elwha Klallam Tribe.

4. ENVIRONMENTAL CONSEQUENCES

Chapter 4, Environmental Consequences, evaluates the potential effects of the alternatives (including the Proposed Action) on the biological, physical, and human resources described in Chapter 3, Affected Environment. NMFS has defined the No-action Alternative as not making a determination under the 4(d) Rule, leading to a termination of the early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins (Subsection 2.1, Alternative 1). All of the hatchery facilities that support the early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins would continue to operate under Alternative 1 because they also raise salmon for hatchery programs that are not part of the Proposed Action or its alternatives.

The effects of Alternative 1 are described relative to baseline conditions (Chapter 3, Affected Environment). The effects of Alternative 2 through Alternative 5 are described relative to Alternative 1. In addition, the effects of Alternative 3 and Alternative 4 are described relative to Alternative 2, the Proposed Action. Where applicable, the relative magnitude of impacts is described using the following terms:

Undetectable:	The impact would not be detectable.
Negligible:	The impact would be at the lower levels of detection and could be beneficial or adverse.
Low:	The impact would be slight, but detectable, and could be beneficial or adverse.
Moderate:	The impact would be readily apparent and could be beneficial or adverse.
High:	The impact would be severe or greatly beneficial.

4.1. Water Quantity

4.1.1. Alternative 1 (No Action) – Do Not Make a Determination under the 4(d) Rule

Under Alternative 1, the early-winter steelhead programs in the Dungeness, Nooksack, and Stillaguamish River Basins would be terminated immediately (Subsection 2.1, Alternative 1). All of the hatchery facilities that support these hatchery programs would continue to operate since they support hatchery programs that are not part of the Proposed Action. However, the hatchery facilities would be raising fewer fish. Therefore, short- and long-term water use would be less under Alternative 1 than under baseline conditions. There would be no change in compliance with water permits or water rights at any of the hatchery facilities under Alternative 1 because less water would be used at the hatchery facilities relative to baseline conditions or the permits, or water rights would no longer be necessary or applicable (Subsection 3.2, Water Quantity). Analyses of the site-specific effects of Alternative 1 is provided below.

Dungeness River Basin: The Dungeness River Hatchery uses surface water exclusively, withdrawn through three water intakes on the Dungeness River and one on Canyon Creek, an adjacent tributary. All water diverted from Dungeness River and Canyon Creek (minus evaporation) is returned after it circulates through the hatchery facility (Subsection 3.1, Water Quantity). Under baseline conditions, the Dungeness River Hatchery uses approximately 2.0 cfs of surface water from the Dungeness River and 0.4 cfs of water from Canyon Creek to support the early-winter steelhead program (Table 15). Water quantity is only affected between the water intake and discharge structures. Under Alternative 1, surface water would not be temporarily diverted into the hatchery to support the early-winter steelhead hatchery program, which would result in a negligible and beneficial effects on water quantity in the Dungeness and moderate and beneficial effects on water quantity in Canyon Creek between the water intake and discharge structures because more water would remain in the Dungeness River and Canyon Creek relative to baseline conditions (Table 15).

The Hurd Creek Hatchery facility uses a combination of groundwater withdrawn from five wells and surface water withdrawn from Hurd Creek for fish rearing and as an emergency back-up source. All water diverted from Hurd Creek (minus evaporation) is returned after it circulates through the hatchery facility (Subsection 3.1, Water Quantity). Under baseline conditions, the Hurd Creek Hatchery withdraws up to 0.26 cfs from Hurd Creek and 0.95 cfs from five wells to support the early-winter steelhead program in the Dungeness River Basin (Table 15). Water quantity is only affected between the water intake and discharge structures. Under Alternative 1, 0.26 cfs of surface water would not be temporarily diverted into the hatchery, which would result in a moderate and beneficial effect on water quantity in Hurd Creek between the water intake and discharge structures because more water would remain in Hurd Creek relative to baseline conditions (Table 15). Under Alternative 1, 0.95 cfs of groundwater would not be used to support the early-winter steelhead hatchery program and may lead to a low and beneficial effect on groundwater supply because an additional 0.95 cfs of water would remain in the aquifer for other water users relative to baseline conditions.

Nooksack River Basin: The Kendall Creek Hatchery uses well and surface water (Subsection 3.1, Water Quantity). All water diverted from Kendall Creek (minus evaporation) is returned to Kendall Creek after it circulates through the hatchery facility (Subsection 3.1, Water Quantity). Under baseline conditions, the Kendall Creek Hatchery uses approximately 6.7 cfs of surface water from Kendall Creek and 7.7 cfs of groundwater to support their early-winter steelhead program (Table 15). Water quantity is only affected between the water intake and discharge structures.

Under Alternative 1, 6.7 cfs of water would not be temporarily diverted from Kendall Creek into the hatchery, which would result in a negligible and beneficial effect on water quantity between the water intake and discharge structures because more water would remain in Kendall Creek relative to baseline conditions (Table 15). Under Alternative 1, 7.7 cfs of groundwater would not be used to support the early-winter steelhead hatchery program and may lead to a low and beneficial effect on groundwater supply because an additional 7.7 cfs of water would remain in the aquifer for other water users relative to baseline conditions.

McKinnon Pond uses surface water exclusively (Subsection 3.1, Water Quality). All water diverted from Peat Bog Creek (minus evaporation) is returned after it circulates through the rearing pond (Subsection 3.1, Water Quantity). Under baseline conditions, McKinnon Pond uses approximately 2.0 cfs of surface water from Peat Bog Creek from December through February (Table 15). These are the only months that steelhead are reared at McKinnon Pond and are the months when many streams and rivers experience higher than average flows. Under Alternative 1, this water would not be temporarily diverted into the rearing pond, which would result in a beneficial, but negligible effect on water quantity in Peat Bog Creek between the water intake and discharge structures because more, but likely only a small amount more, water would remain in the Peat Bog Creek relative to baseline conditions (Table 15).

Stillaguamish River Basin: The Whitehorse Ponds Hatchery uses well and surface water (Subsection 3.1, Water Quantity). All water diverted from Whitehorse Springs Creek (minus evaporation) is returned to Whitehorse Springs Creek after it circulates through the hatchery facility (Subsection 3.1, Water Quantity). Under baseline conditions, the Whitehorse Ponds Hatchery uses approximately 2.4 cfs of surface water from Whitehorse Ponds Creek and 0.5 cfs of groundwater to support their early-winter steelhead program (Table 15).

Under Alternative 1, 2.4 cfs of water would not be temporarily diverted from Whitehorse Springs Creek into the hatchery, which would result in a beneficial but negligible effect on water quantity in Whitehorse Springs Creek because more, though likely just somewhat more, water would remain in Whitehorse Springs Creek relative to baseline conditions (Table 15). Under Alternative 1, 0.5 cfs of groundwater would not be used to support the early-winter steelhead hatchery program and may lead to a beneficial, but negligible effect on groundwater supply because an additional 0.5 cfs of water would remain in the aquifer for other water users relative to baseline conditions.

Table 15. Water used to support steelhead hatchery programs in the Dungeness, Nooksack and Stillaguamish River Basins

	Baseline Conditions	Max Percentage of Minimum Flows Diverted Under Baseline Conditions (%)	Alternative 1 (No Action)	Alternative 2 (Proposed Action)	Alternative 3 (Reduced Production)	Alternative 4 (Native Broodstock)
Dungeness River Hatchery	Surface: 2 cfs from Dungeness River Surface: 0.4 cfs from Canyon Creek	3.6 of Dungeness River 20.0 from Canyon Creek	Surface: 0	Surface: 2 cfs from Dungeness River Surface: 0.4 cfs from Canyon Creek	Surface: 1 cfs from Dungeness River Surface: 0.2 cfs from Canyon Creek	Surface: 2 cfs from Dungeness River Surface: 0.4 cfs from Canyon Creek
Hurd Creek Hatchery	Surface: 0.26 cfs from Hurd Creek	13.0 from Hurd Creek	Surface: 0 Ground: 0	Surface: 0.26 cfs from Hurd Creek Ground: 0.95 cfs	Surface: 0.13 cfs from Hurd Creek Ground: 0.48 cfs	Surface: 0.26 cfs from Hurd Creek Ground: 0.95 cfs
Kendall Creek Hatchery	Ground: 0.95 cfs Surface: 6.7 cfs from Kendall Creek Ground: 7.7 cfs	1.3 from Kendall Creek	Surface: 0 Ground: 0	Surface: 6.7 cfs from Kendall Creek Ground: 7.7 cfs	Surface: 3.4 cfs from Kendall Creek Ground: 3.9 cfs	Surface: 6.7 cfs from Kendall Creek Ground: 7.7 cfs
McKinnon Pond	Surface: 2.0 cfs from Peat Bog Creek	0.3 from Peat Bog Creek (note that steelhead are not reared	Surface: 0	Surface: 2.0 cfs from Peat Bog Creek	Surface: 1.0 cfs from Peat Bog Creek	Surface: 2.0 cfs from Peat Bog Creek

		in McKinnon Pond during low flow conditions so this is the proportion used during average flow conditions)				
Whitehorse Ponds Hatchery	Surface: 2.4 cfs from Whitehorse Springs Creek Ground: 0.5 cfs	1.2 from Whitehorse Springs Creek	Surface: 0 Ground: 0	Surface: 2.4 cfs from Whitehorse Springs Creek Ground: 0.5 cfs	Surface: 1.2 cfs from Whitehorse Springs Creek Ground: 0.3 cfs	Surface: 2.4 cfs from Whitehorse Springs Creek Ground: 0.5 cfs

Source: Table 3.

4.1.2. Alternative 2 (Proposed Action) – Make a Determination that the Submitted HGMPs Meet the Requirements of the 4(d) Rule

Under Alternative 2, the early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins would operate as proposed in submitted HGMPs (Subsection 2.2, Alternative 2). Consequently, short- and long-term water use would be greater under Alternative 2 relative to Alternative 1 and the same as under baseline conditions (Subsection 3.1, Water Quantity). As under Alternative 1, there would be no change in compliance with water permits or water rights at any of the hatchery facilities under Alternative 2 because the hatchery programs have existing permits and water rights to divert water as proposed in the submitted HGMPs. Analyses of the site-specific effects of Alternative 2 is provided below.

Dungeness River Basin: The Dungeness River Hatchery uses surface water exclusively, withdrawn through three water intakes on the Dungeness River and one on Canyon Creek, an adjacent tributary. All water diverted from Dungeness River and Canyon Creek (minus evaporation) is returned after it circulates through the hatchery facility (Subsection 3.1, Water Quantity). Under Alternative 2, the Dungeness River Hatchery would use approximately 2.0 cfs of surface water from the Dungeness River and 0.4 cfs of water from Canyon Creek to support their early-winter steelhead program (Table 15). Because this water would not be withdrawn under Alternative 1, Alternative 2 would result in a moderate and adverse effect on water quantity in the Dungeness River and in Canyon Creek between the water intake and discharge structures relative to Alternative 1.

The Hurd Creek Hatchery facility uses a combination of groundwater withdrawn from five wells, and surface water withdrawn from Hurd Creek for fish rearing and as an emergency back-up source. All water diverted from Dungeness River and Canyon Creek (minus evaporation) is returned after it circulates through the hatchery facility (Subsection 3.1, Water Quantity). Under Alternative 2, the Hurd Creek Hatchery may withdraw up to 0.26 cfs from Hurd Creek to support the early-winter steelhead program in the Dungeness River Basin (Table 15). Because this water would not be withdrawn under Alternative 1, Alternative 2 would have a moderate and adverse effect on water quantity in Hurd Creek between the water intake and discharge structures relative to Alternative 1. Under Alternative 2, 0.95 cfs more groundwater would be used to support the early-winter steelhead hatchery program relative to Alternative 1, which may lead to a low and adverse effect on groundwater supply because 0.95 cfs of water would not remain in the aquifer for other water users in contrast to Alternative 1.

Nooksack River Basin: The Kendall Creek Hatchery uses well and surface water (Subsection 3.1, Water Quantity). All water diverted from Kendall Creek (minus evaporation) is returned to Kendall Creek after it circulates through the hatchery facility (Subsection 3.1, Water Quantity). Under Alternative 2, the Kendall Creek Hatchery would use approximately 6.7 cfs of surface water from Kendall Creek to support the early-winter steelhead program (Table 15). Because this water would not be withdrawn under Alternative 1, Alternative 2 may result in a small adverse effect on water quantity in Kendall Creek relative relative to Alternative 1. Under Alternative 2, 7.7 cfs of groundwater would be used to support the early-winter steelhead hatchery program, and because this water would not be used under Alternative 1, Alternative 2 may lead to a low and adverse effect on groundwater supply relative to Alternative 1.

McKinnon Pond uses surface water exclusively (Subsection 3.1, Water Quality). All water diverted from Peat Bog Creek (minus evaporation) is returned after it circulates through the rearing pond (Subsection 3.1, Water Quantity). Under Alternative 2, McKinnon Pond would use approximately 2.0 cfs of surface water from Peat Bog Creek from December through February (Table 15). These are the only months that steelhead are reared at McKinnon Pond and are the months when many streams and rivers experience higher than average flows. Because this water would not be withdrawn under Alternative 1, Alternative 2 would lead to an adverse, but negligible, effect on water quantity in Peat Bog Creek between the water intake and discharge structures relative to Alternative 1.

Stillaguamish River Basin: The Whitehorse Ponds Hatchery uses well and surface water (Subsection 3.1, Water Quantity). All water diverted from Whitehorse Springs Creek (minus evaporation) is returned to Whitehorse Springs Creek after it circulates through the hatchery facility (Subsection 3.1, Water Quantity). Under Alternative 2, the Whitehorse Ponds Hatchery would use approximately 2.4 cfs of surface water from Whitehorse Ponds Creek to support the early-winter steelhead program (Table 15). Because this water would not be withdrawn under Alternative 1, Alternative 2 would lead to an adverse, but negligible effect on water quantity in Whitehorse Springs Creek relative to Alternative 1. Under Alternative 2, 0.5 cfs of groundwater would be used to support the early-winter steelhead hatchery program. Because this water would not be withdrawn under Alternative 1, Alternative 2 may lead to an adverse, but negligible, effect on groundwater supply because 0.5 cfs of water would not remain in the aquifer for other water users in contrast to Alternative 1.

4.1.3. Alternative 3 (Reduced Production Alternative) – Make a Determination that Revised HGMPs with Released Production Levels Meet the Requirements of the 4(d) Rule

Under Alternative 3, WDFW would reduce proposed production levels by 50 percent, and water use would be reduced by 50 percent relative to Alternative 2. However, relative to Alternative 1, under which the programs would be terminated, both short- and long-term water use would be greater under Alternative 3.

All hatchery facilities would remain in compliance with water permits or water rights under Alternative 3 because less water would be used at the hatchery facilities relative to baseline conditions, and all hatchery facilities would comply with required water permits or water rights described under baseline conditions (Subsection 3.2, Water Quantity). Analyses of the site-specific effects of Alternative 3 are provided below.

Dungeness River Basin: The Dungeness River Hatchery uses surface water exclusively, withdrawn through three water intakes on the Dungeness River and one on Canyon Creek, an adjacent tributary. All water diverted from Dungeness River and Canyon Creek (minus evaporation) is returned after it circulates through the hatchery facility (Subsection 3.1, Water Quantity). Under Alternative 3, the Dungeness River Hatchery would use approximately 1.0 cfs of surface water from the Dungeness River and 0.2 cfs of water from Canyon Creek to support the early-winter steelhead program (Table 15). Because this water would not be withdrawn under Alternative 1, Alternative 3 would result in a moderate and adverse effect on water quantity in the Dungeness River and in Canyon Creek between the water intake and discharge structures relative to Alternative 1.

The Hurd Creek Hatchery facility uses a combination of groundwater withdrawn from five wells, and surface water withdrawn from Hurd Creek for fish rearing and as an emergency back-up source. All water diverted from Dungeness River and Canyon Creek (minus evaporation) is returned after it circulates through the hatchery facility (Subsection 3.1, Water Quantity). Under Alternative 3, the Hurd Creek Hatchery may withdraw up to 0.13 cfs from Hurd Creek to support the early-winter steelhead program (Table 15). Because this water would not be withdrawn under Alternative 1, Alternative 3 would have a moderate and adverse effect on water quantity in Hurd Creek between the water intake and discharge structures relative to Alternative 1. Under Alternative 3, 0.48 cfs more groundwater would be used to support the early-winter steelhead hatchery program relative to Alternative 1, which may lead to a low and adverse effect on groundwater supply relative to Alternative 1.

Nooksack River Basin: The Kendall Creek Hatchery uses well and surface water (Subsection 3.1, Water Quantity). All water diverted from Kendall Creek (minus evaporation) is returned to Kendall Creek after it circulates through the hatchery facility (Subsection 3.1, Water Quantity). Under Alternative 3, the Kendall Creek Hatchery would use approximately 3.4 cfs of surface water from Kendall Creek to support the early-winter steelhead program (Table 15). Because this water would not be withdrawn under Alternative 1, Alternative 3 may result in a low and adverse effect on water quantity in Kendall Creek relative to Alternative 1. Under Alternative 3, 3.9 cfs of groundwater would be used to support the early-winter steelhead hatchery program, and because this water would not be used under Alternative 1, Alternative 3 may lead to a low and adverse effect on groundwater supply relative to Alternative 1.

McKinnon Pond uses surface water exclusively (Subsection 3.1, Water Quality). All water diverted from Peat Bog Creek (minus evaporation) is returned after it circulates through the rearing pond (Subsection 3.1, Water Quantity). Under Alternative 3, McKinnon Pond would use approximately 1.0 cfs of surface water from Peat Bog Creek from December through February (Table 15). These are the only months that steelhead are reared at McKinnon Pond and are the months when many streams and rivers experience higher than average flows. Because this water would not be withdrawn under Alternative 1, Alternative 3 would lead to an adverse, but negligible, effect on water quantity in Peat Bog Creek between the water intake and discharge structures relative to Alternative 1.

Stillaguamish River Basin: The Whitehorse Ponds Hatchery uses well and surface water (Subsection 3.1, Water Quantity). All water diverted from Whitehorse Springs Creek (minus evaporation) is returned to Whitehorse Springs Creek after it circulates through the hatchery facility (Subsection 3.1, Water Quantity). Under Alternative 3, Whitehorse Ponds Hatchery would use approximately 1.2 cfs from Whitehorse Springs Creek. Because this water would not be withdrawn under Alternative 1, Alternative 3 would have an adverse but negligible effect on water quantity in Whitehorse Springs Creek relative to Alternative 1.

Under Alternative 3, 0.3 cfs of groundwater would be used to support the early-winter steelhead hatchery program. Because this water would not be withdrawn under Alternative 1, Alternative 3 may lead to an adverse but negligible effect on groundwater supply relative to Alternative 1.

Relative to the Alternative 2 (Proposed Action), Alternative 3 would reduce water use at the five hatchery facilities that support the early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins by the following amounts:

Dungeness River Basin: 1.0 cfs from Dungeness River, 0.2 cfs from Canyon Creek, 0.13 cfs from Hurd Creek, and 0.95 cfs from wells (Table 15)

Nooksack River Basin: 3.4 cfs from Kendall Creek, 1.0 cfs from Peat Bog Creek, and 3.9 cfs from wells (Table 15)

Stillaguamish River Basin: 1.2 cfs from Whitehorse Springs Creek and 0.5 cfs from wells (Table 15)

Because water use would be reduced by 50 percent at the five hatchery facilities under Alternative 3, effects on surface and groundwater quantity would be low to negligible, localized, and beneficial since less water would be needed to support production compared to Alternative 2.

4.1.4. Alternative 4 (Transition to Native Stock) – Make a Determination that Revised HGMPs that Replace Chambers Creek Stock with a Native Broodstock Meet the Requirements of the 4(d) Rule

Under Alternative 4, WDFW would produce the same number of fish as under the Alternative 2, but would replace the Chambers Creek broodstock with a native steelhead broodstock. Effects on water quantity would be identical as under Alternative 2 because a change in broodstock would not affect water quantity (i.e., the same amount of water would be used in the hatchery).

4.2. Water Quality

4.2.1. Alternative 1 (No Action) – Do Not Make a Determination under the 4(d) Rule

Under Alternative 1, the early-winter steelhead programs in the Dungeness, Nooksack, and Stillaguamish River Basins would be terminated immediately (Subsection 2.1, Alternative 1). All of the hatchery facilities that support these hatchery programs would continue to operate since they support hatchery programs that are not part of the Proposed Action or its alternatives.

However, these hatchery facilities would be raising fewer fish. Therefore, there would be a short and long-term reduction in the discharge of ammonia, nutrients (e.g., nitrogen), biological oxygen demand, pH, suspended solids levels, antibiotics, fungicides, disinfectants, steroid hormones, pathogens, anesthetics, pesticides, and herbicides into the Dungeness, Nooksack, and Stillaguamish River Basins relative to baseline conditions (Subsection 3.1, Water Quality). The effects of a reduction in the discharge of these substances would be slight because hatchery effluent is passed through pollution abatement ponds to settle out uneaten food and waste before being discharged into receiving waters (Subsection 3.1, Water Quality). However, because changes would be detectable in the immediate vicinity of the hatchery discharge structures, Alternative 1 would provide low, localized benefits to water quality relative to baseline conditions.

Alternative 1 would not be expected to change any of the 303(d) listings because the contribution of list-related substances from hatchery programs would remain small relative to the contribution of these substances within the analysis area from activities such as agriculture and development activities (Table 4).

Because water quality would be expected to improve in both the short and long term under Alternative 1, there would be no change in compliance with applicable NPDES permits at the hatchery facilities relative to baseline conditions (Subsection 3.1, Water Quality).

4.2.2. Alternative 2 (Proposed Action) – Make a Determination that the Submitted HGMPs Meet the Requirements of the 4(d) Rule

Under Alternative 2, the early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins would operate as proposed in submitted HGMPs (Subsection 2.2, Alternative 2). Relative to the Alternative 1, Alternative 2 would result in a short and long-term increase in the discharge of ammonia, nutrients (e.g., nitrogen), biological oxygen demand, pH, suspended solids levels, antibiotics, fungicides, disinfectants, steroid hormones, pathogens, anesthetics, pesticides, and herbicides into the Dungeness, Nooksack, and Stillaguamish River Basins (Subsection 3.2, Water Quality). The effects would be slight because hatchery effluent would be passed through pollution abatement ponds to settle out uneaten food and waste before being discharged into receiving waters (Subsection 3.1, Water Quality). However, because changes would be detectable in the immediate vicinity of the hatchery discharge structures, Alternative 2 would result in low, localized adverse impacts on water quality relative to Alternative 1.

As under Alternative 1, Alternative 2 would not be expected to change any of the 303(d) listings because the contribution of substances from hatchery programs would be small relative to the contribution of substances from activities such as agriculture and development activities (Table 4).

Although there would be low, localized adverse impacts on water quality relative to Alternative 1, there would be no change in compliance with applicable NPDES permits at the hatchery facilities relative to Alternative 1 because production levels would fall within the limits of existing permits or plans (Subsection 3.1, Water Quality).

4.2.3. Alternative 3 (Reduced Production Alternative) – Make a Determination that Revised HGMPs with Released Production Levels Meet the Requirements of the 4(d) Rule

Under Alternative 3, WDFW would reduce proposed production levels by 50 percent. Relative to Alternative 1, under which the programs would be terminated, there would be a short- and long-term increase in the discharge of ammonia, nutrients (e.g., nitrogen), biological oxygen demand, pH, suspended solids levels, antibiotics, fungicides, disinfectants, steroid hormones, pathogens, anesthetics, pesticides, and herbicides into the Dungeness, Nooksack, and Stillaguamish River Basins. The effects of a change in the discharge of these substances would be slight because hatchery effluent would be passed through pollution abatement ponds to settle out uneaten food and waste before being discharged into receiving waters (Subsection 3.2, Water Quality). However, because changes would be detectable in the immediate vicinity of the hatchery discharge structures, Alternative 3 would provide low, localized adverse impacts on water quality relative to Alternative 1.

Relative to Alternative 2 (Proposed Action), Alternative 3 would reduce the discharge of ammonia, nutrients (e.g., nitrogen), biological oxygen demand, pH, suspended solids levels, antibiotics, fungicides, disinfectants, steroid hormones, pathogens, anesthetics, pesticides, and herbicides into the Dungeness, Nooksack, and Stillaguamish River Basins. A reduction in the discharge of these substances may be detectable in the immediate vicinity of the hatchery discharge structures. Overall, Alternative 3 would provide low to negligible, localized beneficial impact on water quality relative to Alternative 2.

4.2.4. Alternative 4 (Transition to Native Stock) – Make a Determination that Revised HGMPs that Replace Chambers Creek Stock with a Native Broodstock Meet the Requirements of the 4(d) Rule

Under Alternative 4, WDFW would produce the same number of fish as under Alternative 2, but would replace the Chambers Creek broodstock with a native steelhead broodstock. Effects on water quality would be the same as under Alternative 2 (Subsection 3.2.2, Water Quality) because production levels would be identical.

4.3. Salmon and Steelhead

4.3.1. Alternative 1 (No Action) – Do Not Make a Determination under the 4(d) Rule

Under Alternative 1, the early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins would be terminated immediately (Subsection 2.1, Alternative 1). Therefore, all risks to ESUs, DPSs, non-listed salmon species, and designated critical habitat associated with these ongoing hatchery programs would be eliminated (Subsection 3.3, Salmon and Steelhead). Relative to baseline conditions, Alternative 1 would result in the following effects:

- Gene flow from early-winter hatchery-origin steelhead would be reduced from less than 2 percent under baseline conditions to zero (Subsection 3.3.1, Genetic Risks), which would result in a small positive effect on natural-origin steelhead populations in the Dungeness, Nooksack, and Stillaguamish River Basins.
- The risk of predation on juvenile fall Chinook salmon, fall chum salmon, pink salmon, and sockeye salmon would be reduced (Subsection 3.3.2, Competition and Predation), which would result in a low, positive effect on natural-origin populations of these species.
- The risk of competition between hatchery-origin steelhead and natural-origin steelhead, spring Chinook salmon, and coho salmon would be reduced (Subsection 3.3.2, Competition and Predation), which would result in a low, positive effect on natural-origin steelhead, spring Chinook salmon, and coho salmon populations.
- Hatchery facility risks would remain the same as under baseline conditions since all hatchery facilities would continue to operate for other species under Alternative 1, and all instream structures (including weirs) would continue to be used and maintained. There would be no change in the hatchery facilities' compliance with NMFS screening criteria at Dungeness River Hatchery, Hurd Creek Hatchery, McKinnon Pond, or Whitehorse Ponds Hatchery (Subsection 3.3.3, Hatchery Facility Risks). WDFW would be expected to complete its already planned upgrade to the water intake screen at Kendall Creek Hatchery and improve fish passage at the Dungeness River Hatchery (Subsection 3.3.3, Hatchery Facility Risks).
- There would be no steelhead fisheries in the Dungeness, Nooksack, and Stillaguamish River Basins. Therefore, incidental fishing effects would be eliminated, which would provide a low, positive effect on natural-origin steelhead populations.
- There would be no expected change in the risk of disease transfer since all of the hatchery facilities would continue to propagate salmon species, and salmon can harbor the same diseases as steelhead (Subsection 3.3.5, Risk of Disease Transfer; Table 9).

- There would be no change in the risk of "mining" the natural-origin population through the collection of broodstock because no natural-origin fish are incorporated into the broodstock under baseline conditions, and there would be no broodstock under Alternative 1 (i.e., the programs would be terminated) (Table 16).

Table 16. Number of natural-origin winter steelhead in the hatchery broodstock by alternative in the Dungeness, Nooksack, and Stillaguamish River Basins.

	Average Natural-origin Winter Run[1]	TRT Interim Viable Abundance Target	Number of Natural-origin Winter Steelhead in Broodstock				
			Baseline Conditions	**Alt. 1[2]**	**Alt. 2**	**Alt. 3**	**Alt. 4**
Dungeness River Basin	487	1,232	0	N/A	0	0	Up to 30 with a 1:1 sex ratio
Nooksack River Basin	1,760	11,023	0	N/A	0	0	Up to 100 with a 1:1 sex ratio
Stillaguamish River Basin	1,852	9,559	0	N/A	0	0	Up to 120 adults with a 1:1 sex ratio

[1] Source: Table 11
[2] The hatchery programs would be terminated under Alternative 1, so no broodstock would be needed.

4.3.2. Alternative 2 (Proposed Action) – Make a Determination that the Submitted HGMPs Meet the Requirements of the 4(d) Rule

Under Alternative 2, the early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins would operate as proposed in submitted HGMPs (Subsection 2.2, Alternative 2), and release levels would be the same as under baseline conditions (Chapter 3, Affected Environment). Relative to Alternative 1 under which the hatchery programs would be terminated, Alternative 2 would result in the following effects:

- Gene flow from early-winter hatchery-origin steelhead would increase from zero under Alternative 1 to less than 2 percent (Subsection 3.3.1, Genetic Risks), which would result in a low, negative effect on natural-origin steelhead populations in the Dungeness, Nooksack, and Stillaguamish River Basins.

- The risk of predation on juvenile fall Chinook, fall chum, pink, and sockeye salmon would increase (Subsection 3.3.2, Competition and Predation), but hatchery managers would minimize competitive interactions by releasing the hatchery-origin steelhead when they are fully smolted and, thus, actively migrating to marine waters (WDFW 2014a; WDFW 2014b; WDFW 2014c). Therefore, Alternative 2 would result in a low, negative effect on predation of natural-origin fall Chinook, fall chum, pink, and sockeye salmon.

- The risk of competition between hatchery-origin steelhead and natural-origin steelhead, spring Chinook salmon, and coho salmon would increase (Subsection 3.3.2, Competition and Predation), but hatchery managers would minimize competitive interactions by releasing the hatchery-origin steelhead when they are fully smolted and thus actively migrating to marine waters (WDFW 2014a; WDFW 2014b; WDFW 2014c). Therefore, Alternative 2 would result in a low, negative effect on competition with natural-origin steelhead, spring Chinook salmon, and coho salmon populations.

- Hatchery facility risks would be the same since all hatchery facilities would continue to operate under both Alternative 1 and Alternative 2, and all instream structures (including weirs) would continue to be used and maintained. There would be no change in the hatchery facilities' compliance with NMFS screening criteria at Dungeness River Hatchery, Hurd Creek Hatchery, McKinnon Pond, or Whitehorse Ponds Hatchery (Subsection 3.3.3, Hatchery Facility Risks). As under Alternative 1, WDFW would be expected to complete its already planned upgrade to the water intake screen at Kendall Creek Hatchery and improve fish passage at the Dungeness River Hatchery (Subsection 3.3.3, Hatchery Facility Risks).

- Unlike under Alternative 1, there would be steelhead fisheries in the Dungeness, Nooksack, and Stillaguamish River Basins. Therefore, incidental fishing effects would be greater than under Alternative 1. However, incidental fishing impacts of the natural-origin population would be low because (1) 100 percent of the hatchery-origin fish would be marked, (2) the run timing of the hatchery-origin and natural-origin steelhead populations would be staggered, with the result that harvest managers would continue to be able to shape fisheries to avoid most effects on natural-origin fish, and (3) cool water temperatures during the months when the steelhead fishery is open would minimize incidental hook-and-release mortality of natural-origin steelhead (WDFW 2014a; WDFW 2014b; WDFW 2014c)

- There would be no expected change in the risk of disease transfer since all of the hatchery facilities would continue to propagate salmon species under Alternative 1, and salmon harbor many of the same diseases as steelhead (Subsection 3.3.5, Risk of Disease Transfer; Table 9).

- There would be no change in the risk of "mining" the natural-origin population through the collection of broodstock because no natural-origin fish would be incorporated into the broodstock under Alternative 1 or Alternative 2 (Table 16).

4.3.3. Alternative 3 (Reduced Production Alternative) – Make a Determination that Revised HGMPs with Released Production Levels Meet the Requirements of the 4(d) Rule

Under Alternative 3, the early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins would be reduced by 50 percent relative to the proposed hatchery programs (Subsection 2.3, Alternative 3). Relative to Alternative 1 under which the hatchery programs would be terminated, Alternative 3 would result in the following effects:

- Gene flow from early-winter hatchery-origin steelhead would increase from zero under Alternative 1 to less than 2 percent (Subsection 3.3.1, Genetic Risks), which would result in a low, negative effect on natural-origin steelhead populations in the Dungeness, Nooksack, and Stillaguamish River Basins.
- The risk of predation on juvenile fall Chinook, fall chum, pink, and sockeye salmon would increase (Subsection 3.3.2, Competition and Predation), but hatchery managers would minimize competitive interactions by releasing the hatchery-origin steelhead when they are fully smolted, and, thus, actively migrating to marine waters (WDFW 2014a; WDFW 2014b; WDFW 2014c). Therefore, Alternative 3 would result in a low, negative effect on predation of natural-origin fall Chinook, fall chum, pink, and sockeye salmon.
- The risk of competition between hatchery-origin steelhead and natural-origin steelhead, spring Chinook salmon, and coho salmon would increase (Subsection 3.3.2, Competition and Predation), but hatchery managers would minimize competitive interactions by releasing the hatchery-origin steelhead when they are fully smolted, and, thus, actively migrating to marine waters (WDFW 2014a; WDFW 2014b; WDFW 2014c). Therefore, Alternative 3 would result in a low, negative effect on competition with natural-origin steelhead, spring Chinook salmon, and coho salmon populations.
- Hatchery facility risks would be the same since all hatchery facilities would continue to operate under both Alternative 1 and Alternative 3, and all instream structures (including weirs) would continue to be used and maintained. There would be no change in the hatchery facilities' compliance with NMFS screening criteria at Dungeness River Hatchery, Hurd Creek Hatchery, McKinnon Pond, or Whitehorse Ponds Hatchery (Subsection 3.3.3, Hatchery Facility Risks). As under Alternative 1, WDFW would be expected to complete its already planned upgrade to the water intake screen at Kendall Creek Hatchery and improve fish passage at the Dungeness River Hatchery (Subsection 3.3.3, Hatchery Facility Risks).
- Unlike under Alternative 1, there would be steelhead fisheries in the Dungeness, Nooksack, and Stillaguamish River Basins. Therefore, incidental fishing effects would be greater than under Alternative 1. However, incidental fishing impacts of the natural-origin population would be low because (1) 100 percent of the hatchery-origin fish would be marked, (2) the run timing of the hatchery-origin and natural-origin steelhead populations would be staggered, with the result that harvest managers would continue to

be able to shape fisheries to avoid most effects on natural-origin fish, and (3) cool water temperatures during the months when the steelhead fishery is open would minimize incidental hook-and-release mortality of natural-origin steelhead (WDFW 2014a; WDFW 2014b; WDFW 2014c).

- There would be no expected change in the risk of disease transfer since all of the hatchery facilities would continue to propagate salmon species under Alternative 1, and salmon harbor many of the same diseases as steelhead (Subsection 3.3.5, Risk of Disease Transfer; Table 9).
- There would be no change in the risk of "mining" the natural-origin population through the collection of broodstock because no natural-origin fish would be incorporated into the broodstock under Alternative 1 or Alternative 3 (Table 16).

Relative to the Alternative 2 (Proposed Action), Alternative 3 would result the following effects:

- Less gene flow, competition and predation risks, and incidental fishing effects because fewer hatchery-origin fish would be released under Alternative 3 relative to Alternative 2. However, these risks would be low under both alternatives.
- The same hatchery facility risks as under Alternative 2 because the hatchery facilities would continue to operate under both alternatives.
- The same risk of disease transfer as under Alternative 2 because the same diseases would be present inside the hatchery facilities under both alternatives.
- The same lack of risk of "mining" the natural-origin population through the collection of broodstock as under Alternative 2 because no natural-origin fish would be incorporated into the broodstock under either alternative (Table 16).

4.3.4. Alternative 4 (Transition to Native Stock) – Make a Determination that Revised HGMPs that Replace Chambers Creek Stock with a Native Broodstock Meet the Requirements of the 4(d) Rule

Under Alternative 4, WDFW would produce the same number of fish as under the Proposed Action, but would replace the Chambers Creek broodstock with a local, native steelhead broodstock. Relative to Alternative 1 under which the hatchery programs would be terminated, Alternative 4 would result in the following effects:

- Gene flow from hatchery-origin steelhead would increase from zero under Alternative 1 to up to 10 percent under Alternative 4 (Subsection 2.4, Alternative 4). However, because the gene flow would be between the natural-origin steelhead population and a hatchery-origin fish derived from a native broodstock, these gene flow levels would have a low genetic effect on natural-origin steelhead populations in the Dungeness, Nooksack, and Stillaguamish River Basins (Subsection 3.3, Salmon and Steelhead; HSRG 2009).

- Predation on juvenile fall Chinook, fall chum, pink, and sockeye salmon would increase (Subsection 3.3.2, Competition and Predation), but hatchery managers would minimize competitive interactions by releasing the hatchery-origin steelhead when they are fully smolted, and, thus, actively migrating to marine waters (WDFW 2014a; WDFW 2014b; WDFW 2014c). Therefore, Alternative 4 would result in a low, negative effect on predation of natural-origin fall Chinook, fall chum, pink, and sockeye salmon.
- Competition between hatchery-origin steelhead and natural-origin steelhead, spring Chinook salmon, and coho salmon would increase (Subsection 3.3.2, Competition and Predation), but hatchery managers would minimize competitive interactions by releasing the hatchery-origin steelhead when they are fully smolted, and, thus, actively migrating to marine waters (WDFW 2014a; WDFW 2014b; WDFW 2014c). Therefore, Alternative 4 would result in a low, negative effect on competition with natural-origin steelhead, spring Chinook salmon, and coho salmon populations.
- Hatchery facility risks would remain the same as under Alternative 1 since all hatchery facilities would continue to operate under both Alternative 1 and Alternative 4, and all instream structures (including weirs) would continue to be used and maintained. There would be no change in the hatchery facilities' compliance with NMFS screening criteria at Dungeness River Hatchery, Hurd Creek Hatchery, McKinnon Pond, or Whitehorse Ponds Hatchery (Subsection 3.3.3, Hatchery Facility Risks). As under Alternative 1, WDFW would be expected to complete its already planned upgrade to the water intake screen at Kendall Creek Hatchery and improve fish passage at the Dungeness River Hatchery (subsection 3.3.3, Hatchery Facility Risks).
- Unlike under Alternative 1, there would be a steelhead fishery in the Dungeness, Nooksack, and Stillaguamish River Basins. Therefore, incidental fishing effects would be greater than under Alternative 1. However, incidental fishing impacts of the natural-origin population would be low because (1) 100 percent of the hatchery-origin fish would be marked, (2) harvest managers could still shape fisheries to focus effort on hatchery-origin fish, and (3) cool water temperatures during the months when the steelhead fishery is open would minimize incidental hook-and-release mortality of natural-origin steelhead (WDFW 2014a; WDFW 2014b; WDFW 2014c)
- There would be no expected change in the risk of disease transfer since all of the hatchery facilities would continue to propagate salmon species under Alternative 1, and salmon harbor many of the same diseases as steelhead (Subsection 3.3.5, Risk of Disease Transfer; Table 9).
- While there is generally a risk of "mining" the natural-origin population through the collection of broodstock when a hatchery program incorporates natural-origin fish are

into the broodstock, and natural-origin steelhead populations are depressed in the Dungeness, Nooksack, and Stillaguamish River Basins (Table 16), in this case, the risk would be negligible under Alternative 4, because broodstock collection would be contingent upon availability of natural-origin fish, ensuring first that an appropriate minimum number of fish would be able to spawn naturally; only after that threshold is ensured would a proportion of additional returns would be taken into the hatchery facilities.

Relative to the Proposed Action (Alternative 2), Alternative 4 would result in the following effects:

- Alternative 4 would result in the higher levels of gene flow because hatchery-origin steelhead derived from local, native steelhead populations would have a more similar spawn timing compared to the hatchery-origin steelhead derived from Chambers Creek lineage (Figure 4). However, because the hatchery-origin fish would be derived from the local, native steelhead populations, these higher levels of gene flow would provide a similar genetic risk as the less than 2 percent gene flow under Alternative 2.
- Alternative 4 would result in the same levels of competition and predation risks as under Alternative 2 because the same number of hatchery-origin fish would be released under both alternatives.
- Hatchery facility risks would remain the same as under Alternative 2 since all hatchery facilities would continue to operate under both Alternative 2 and Alternative 4, and all instream structures (including weirs) would continue to be used and maintained.
- Incidental fishing effects may be greater under Alternative 4 relative to Alternative 2 because the hatchery-origin fish derived from a local, native broodstock would have the same run timing as natural-origin steelhead in the Dungeness, Nooksack, and Stillaguamish River Basins, the ability to shape fisheries to avoid natural-origin fish would be reduced, and so more natural-origin steelhead would be incidentally captured and released.
- There would be no expected change in the risk of disease transfer since the same species of fish would be propagated under Alternative 2 and Alternative 4 (Subsection 3.3.5, Risk of Disease Transfer; Table 9).
- While there is generally a risk of “mining” the natural-origin population through the collection of broodstock when a hatchery program incorporates natural-origin fish are into the broodstock, and natural-origin steelhead populations are depressed in the Dungeness, Nooksack, and Stillaguamish River Basins (Table 16), in this case, the risk would be negligible under Alternative 4, because broodstock collection would be contingent upon availability of natural-origin fish, ensuring first that an appropriate

minimum number of fish would be able to spawn naturally; only after that threshold is ensured would a proportion of additional returns would be taken into the hatchery facilities.

4.4. Other Fish Species

4.4.1. Alternative 1 (No Action) – Do Not Make a Determination under the 4(d) Rule

Under Alternative 1, the early-winter steelhead programs in the Dungeness, Nooksack, and Stillaguamish River Basins would be terminated immediately, and 290,000 fewer steelhead would be produced by hatcheries in the Puget Sound relative to baseline conditions[8]. Therefore, there would be a short- and long-term reduction in competition for space and food among freshwater species relative to baseline conditions. There would also be a reduction in predation risk by steelhead on other fish species, and a potentially measurable reduction in the number of prey eaten by steelhead in the Puget Sound. However, because (1) the analysis area is only a small portion of each species range and (2) steelhead are not exclusive predators or prey for any of the fish species, Alternative 1 would be expected to have a negligible effect on other fish species (positive for some species and negative for others) relative to baseline conditions. Consequently, Alternative 1 would not be expected to change any state or federal species designations relative to baseline conditions (Subsection 3.4, Other Fish Species).

4.4.2. Alternative 2 (Proposed Action) – Make a Determination that the Submitted HGMPs Meet the Requirements of the 4(d) Rule

Under Alternative 2, the early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins would operate as proposed in submitted HGMPs (Subsection 2.2, Alternative 2). Relative to Alternative 1, Alternative 2 would increase the number of steelhead produced in the Puget Sound by 290,000 smolts. Therefore, there would be a short- and long-term increase in risk of competition for space and food among freshwater species relative to Alternative 1. There would also be an increase in the risk of predation by steelhead on other fish species, and an potentially measurable increase in the number of prey eaten by steelhead in the Puget Sound relative to Alternative 1. However, because (1) the analysis area is only a small portion of each species range, and (2) steelhead are not exclusive predators or prey for any of the fish species, Alternative 2 would be expected to have negligible effects (positive for fish that eat steelhead and negative for fish that are eaten by steelhead) relative to Alternative 1. Consequently, Alternative 2 would not be expected to change any State or Federal species designations relative to baseline conditions (Subsection 3.4, Other Fish Species).

---

[8] Under baseline conditions, the early-winter steelhead programs in the Dungeness, Nooksack, and Stillaguamish River Basins produce 290,000 steelhead. 1,734,450 steelhead are produced in Puget Sound tributaries (1,075,000 for harvest augmentation and 659,450 for conservation)

4.4.3. Alternative 3 (Reduced Production Alternative) – Make a Determination that Revised HGMPs with Released Production Levels Meet the Requirements of the 4(d) Rule

Under Alternative 3, the early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins would be reduced by 50 percent relative to the proposed hatchery programs (Subsection 2.3, Alternative 3). Relative to Alternative 1 under which the hatchery programs would be terminated, Alternative 3 would increase the number of juvenile steelhead released into the Dungeness, Nooksack, and Stillaguamish River Basins by 145,000 smolts, which would lead to a short- and long-term increase in the risk of competition for space and food among freshwater species relative to Alternative 1. There would also be an increase in the risk of predation by steelhead on other fish species, and a potentially measurable increase in the number of prey eaten by steelhead in the Puget Sound relative to Alternative 1. However, because (1) the analysis area is only a small portion of each species range, and (2) steelhead are not exclusive predators or prey for any of the fish species, Alternative 3 would be expected to have negligible effects (positive for fish that eat steelhead and negative for fish that are eaten by steelhead) relative to Alternative 1. Consequently, Alternative 3 would not be expected to change any State or Federal species designations relative to Alternative 1 (Subsection 3.4, Other Fish Species).

Relative to the Alternative 2 (Proposed Action), Alternative 3 would release 145,000 fewer steelhead into the Dungeness, Nooksack, and Stillaguamish River Basins, which would lead to a short- and long-term reduction in the risk of competition for space and food among freshwater species relative to Alternative 2. There would also be a reduction in the risk of predation by steelhead on other fish species, and a potentially measurable reduction in the number of prey eaten by steelhead in the Puget Sound relative to Alternative 2. However, because (1) the analysis area is only a small portion of each species range, and (2) steelhead are not exclusive predators or prey for any of the fish species, Alternative 3 would be expected to have a negligible effect on other fish species (positive for fish that are eaten by steelhead and negative for fish the eat steelhead) relative to Alternative 2. Consequently, Alternative 3 would not be expected to change any State or Federal species designations relative to Alternative 2 (Subsection 3.4, Other Fish Species).

4.4.4. Alternative 4 (Transition to Native Stock) – Make a Determination that Revised HGMPs that Replace Chambers Creek Stock with a Native Broodstock Meet the Requirements of the 4(d) Rule

Under Alternative 4, WDFW would produce the same number of fish as under Alternative 2, but would replace the Chambers Creek broodstock with a local, native steelhead broodstock. Effects on other fish species would be identical as under Alternative 2 because a change in broodstock would not affect ecological interactions between hatchery-origin steelhead and other fish species.

4.5. Wildlife and Marine Mammals

4.5.1. Alternative 1 (No Action) – Do Not Make a Determination under the 4(d) Rule

Under Alternative 1, the early-winter steelhead programs in the Dungeness, Nooksack, and Stillaguamish River Basins would be terminated immediately (Subsection 2.1, Alternative 1), and fewer steelhead (juvenile and adult) would be available as a food source for predators that use steelhead as a food source, including federally listed grizzly bears, Steller sea lions, and southern resident killer whales (Subsection 3.5, Wildlife and Marine Mammals). However, because (1) Alternative 1 would only lead to a small reduction in the total number of salmon and steelhead in the Dungeness, Nooksack, and Stillaguamish River Basins or in the Puget Sound, and (2) none of these species feed exclusively on steelhead, Alternative 1 would not be expected to change the diet, survival, or distribution of any of these species relative to baseline conditions.

4.5.2. Alternative 2 (Proposed Action) – Make a Determination that the Submitted HGMPs Meet the Requirements of the 4(d) Rule

Under Alternative 2, the early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins would operate as proposed in submitted HGMPs (Subsection 2.2, Alternative 2). Consequently, relative to Alternative 1, more steelhead (juvenile and adult) would be available as a food source for predators that use steelhead as a food source, including federally listed grizzly bear, Steller sea lion, and southern resident killer whale (Subsection 3.5, Wildlife and Marine Mammals). However, because (1) Alternative 2 would only lead to a small increase in the total number of salmon and steelhead in the Dungeness, Nooksack, and Stillaguamish River Basins or in the Puget Sound, and (2) none of these species feed exclusively on steelhead, Alternative 2 would not be expected to change the diet, survival, or distribution of any of these species relative to Alternative 1.

4.5.3. Alternative 3 (Reduced Production Alternative) – Make a Determination that Revised HGMPs with Released Production Levels Meet the Requirements of the 4(d) Rule

Under Alternative 3, the early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins would be reduced by 50 percent relative to the proposed hatchery programs (Subsection 2.3, Alternative 3). Relative to Alternative 1 under which the hatchery programs would be terminated, Alternative 3 would increase the number of juvenile steelhead in the Dungeness, Nooksack, and Stillaguamish River Basins, and more steelhead (juvenile and adult) would be available as a food source for predators that use steelhead as a food source, including federally listed grizzly bear, Steller sea lion, and southern resident killer whale (Subsection 3.5, Wildlife and Marine Mammals). However, because (1) Alternative 3 would only lead to a small increase in the total number of salmon and steelhead in the Dungeness, Nooksack, and Stillaguamish River Basins or in the Puget Sound relative to Alternative 1, and

(2) none of these species feed exclusively on steelhead, Alternative 3 is not expected to change the diet, survival, distribution, or listing status of any of these species relative to Alternative 1.

Relative to Alternative 2 (Proposed Action), Alternative 3 would reduce the number of hatchery-origin steelhead released in the Dungeness, Nooksack, and Stillaguamish River Basins and, therefore, reduce the total number of steelhead available to wildlife and marine mammal predators. However, because (1) Alternative 3 would reduce the total number of juvenile hatchery-origin steelhead in the Puget Sound by a very small percentage relative to the total number of salmon and steelhead in the Dungeness, Nooksack, or Stillaguamish Basin or in Puget Sound relative to Alternative 2, and (2) none of these species feed exclusively on steelhead, Alternative 3 would not be expected to change the diet, survival, distribution, or listing status of any of these species relative to Alternative 2.

4.5.4. Alternative 4 (Transition to Native Stock) – Make a Determination that Revised HGMPs that Replace Chambers Creek Stock with a Native Broodstock Meet the Requirements of the 4(d) Rule

Under Alternative 4, WDFW would produce the same number of fish as under Alternative 2, but would replace the Chambers Creek broodstock with a local, native steelhead broodstock. Effects on wildlife and marine mammals would be identical as under Alternative 2 because a change in broodstock would not affect the number of hatchery-origin steelhead available for wildlife and marine mammals to eat.

4.6. Socioeconomics

4.6.1. Alternative 1 (No Action) – Do Not Make a Determination under the 4(d) Rule

Under Alternative 1, the early-winter steelhead programs in the Dungeness, Nooksack, and Stillaguamish River Basins would be terminated immediately (Subsection 2.1, Alternative 1). All of the hatchery facilities that support these hatchery programs would continue to operate since they support hatchery programs that are not part of the Proposed Action or its alternatives. However, these hatchery facilities would be raising fewer fish. The five hatchery facilities that are used by the early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins employ 11 full-time employees and 3 seasonal employees (Subsection 3.6, Socioeconomics), and some of these jobs may be lost under Alternative 1. Additionally, the hatchery programs would no longer procure local goods and services, which contribute to personal income or jobs in the regional economy. NMFS estimates that the early-winter steelhead programs in the Dungeness, Nooksack, and Stillaguamish River Basins result in \$1.89 million in annual angler expenditure and \$3.58 million in economic output (Subsection 3.6, Socioeconomics). The economic contribution of these hatchery programs would be eliminated under Alternative 1.

Alternative 1 would reduce the number of steelhead available to tribal members as a food source and may increase tribal reliance on other consumer goods or increase travel costs to participate in other fisheries relative to baseline conditions (Subsection 3.6, Socioeconomics). Further, Alternative 1would reduce the amount of revenue that could be generated through the sale of fish relative to baseline conditions.

4.6.2. Alternative 2 (Proposed Action) – Make a Determination that the Submitted HGMPs Meet the Requirements of the 4(d) Rule

Under Alternative 2, the early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins would operate as proposed in submitted HGMPs (Subsection 2.2, Alternative 2). Relative to Alternative 1, Alternative 2 would increase the number of full-time and seasonal jobs and the local procurement of goods and services, which would contribute to personal income or jobs in the regional economy. These effects would, however, continue to represent baseline conditions. NMFS estimates that the early-winter steelhead programs in the Dungeness, Nooksack, and Stillaguamish River Basins result in $1.89 million in annual angler expenditure and $3.58 million in economic output under baseline conditions (Subsection 3.6, Socioeconomics). These socioeconomic benefits would continue under Alternative 2.

Relative to Alternative 1, Alternative 2 would increase the number of steelhead available to tribal members as a food source and may reduce tribal reliance on other consumer goods or reduce travel costs to participate in other fisheries (Subsection 3.6, Socioeconomics). Further, relative to Alternative 1, Alternative 2 would increase the amount of revenue that could be generated through the sale of fish. These effects would, however, continue to represent baseline conditions.

4.6.3. Alternative 3 (Reduced Production Alternative) – Make a Determination that Revised HGMPs with Released Production Levels Meet the Requirements of the 4(d) Rule

Under Alternative 3, the early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins would be reduced by 50 percent relative to the proposed hatchery programs (Subsection 2.3, Alternative 3). Relative to Alternative 1 under which the hatchery programs would be terminated, Alternative 3 would increase the number of full-time and seasonal jobs and the local procurement of goods and services, which would contribute to personal income or jobs in the regional economy. Such an increase would not likely match current employment and expenditure conditions, however, since production would be decreased compared to baseline conditions. NMFS estimates that the early-winter steelhead programs in the Dungeness, Nooksack, and Stillaguamish River Basins result in $1.89 million in annual angler expenditure and $3.58 million in economic output (Subsection 3.6, Socioeconomics). Under Alternative 3, these economic benefits would continue, but at a lesser level.

Relative to Alternative 1, Alternative 3 would increase the number of steelhead available to tribal members as a food source and may reduce tribal reliance on other consumer goods or reduce travel costs to participate in other fisheries (Subsection 3.6, Socioeconomics). Further, relative to Alternative 1, Alternative 3 would increase the amount of revenue that could be generated through the sale of fish. Such increases would not likely match current food source availability and revenues, however, since production would be decreased compared to baseline conditions.

Relative to Alternative 2 (Proposed Action), Alternative 3 would reduce the number of hatchery-origin steelhead released in the Dungeness, Nooksack, and Stillaguamish River Basins and, therefore, reduce the total number of steelhead harvested in these three river basins. Under Alternative 2, the five hatchery facilities that are used by the early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins would be expected to employ 11 full-time employees and 3 seasonal employees (Subsection 3.6, Socioeconomics), and some of these jobs may be lost under Alternative 3. Relative to Alternative 2, Alternative 3 would reduce angler expenditure and economic output.

Relative to Alternative 2, Alternative 3 would reduce the number of steelhead available to tribal members as a food source and may increase tribal reliance on other consumer goods or increase travel costs to participate in other fisheries (Subsection 3.6, Socioeconomics). Further, relative to Alternative 2, Alternative 3 would reduce the amount of revenue that could be generated through the sale of fish.

4.6.4. Alternative 4 (Transition to Native Stock) – Make a Determination that Revised HGMPs that Replace Chambers Creek Stock with a Native Broodstock Meet the Requirements of the 4(d) Rule

Under Alternative 4, WDFW would produce the same number of fish as under the Alternative 2, but would replace the Chambers Creek broodstock with a native steelhead broodstock. Effects on socioeconomic would be identical as under Alternative 2 because the same number of fish would be produced and harvested.

4.7. Environmental Justice

4.7.1. Alternative 1 (No Action) – Do Not Make a Determination under the 4(d) Rule

Under Alternative 1, the early-winter steelhead hatchery programs would be terminated, and there would be a loss of fishing opportunity in the Dungeness, Nooksack, and Stillaguamish River Basins. Two of the three counties in the analysis area are environmental justice communities of concern because they meaningfully exceed thresholds for low income or minority populations: Clallam and Snohomish Counties (Table 14). However, all counties in the analysis area would be similarly affected by the termination of the early-winter steelhead hatchery programs under Alternative 1. Therefore, Alternative 1 would not be expected to have a disproportionate impact on Clallam or Snohomish Counties.

Because of the unique connection of Native American tribes to salmon and steelhead, any reduction in harvest opportunity poses a disproportionate effect on Native American tribes. Therefore, Alternative 1 would have a moderate, adverse impact on the following tribes: Lummi Nation, Nooksack Tribe, Stillaguamish Indian Tribe, Tulalip Tribes, Port Gamble S'Klallam Tribe, Jamestown S'Klallam Tribe, and Lower Elwha Klallam Tribe.

4.7.2. Alternative 2 (Proposed Action) – Make a Determination that the Submitted HGMPs Meet the Requirements of the 4(d) Rule

Under Alternative 2, the early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins would operate as proposed in submitted HGMPs (Subsection 2.2, Alternative 2). Relative to Alternative 1, Alternative 2 would increase fishing opportunity in the Dungeness, Nooksack, and Stillaguamish River Basins. However, such increases in fishing opportunities would be at the same level as under current, baseline conditions.

Two of the three counties in the analysis area are environmental justice communities of concern because they meaningfully exceed thresholds for low income or minority populations: Clallam and Snohomish Counties (Table 14). However, all counties in the analysis area would be similarly affected by implementation of the proposed HGMPs under Alternative 2. Therefore, Alternative 2 would not be expected to have a disproportionate impact on Clallam or Snohomish Counties.

Because of the unique connection of Native American tribes to salmon and steelhead, any changes in harvest opportunity would pose a disproportionate effect on Native American tribes if the change reduces harvest in their "usual and accustomed" fishing areas. Because Alternative 2 would increase harvest opportunity for tribes in the analysis area relative to Alternative 1, there would be a moderate, beneficial impact on the following tribes: Lummi Nation, Nooksack Tribe, Stillaguamish Indian Tribe, Tulalip Tribse, Port Gamble S'Klallam Tribe, Jamestown S'Klallam Tribe, and Lower Elwha Klallam Tribe. However, such increases in harvest opportunities would be at the same levels as under current, baseline conditions.

4.7.3. Alternative 3 (Reduced Production Alternative) – Make a Determination that Revised HGMPs with Released Production Levels Meet the Requirements of the 4(d) Rule

Under Alternative 3, the early-winter steelhead hatchery programs in the Dungeness, Nooksack, and Stillaguamish River Basins would be reduced by 50 percent relative to the proposed hatchery programs (Subsection 2.3, Alternative 3). Relative to Alternative 1 under which the hatchery programs would be terminated, Alternative 3 would increase fishing opportunity in the

Dungeness, Nooksack, and Stillaguamish River Basins. Such increases would not be at the same levels as under current, baseline conditions.

Two of the three counties in the analysis area are environmental justice communities of concern because they meaningfully exceed thresholds for low income or minority populations: Clallam and Snohomish Counties (Table 14). However, all counties in the analysis area would be similarly affected by implementation of the proposed HGMPs under Alternative 2. Therefore, Alternative 2 would not be expected to have a disproportionate impact on Clallam or Snohomish Counties.

Because of the unique connection of Native American tribes to salmon and steelhead, any changes in harvest opportunity would pose a disproportionate effect on Native American tribes if the change reduces harvest in their "usual and accustomed" fishing areas. Because Alternative 3 would increase harvest opportunity for tribes in the analysis area relative to Alternative 1, there would be a moderate, beneficial impact on the following tribes: Lummi Nation, Nooksack Tribe, Stillaguamish Indian Tribe, Tulalip Tribes, Port Gamble S'Klallam Tribe, Jamestown S'Klallam Tribe, and Lower Elwha Klallam Tribe. This benefit would, however, be lower than under current, baseline conditions.

Relative to Alternative 2 (Proposed Action), Alternative 3 would reduce harvest opportunity for tribes in the analysis area, and there would be a moderate, adverse impact on the following tribes: Lummi Nation, Nooksack Tribe, Stillaguamish Indian Tribe, Tulalip Tribes, Port Gamble S'Klallam Tribe, Jamestown S'Klallam Tribe, and Lower Elwha Klallam Tribe.

4.7.4. Alternative 4 (Transition to Native Stock) – Make a Determination that Revised HGMPs that Replace Chambers Creek Stock with a Native Broodstock Meet the Requirements of the 4(d) Rule

Under Alternative 4, WDFW would produce the same number of fish as under Alternative 2, but would replace the Chambers Creek broodstock with a native steelhead broodstock. Effects on environmental justice would be identical as under Alternative 2 because the same number of fish would be produced and harvested.

5. CUMULATIVE EFFECTS

5.1. Introduction

The National Environmental Policy Act defines cumulative effects as “the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency (Federal or non-Federal) or person undertakes such other actions” (40 CFR 1508.7). Chapter 3, Affected Environment, describes the baseline conditions for each resource and reflects the effects of past and existing actions. Chapter 4, Environmental Consequences, evaluates the direct and indirect effects of the alternatives on each resource’s baseline conditions. This chapter considers the cumulative effects of each alternative in the context of past actions, existing conditions, and reasonably foreseeable future actions and conditions.

The cumulative effects analysis area includes the project area described in Subsection 1.4, and additionally includes the entire United States and Canadian portions of the Strait of Juan de Fuca, Strait of Georgia, and all connecting channels and adjoining waters, all of which encompasses an area collectively known as the Salish Sea. The area is also commonly referred to as the Georgia Basin, Strait of Juan de Fuca, and Puget Sound ecosystem. This cumulative effects area was determined based on the geography, topography, waterways, and natural interactions that occur among the ecosystems present in Puget Sound. Biological resources and human populations within the Salish Sea cumulative effects area share a common airshed, common watershed, and common flyway. The developed area has a population of approximately 7 million people with some population projections to 9.4 million by 2025 (EPA 2008).

Provided below are known past, present, and future actions from a regional context that have occurred, are occurring, and are reasonably likely to occur within the cumulative effects analysis area. Expected future actions include climate change, human development, and planned restoration activities. Many plans, regulations, and laws are in place, as well as agreements between the United States and Canada to minimize the effects of development and to restore habitat function. However, it is unclear if these plans, regulations, and laws will be successful in meeting their environmental goals and objectives. In addition, it is impossible to predict the magnitude of effects from future development and habitat restoration for several reasons: (1) the activities may not have yet been formally proposed, (2) mitigation measures specific to future actions may not have been identified for many proposed projects, and (3) there is uncertainty whether mitigation measures for these actions will be fully implemented. However, when combined with climate change, a general trend in expected cumulative effects can be estimated for each resource as described in Subsection 5.5, Cumulative Effects by Resource.

Subsection 5.2, Historical Actions, summarizes past actions that affected the cumulative effects analysis area; Subsection 5.3, Current Conditions, describes current overall trends for the area;

and Subsection 5.4, Future Actions, describes climate change effects, development, and habitat restoration activities and objectives supported by agencies and other non-governmental organizations to restore habitat in the cumulative effects analysis area. Finally, Subsection 5.5, Cumulative Effects by Resource, describes how these past, present, and future actions affect each resource evaluated in this EA, and specifically focuses on the effects of alternatives, when possible. Because of the large geographic scope of the analysis, it is not feasible to conduct a detailed assessment of all project-level activities that have occurred, are occurring, or are planned in the future for the cumulative effects analysis area. Rather, this cumulative effects analysis qualitatively assesses the overall trends in cumulative effects considering past, present, and reasonably foreseeable future actions, and describes how the alternatives contribute to that trend.

5.2. Historical Actions

Humans occupied the shores and islands of the Salish Sea for at least the past 8,000 years (Stein 2000). Before Europeans arrived in the Salish Sea ecosystem, most human inhabitants were hunter-gatherers. They relied on sea life for food, animals for food and warm clothing, and trees for building materials. Indigenous peoples were known to use the waterways of the Salish Sea as trading routes. Fire was used to modify the environment, to clear areas to aid hunting, to promote berry production, and to support the growth of grasses for making nets, baskets, and blankets (Barsh 2003).

In the 1800s, with the arrival of the first Europeans, trapping and logging were initiated on a large scale, which changed the landscape. Washington State became one of the top five producers of timber, and salmon harvest increased by over 2,000 percent compared to harvest before European arrival. As natural resource extraction and the number of people in the area increased, the quality of the Salish Sea ecosystem declined. Most of the old-growth forest was harvested, and much forestland was converted to human-dominated uses, such as agriculture and urban development. The quantity and availability of tidal marsh and other freshwater estuarine ecosystem types declined, floodplains were altered, rivers and streams were channelized, estuaries were filled, shorelines were hardened and/or modified, water and air quality declined, pollution and marine traffic increased, and habitat was lost (British Columbia Ministry of Water, Land, and Air Protection [BCMWLAP] 2002; Puget Sound Partnership [PSP] 2012). As a result, the number of marine-related species at risk in the Salish Sea ecosystem increased, as did the presence of non-native invasive species (Quinn 2010).

5.3. Current Conditions

As described in Subsection 5.2, Historical Actions, substantial changes have occurred to land uses and the marine environment in the Salish Sea cumulative effects analysis area, but the area remains one of the most ecologically diverse in North America, containing a wide range of species and habitats that span international boundaries (EPA 2011). The topography of the area creates highly variable local-scale climates and, in combination with diverse soil types, results in a wide variety of environmental conditions. This variety is important because it supports a diversity of fish species and life histories as described in Subsection 3.3, Salmon and Steelhead, and Subsection 3.4, Other Fish Species. For example, the diversity (genetic and behavioral) represented by variation in Chinook salmon and steelhead life histories helps both species adapt to short-term and long-term changes in their environment over time (McElhany et al. 2000).

The Center for Biological Diversity (2005) identified 7,000 species of organisms that occur in Puget Sound, and the area is considered one of the most productive areas for salmon along the Pacific Coast (Lombard 2006). However, the World Wildlife Fund (2012) considers the remaining natural habitats in the Salish Sea area to be threatened from ongoing urbanization, agricultural practices, fire suppression, introduction of noxious weeds, flood control efforts, operation of hydroelectric dams, and logging. For example, these human-induced factors (e.g., habitat modifications, water quality degradation, presence of dams and fish barriers, and other factors) have affected overall abundance, productivity, diversity, and distribution of salmon and steelhead in Puget Sound. In addition, aquaculture (farming of fish, shellfish, and aquatic plants in fresh and marine water for direct harvest), which is practiced in Washington and British Columbia, has the potential to affect other aquatic organisms. Altogether, these stressors under current conditions are expected to continue under future actions as described below.

5.4. Future Actions and Conditions

Reasonably foreseeable future actions include climate change, development, and habitat restoration.

5.4.1. Climate Change

The changing climate is becoming recognized as a long-term trend that is occurring throughout the world. Within the Pacific Northwest, Ford (2011) summarized expected climate changes in the coming years as leading to the following physical and chemical changes (certainty of occurring is in parentheses):

- Increased air temperature (high certainty)
- Increased winter precipitation (low certainty)
- Decreased summer precipitation (low certainty)
- Reduced winter and spring snowpack (high certainty)

- Reduced summer stream flow (high certainty)
- Earlier spring peak flow (high certainty)
- Increased flood frequency and intensity (moderate certainty)
- Higher summer stream temperatures (moderate certainty)
- Higher sea level (high certainty)
- Higher ocean temperatures (high certainty)
- Intensified upwelling (moderate certainty)
- Delayed spring transition (moderate certainty)
- Increased ocean acidity (high certainty)

These changes will affect human and other biological ecosystems within the cumulative effects analysis area (Ecology 2012a). Changes to biological organisms and their habitats are likely to include shifts in timing of life history events, changes in growth and development rates, changes in habitat and ecosystem structure, and rise in sea level and increased flooding (Littell et al. 2009; Johannessen and Macdonald 2009).

For the Pacific Northwest portion of the United States, Hamlet (2011) notes that climate changes will have multiple effects. Expected effects include:

- Overtaxing of storm water management systems at certain times
- Increases in sediment inputs into water bodies from roads
- Increases in landslides
- Increases in debris flows and related scouring that damages human infrastructure
- Increases in fires and related loss of life and property
- Reductions in the quantity of water available to meet multiple needs at certain times of year (e.g., for irrigated agriculture, human consumption, and habitat for fish)
- Shifts in irrigation and growing seasons
- Changes in plant, fish, and wildlife species' distributions and increased potential for invasive species
- Declines in hydropower production
- Changes in heating and energy demand

- Impacts to homes along coastal shorelines from beach erosion and rising sea levels

The most heavily affected ecosystems and human activities along the Pacific coast are likely to be near areas having high human population densities, and the continental shelves off Oregon and Washington (Halpern et al. 2009).

Several studies note that similar changes are expected to occur in British Columbia. For example, climate change effects in Georgia Strait are expected to include warming of marine waters (Littell et al. 2009) and fresh waters (Perry 2009), and changes in river flow patterns from snow-melt-dominated conditions to rainfall-dominated conditions. Examples of the effects of climate change on human populations include loss of agricultural land because of inundation by rising sea levels, increases in storm intensity duration and frequency, salinization of municipal water intakes, and increases in the risk of tidal flat erosion and dike breaching and flooding (Natural Resources Canada [NRC] 2014).

5.4.2. Development

Future human population growth in the Seattle and Vancouver areas, and the areas between them, is expected to continue over the next 15 years (Metro Vancouver 2013; Puget Sound Regional Council 2013) and will result in increased demand for housing, transportation, food, water, energy, and commerce. These needs will result in changes to existing land uses because of increases in residential and commercial development and roads, increases in impervious surfaces, conversions of private agricultural and forested lands to developed uses, increases in use of non-native species and increased potential for invasive species, and redevelopment and infill of existing developed lands. The need to provide food and supplies to a growing human population in the cumulative effects analysis area will result in increases in shipping, increases in withdrawals of fresh water to meet increasing food and resource requirements, and increases in energy demands. Although the rate of urban sprawl has been decreasing in comparison to previous increases in the late 1900s (Puget Sound Regional Council 2012), development will continue to affect the natural resources in the cumulative effects analysis area.

To help protect environmental resources in the cumulative effects analysis area from potential future development effects, both the United States and Canada have Federal environmental protection agencies and Federal laws, regulations, and policies that are designed to conserve each nation’s air, water, and land resources. Regulatory processes involve agency review, approval, and permitting of development actions. Regulatory examples include the Federal Endangered Species Act in the United States and the Species at Risk Act in Canada. Other examples include the Navigable Waters regulations of the Clean Water Act in the United States, and the Navigable Waters Protection Act in Canada. In the United States, aquaculture facilities (such as enclosed facilities for raising and selling fish, shellfish [including geoducks], and aquatic plants) are regulated by Washington State. In Canada, aquaculture facilities are regulated by British Columbia Department of Fisheries, and Fisheries and Oceans Canada. These environmental laws will continue to require agency review and approval of proposed activities.

In addition to Federal laws and processes, state and provincial laws, regulations, and guidelines will help decrease the effects of future commercial, industrial, and residential development on natural ecosystems. In Washington State, various habitat conservation plans (HCPs) have been implemented, such as the Washington Department of Natural Resources (DNR) Forest Practices HCP (DNR 2005), and other HCPs are in development (e.g., DNR Aquatic Lands HCP and WDFW Wildlife Areas HCP). These plans will provide long-term, landscape-based protection of federally listed and non-listed species considered at risk of extinction in Washington's private and state forested lands. Other state laws, regulations, and guidance include the Washington State Environmental Policy Act, and its Endangered, Threatened, and Sensitive Species Act as described in Subsection 1.7.3, State Guidance and Regulations. A law unique to the State of Washington is the Growth Management Act (Chapter 36.70A Revised Code of Washington), which requires local land use planning and development of regulations, including identification and protection of critical areas from future development.

Although the Province of British Columbia does not have comparable growth management laws and regulations for future development, the province reviews and approves future development primarily through its Environmental Assessment Act (which is separate from the Federal Canadian Environmental Assessment Act) and other laws and regulations (such as the Environment and Land Use Act, Environmental Management Act, Forest Act, Water Act, Water Protection Act, Wildlife Act, Fisheries Act, Shorelines Management Act, and Fish Protection Act). These provincial and state regulations will continue to help decrease habitat fragmentation, avoid residential development and urban sprawl in sensitive habitat and ecosystems, and decrease contamination to air, lands, and waterways.

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 (PSRC 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.

In lower British Columbia, local zoning and development laws will help to protect open space from future development. The Greater Vancouver Regional District designates Green Zones to protect natural land assets (Greater Vancouver Regional District 2005). In addition, the Fraser River Estuary Management 1 Plan was developed by a partnership of agencies and serves as a policy guide for municipalities and other agencies with jurisdiction or interest in the Fraser River estuary (Fraser River Estuary Management Program 2012). In ecologically sensitive areas, this plan is focused on protecting critical fish and wildlife functions. In addition, municipalities in British Columbia have community plans with policies and guidelines related to land use, development, services, amenities, and infrastructure related to future development (NRC 2014). The plans identify environmentally sensitive areas where future development is limited to protect environmental attributes.

In summary, in the Washington and British Columbia portions of the cumulative effects analysis area, Federal, state, and local laws, regulations, and policies will be applied with the intent to better enforce environmental protection for proposed future project developments. These laws, regulations, and policies include processes for public input, agency reviews, mitigation measures, permitting, and monitoring. The intent of these processes is to help ensure that development projects will occur in a manner that protects sensitive natural resources. The environmental goals and objectives of these processes are aimed at protecting ecosystems from activities that are regulated; however, not all activities are regulated to the same extent (e.g., large developments tend to be regulated more than smaller developments). Further, it is uncertain if all environmental goals and objectives can be successfully met by such processes. Unregulated or minimally regulated activities may lead to cumulative effects on sensitive natural resources over time. Thus, although Federal, state, and local laws, regulations, policies, and guidelines are in place to protect environmental resources from future development effects, there will continue to be some cumulative environmental degradation in the future from development, albeit likely to a lesser extent than has occurred historically when environmental regulatory protections did not exist or were not comprehensive and collaborative.

5.4.3. Habitat Restoration

To counterbalance the human-induced changes that will affect biodiversity in the cumulative effects analysis area (Subsection 5.4.2, Development), future funding for environmental restoration efforts will continue to help create a healthy environment and sustainable ecosystem (PSRC 2009; BCMWLAP 2002). United States Federal agencies and organizations are expected to continue to support habitat protection and restoration initiatives/processes in Puget Sound, including projects such as the Puget Sound Nearshore Ecosystem Restoration Project (Puget Sound Nearshore Ecosystem Restoration Partnership 2013), which is a partnership between the U.S. Army Corps of Engineers and WDFW for the purpose of identifying ecosystem degradation, formulating solutions, and recommending actions and projects to help restore Puget Sound. The Puget Sound Partnership (formerly the Shared Strategy for Puget Sound) is a collaborative initiative that will continue efforts to recover the Puget Sound ecosystem (including listed salmon, steelhead, and other species) with the support of NMFS, U.S. Fish and Wildlife Service, Washington State, Puget Sound tribes, local governments, and key non-government organizations. In addition, implementation of salmon recovery plans in Puget Sound (72 Fed. Reg. 2493, January 19, 2007, for Chinook salmon, and 72 Fed. Reg. 29121, May 24, 2007, for Hood Canal summer-run chum salmon), will continue to recover salmon and steelhead and the habitats on which they depend in Puget Sound (Subsection 1.5.11, Recovery Plans for Puget Sound Salmon). It is expected that NMFS will continue to provide funding for habitat restoration initiatives through the Pacific Coastal Salmon Recovery Fund (NMFS 2011a). However, based on a recent review of the implementation of the Puget Sound Chinook salmon recovery plan (NMFS 2011b), habitat continues to decline and habitat protection tools currently in place continue to need improvement.

Federal Canadian funding for habitat restoration includes several ongoing and expected future funded programs supported by Environment Canada. These projects regularly provide annual funding for habitat restoration and include:

- B.C. Hydro Bridge Coastal Fish and Wildlife Restoration Program (designed to fund projects to restore fish and wildlife populations and habitats in watersheds impacted by hydroelectric generation facilities)
- Habitat Conservation Trust Fund (includes funds for habitat enhancement and restoration)
- Public Conservation Assistance Fund (with objectives similar to the Habitat Conservation Trust Fund)
- EcoAction Community Funding Program (with several objectives that include habitat enhancement and rehabilitation)

It is expected that Washington State will continue to support habitat restoration through actions similar to recent support efforts. In addition to cooperative partnerships with Federal agencies as described above, Ecology (2012b) reserves funding for cleanups of toxics in Puget Sound. Although receiving substantial Federal support, the Puget Sound Partnership is a state agency that was created to lead the recovery of the Puget Sound ecosystem (PSP 2010). The agency created, and is overseeing implementation of, a roadmap to a healthy Puget Sound. Objectives include prioritizing cleanup and improvement projects; coordinating Federal, state, local, tribal, and private resources; and ensuring that all agencies and funding partners are working cooperatively. Washington State also created the Salmon Recovery Funding Board, which administers Federal and Washington State funds to protect and restore salmon and steelhead habitat. Priorities for recovering the Puget Sound ecosystem include reducing land development pressure on ecologically important and sensitive areas, protecting and restoring floodplain function, and protecting and recovering salmon and freshwater resources (PSP 2012). In marine and freshwater areas, development will continue to be encouraged away from ecologically important and sensitive nearshore areas and estuaries, and efforts will be made to reduce sources of pollution into Puget Sound (including stormwater runoff). Approaches will be used to help preserve the natural functions of the ecosystem and support sustainable economic growth. Local community efforts, such as smaller community habitat restoration and protection efforts, will help protect sensitive areas in Puget Sound.

In British Columbia, the provincial Watershed Restoration Program under Forest Renewal British Columbia will continue to restore the productive capacity of fisheries, and forest and aquatic resources that have been impacted by past forest practices. The Watershed Restoration Program hastens the recovery of degraded environmental resources in logged watersheds by identifying the needs for proposed restoration projects and by designing and implementing restoration that re-establishes conditions more similar to those found in watersheds that are not degraded. Other provincial and local habitat restoration initiatives will be continued, including the Salmon Habitat Restoration Program, which has historically been supported by the Canadian Federal government, but is now supported by the provincial and local governments.

In summary, a variety of Federal, state, provincial, and local programs will help restore degraded habitat conditions in the cumulative effects analysis area. Collectively, these programs will help to counterbalance habitat degradation and long-term detrimental cumulative impacts to natural resources in the cumulative effects analysis area, which have previously contributed to Federal and state listings of fish and wildlife species (Subsection 3.3, Salmon and Steelhead; Subsection 3.4, Other Fish Species; and Subsection 3.5, Wildlife).

5.5. Cumulative Effects by Resource

Provided below is an analysis of the cumulative effects of climate change, development, and habitat restoration under the alternatives and for each resource analyzed in this EA. The resources for which cumulative effects are described are: water quantity and quality, salmon and steelhead, other fish species, wildlife, socioeconomics, and environmental justice.

5.5.1. Water Quantity and Quality

Subsection 3.1, Water Quantity, and Subsection 3.2, Water Quality, describes the baseline conditions of water quantity and quality. These conditions are the result of many years of climate change, development, and habitat restoration. The effects of the alternatives on water quality and quantity are described in Subsection 4.1, Water Quantity, and Subsection 4.2, Water Quality. Future actions in the overall cumulative effects analysis area are described in Subsection 5.4, Future Actions. This subsection considers effects that may occur as a result of the alternatives being implemented at the same time as other anticipated future actions. This subsection discusses the incremental impacts of the alternatives in addition to past, present, and reasonably foreseeable future actions (i.e., cumulative effects) on water quantity and water quality.

Successful operation of hatcheries depends on a constant supply of high quality surface, spring, or groundwater that, after use in hatchery facilities, is discharged to adjacent receiving environments. Climate change and development are expected to affecting water quality by increasing water temperatures and affect water quantity by changing seasonality and magnitude of river flows. Although existing regulations are intended to help protect water quality and quantity from effects related to future development, the effectiveness of these regulations over time is likely to vary. Future habitat restoration would likely improve water quality and quantity (such as helping to decrease water temperatures through shading, decrease sedimentation, decrease water diversions, and protect aquifers and recharge areas). Overall, cumulative effects of climate change and development on water quality and quantity are more likely to impair water quality and reduce water quantity than is described in Subsection 4.1, Water Quantity, and Subsection 4.2, Water Quality. These effects may be offset to some extent by habitat restoration; however, these habitat actions may not fully, or even partially, mitigate for the impacts of climate change and development on water quality and quantity, but this is the goal of many of the restoration programs.

In summary, cumulative effects from climate change, development, and habitat restoration would likely impact water quality (particularly water temperature changes) and water quantity (increased demand on limited water supplies) in the analysis area more than that described in Subsection 4.1, Water Quantity, and Subsection 4.2, Water Quality) under all alternatives. None of the alternatives would affect the overall trend in cumulative effects on water quantity and quality.

5.5.2. Salmon and Steelhead

Subsection 3.3, Salmon and Steelhead, describes baseline conditions for salmon and steelhead. These conditions are the result of many years of climate change, development, and habitat restoration. The expected direct and indirect effects of the alternatives on salmon and steelhead are described in Subsection 4.3, Salmon and Steelhead. Future actions are described in Subsection 5.4, Future Actions. This subsection describes cumulative effects on salmon and steelhead that may occur as a result of implementing any of the alternatives at the same time as other future actions. This subsection discusses the incremental impacts of the alternatives in addition to past, present, and reasonably foreseeable future actions (i.e., cumulative effects) on salmon and steelhead.

Salmon and steelhead abundance naturally alternates between high and low levels on large temporal and spatial patterns that may last centuries and on more complex ecological scales than can be easily observed (Rogers et al. 2013). Current run sizes of salmon and steelhead in the cumulative effects analysis area are about 36 percent of historical run sizes in British Columbia, and are about 8 percent of historical run sizes in Puget Sound (Lackey et. al. 2006). Thus, cumulative effects on salmon and steelhead may be greater than the direct and indirect effects of each alternative as analyzed in Subsection 4.3, Salmon and Steelhead, under all alternatives. This subsection provides brief overviews of the effects of climate changes, development, and habitat restoration on salmon and steelhead.

In addition to hatchery production of salmon and steelhead in Puget Sound (described in Subsection 3.3, Salmon and Steelhead), hatchery production and salmon aquaculture also occur in the Canadian portion of the cumulative effects analysis area. The Canadian Salmonid Enhancement Program uses hatcheries, along with other strategies, to conserve and rebuild populations of natural-origin salmon and to provide fishing opportunities for Canadians (MacKinlay et al. 2004). In 2002, these hatcheries raised 173 million salmon, steelhead, and trout (Chinook salmon, 30 percent; chum salmon, 42 percent; coho salmon, 11 percent; pink salmon, 10 percent; sockeye salmon, 7 percent; steelhead, less than 1 percent; and cutthroat trout, less than 1 percent). Total time in hatcheries for these fish is 10 months or less with subsequent release into freshwater or marine environments. Releases are from 18 major hatcheries, 21 community hatcheries, and 16 public involvement or educational hatcheries. Releases in 2009 (most recent information available) were 300 million fish. The majority of the 2009 fish released were sockeye salmon (about half the fish released) followed by chum salmon, Chinook salmon, pink salmon, coho salmon, steelhead, and cutthroat trout (Sandher et al. 2010). Aquaculture operations also occur in British Columbia where salmon are raised in marine pens to adulthood with subsequent seafood processing and no fish releases into the freshwater or marine environment. These aquaculture operations raise almost exclusively Atlantic salmon. Hatchery releases within the Salish Sea, along with other observed environmental trends as described in the following subsections, would affect continued long-term viability of natural-origin salmon and steelhead.

The effects of climate change on salmon and steelhead are described in general in ISAB (2007), and would vary among species and among species' life history stages. Effects of climate change may affect virtually every species and life history type of salmon and steelhead in the cumulative effects analysis area (Glick et al. 2007; Mantua et al. 2009). Cumulative effects from climate change, particularly changes in streamflow and water temperatures, would likely impact hatchery-origin and natural-origin salmon and steelhead life stages in various ways as described below and shown in Table 17. Under all alternatives, impacts to salmon and steelhead from climate change are expected to be similar, because climate change would impact fish habitat under each alternative in the same manner.

Table 17. Examples of potential impacts of climate change by salmon and steelhead life stage under all alternatives.

Life Stage	Effects
Egg	1) Increased water temperatures and decreased flows during spawning migrations for some species would increase pre-spawning mortality and reduce egg deposition. 2) Increased maintenance metabolism would lead to smaller fry. 3) Lower disease resistance may lead to lower survival. 4) Changed thermal regime during incubation may lead to lower survival. 5) Faster embryonic development would lead to earlier hatching.
Spring and Summer Rearing	1) Faster yolk utilization may lead to early emergence. 2) Smaller fry are expected to have lower survival rates. 3) Higher maintenance metabolism would lead to greater food demand. 4) Growth rates would be slower if food is limited or if temperature increases exceed optimal levels; growth could be enhanced where food is available, and temperatures do not reach stressful levels. 5) Predation risk would increase if temperatures exceed optimal levels. 6) Lower flows would decrease rearing habitat capacity.
Overwinter Rearing	1) Smaller size at start of winter is expected to result in lower winter survival. 2) Mortality would increase because of more frequent flood flows as snow level rises. 3) Warmer winter temperatures would lead to higher metabolic demands, which may also contribute to lower winter survival if food is limited, or higher winter survival if growth and size are enhanced.

Sources: ISAB (2007), Glick et al. (2007), Beamish et al. (2009), and Beechie et al. (2013).

Previous and new developments (such as residential, commercial, transportation, and energy development); accidental discharges of oil, gas, and other hazardous materials; and the potential for landowner and developer noncompliance with regulations continue to affect aquatic habitat used by salmon and steelhead (Puget Sound Action Team 2007). Although regulatory changes for increased environmental protection (such as local critical areas ordinances), monitoring, and enforcement have helped reduce impacts of development on salmon and steelhead in fresh and marine waters, development may continue to reduce salmon and steelhead habitat, decrease water quality, and contribute to salmon and steelhead mortality. These developments result in environmental effects such as land conversion, sedimentation, impervious surface water runoff to streams, changes in stream flow because of increased consumptive uses, shoreline armoring effects, channelization in lower river areas, barriers to fish passage, and other types of environmental changes that would continue to affect hatchery-origin and natural-origin salmon and steelhead (Quinn 2010).

The primary cause of these continuing development changes is the continued increase in human population in the cumulative effects analysis area, which also leads to fisheries management challenges associated with overfishing (Puget Sound Action Team 2007). Development would more likely affect species that reside in lower river areas (such as floodplains and estuaries) most directly because that is where development tends to be concentrated. Effects from development are expected to affect salmon and steelhead similarly under all alternatives because preferred development sites would not change by alternative scenario.

Restoration of habitat in the cumulative effects analysis area will improve salmon and steelhead habitat in general under all alternatives, with particular benefits to freshwater and estuarine environments considered to be important for the survival and reproduction of fish. As a result, habitat restoration would be expected to improve fish survival in local areas (Puget Sound Action Team 2007). However, habitat restoration alone will not substantially increase survival and abundance of salmon and steelhead. In addition, habitat restoration is dependent on continued funding, which is difficult to predict when economic recessions occur or governments experience deficits. Benefits from habitat restoration are expected to affect salmon and steelhead survival similarly under all alternatives.

The potential benefits of habitat restoration actions within the cumulative effects analysis area are difficult to quantify, but are expected to occur in localized areas where the activities occur. These actions may not fully mitigate for the impacts of climate change and development on fish and wildlife and their associated habitats. However, climate change and development will continue to occur over time and affect aquatic habitat, while habitat restoration (which is dependent on funding and is localized in areas where agencies and stakeholders' habitat restoration actions occur) is less certain under all alternatives.

In summary, aquatic habitat may continue to degrade over time under all alternatives, which may reduce the abundance and productivity of natural-origin salmon and steelhead populations. Hatchery-origin salmon and steelhead may be similarly affected. Although none of the alternatives would affect the overall trend in cumulative effects on salmon and steelhead, Alternative 4 could help mitigate adverse effects on steelhead. That is, because Alternative 4 would use a local, native broodstock (unlike under Alternative 1 through Alternative 3), the hatchery programs could be used to reduce the extinction risk of natural-origin populations resulting from cumulative effects such as habitat degradation in the Dungeness, Nooksack, and Stillaguamish River Basins.

5.5.3. Other Fish Species

Subsection 3.4, Other Fish Species, describes the baseline conditions of fish species other than salmon and steelhead. These conditions are the result of many years of climate change, development, and habitat restoration. The effects of the alternatives on other fish species are described in Subsection 4.4, Other Fish Species. Future actions in the overall cumulative effects analysis area are described in Subsection 5.4, Future Actions. This subsection considers effects that may occur as a result of the alternatives being implemented at the same time as other anticipated future actions. This subsection discusses the incremental impacts of the alternatives in addition to past, present, and reasonably foreseeable future actions (i.e., cumulative effects) on fish species other than salmon and steelhead.

Other fish species that have a relationship to salmon and steelhead include bull trout, rainbow trout, coastal cutthroat trout, sturgeon and lamprey, forage fish, groundfish, and resident freshwater fish (Subsection 3.4, Other Fish Species). Similar to salmon and steelhead species, these fish species require and use a diversity of habitats. However, similar to effects described above for salmon and steelhead, these other fish species may also be affected by climate change and development because of the overall potential for loss or degradation of aquatic habitat or the inability to adapt to warmer water temperatures. In addition, climate change and development may attract non-native aquatic plants that may, over time, out-compete native aquatic plants that provide important habitat to native fish (Patrick et al. 2012).

As discussed in Subsection 5.4.3, Habitat Restoration, the extent to which habitat restoration actions may mitigate impacts from climate change and development is difficult to predict. These actions may not fully mitigate for the effects of climate change and development.

In summary, cumulative effects from climate change, development, and habitat restoration on other fish species would likely result in a decrease in the abundance of those fish species in the analysis area. Cumulative effects on fish species that compete, predate on, or are prey items for salmon and steelhead may be greater than described under Subsection 4.4, Other Fish Species. None of the alternatives would affect the overall trend in cumulative effects on other fish species because the range of production levels under the alternatives (e.g., from zero to 290,000 steelhead smolts) would be a small fraction of the total salmon and steelhead in the analysis area that these other fish species could compete with, prey on, or be prey items for.

5.5.4. Wildlife

Subsection 3.5, Wildlife, describes the baseline conditions of wildlife. These conditions represent the effects of many years of climate change, development, and habitat restoration. The effects of the alternatives on wildlife in Puget Sound are described in Subsection 4.5, Wildlife. Future actions for the overall cumulative effects analysis area are described in Subsection 5.4, Future Actions. This subsection considers potential effects that may occur as a result of implementing any one of the alternatives at the same time as other anticipated actions. This subsection discusses the incremental impacts of the alternatives in addition to past, present, and reasonably foreseeable future actions (i.e., cumulative effects) on wildlife.

As described in Subsection 5.5.2, Salmon and Steelhead, climate change and development in the cumulative effects analysis area may reduce the abundance and productivity of natural-origin salmon and steelhead populations. Hatchery-origin salmon and steelhead may be similarly affected. Consequently, the total number of salmon and steelhead available as prey to wildlife may be lower than that considered in Subsection 4.5, Wildlife. Effects would be greatest on wildlife species that have a strong relationship with salmon and steelhead, including Southern Resident killer whale, common merganser, bald eagle, and Caspian terns. Cumulative effects to these species may include changes in distribution in response to changes in the distribution of their food supply, decreases in abundance, and decreases in reproductive success compared to that described in Subsection 4.5, Wildlife. Effects to other wildlife species that have a recurring relationship with salmon and steelhead may also occur depending on how their overall aquatic prey base (which includes salmon and steelhead) would also be affected by climate change, development, and habitat restoration.

The potential benefits of habitat restoration actions within the cumulative effects analysis area are difficult to quantify. These actions may not fully, or even partially, mitigate for the effects of climate change and development on salmon and steelhead abundances.

In summary, it is likely that cumulative effects from climate change, development, and habitat restoration would affect those wildlife species that have a strong relationship with salmon and steelhead, and may impact other wildlife based on whether their overall food supply would decrease or otherwise change in some way (e.g., distribution, composition) as a result of climate change, development, and habitat restoration. However, none of the alternatives would affect the overall trend in cumulative effects on wildlife because the range of production levels under the alternatives (e.g., from zero to 290,000 steelhead smolts) would be a small fraction of the total number of prey items for wildlife in the analysis area.

5.5.5. Socioeconomics

Subsection 3.6, Socioeconomics, describes the baseline conditions for socioeconomics. These conditions represent the effects of many years of climate change, development, and habitat restoration. The expected effects of the alternatives on socioeconomics are described in Subsection 4.3, Socioeconomics. Future actions are described in Subsection 5.5, Future Actions. This subsection considers potential effects that may occur as a result of implementing any one of the alternatives at the same time as other anticipated actions. This subsection discusses the incremental impacts of the alternatives in addition to past, present, and reasonably foreseeable future actions (i.e., cumulative effects) on socioeconomic resources.

Although unquantifiable, climate change and development actions may reduce the number of salmon and steelhead available for harvest over time as described in Subsection 5.5.3, Salmon and Steelhead. This, in turn, may reduce angler expenditure and economic output relative to conditions considered in Subsection 4.6, Socioeconomics. Likewise, it may reduce the number of steelhead available to tribal members as a food source and may increase tribal reliance on other consumer goods or increase travel costs to participate in other fisheries. Further, these changes may reduce the amount of revenue that could be generated through the sale of fish relative to effects considered under Subsection 4.6, Socioeconomics.

The potential benefits of habitat restoration actions within the cumulative effects analysis area are difficult to quantify. These actions may not fully mitigate for the impacts of climate change and development.

In summary, it is likely that cumulative effects from climate change and development would decrease the number of fish available for harvest and reduce angler expenditure and economic output relative to conditions considered in Subsection 4.6, Socioeconomic. However, none of the alternatives would affect the overall trend in cumulative effects on socioeconomics because the range of production levels under the alternatives (e.g., from zero to 290,000 steelhead smolts) would result in a small fraction of the total harvestable salmon and steelhead in the analysis area, and, therefore, a small fraction of the overall economic benefits derived from salmon harvest in the analysis area

5.5.6. Environmental Justice

Subsection 3.7, Environmental Justice, describes environmental justice communities in the analysis area. Subsection 3.7, Environmental Justice, also describes methods for identifying environmental justice user groups and communities of concern. Environmental justice user groups and communities of concern within the cumulative effects analysis area include Indian tribes that fish for salmon and steelhead and low income or minority communities. The expected effects of the alternatives on environmental justice are described in Subsection 4.7, Environmental Justice. Future actions are described in Subsection 5.4, Future Actions. This subsection considers potential effects that may occur as a result of implementing any one of the alternatives at the same time as other anticipated actions. This subsection discusses the incremental impacts of the alternatives in addition to past, present, and reasonably foreseeable future actions (i.e., cumulative effects) on environmental justice user groups and communities of concern.

Climate change and development actions may reduce the number of salmon and steelhead available for harvest over time as described in Subsection 5.5.3, Salmon and Steelhead. This, in turn, may reduce fishing opportunity in the analysis area relative to conditions considered in Subsection 4.7, Environmental Justice.

The potential benefits of habitat restoration actions within the cumulative effects analysis area are difficult to quantify. These actions may not fully mitigate for the impacts of climate change and development on the abundance of fish that would be available for commercial or recreational harvest.

In summary, it is likely that cumulative effects from climate change and development would decrease the number of fish available relative to conditions considered in Subsection 4.7, Environmental Justice. However, none of the alternatives would affect the overall trend in cumulative effects on environmental justice because the range of production levels under the alternatives (e.g., from zero to 290,000 steelhead smolts) would result in a small fraction of the total harvestable salmon and steelhead in the analysis area available to environmental justice communities.

6. AGENCIES CONSULTED

Washington Department of Fish and Wildlife
Northwest Indian Fisheries Commission
Lummi Nation
Nooksack Tribe
Stillaguamish Indian Tribe
Tulalip Tribe
Jamestown S'Klallam Tribe

7. LITERATURE CITED

Chapter 1 and Chapter 2

Cohen, F. 2005. Cohen's Handbook of Federal Indian Law. LexisNexis. Newark, NJ. 647p.

Hood Canal Coordinating Council. 2005. Hood Canal and Eastern Strait of Juan de Fuca summer chum salmon recovery plan. Adopted by the National Marine Fisheries Service in 2007. 334 pages.

Newton, N.J., R.T. Anderson, C.E. Goldberg, J.P. La Velle, J.V. Royster, J.W. Singer, R. Strickland, and B.R. Berger. 2005. Cohen's Handbook of Federal Indian Law, 2005 edition. LexisNexis Matthew Bender Publications, San Francisco, California.

Scott, J. B., Jr. 2014. letter from Scott, J. B., Jr., to Robert Turner, NMFS, WCR, SMD. Resubmittal of five early winter steelhead HGMPs in Puget Sound for review under ESA- Limit 6 of the 4(d) rule (50 CFR Part 223). 1p. WDFW. July 28, 2014.

SSPS (Shared Strategy for Puget Sound). 2005. Shared Strategies for Puget Sound- Nooksack Watershed Profile. WRIA 1. In Volume II of the Shared Strategy for Puget Sound. Plan adopted by the National Marine Fisheries Service (NMFS) January 19, 2007. Seattle, WA. June, 2005.

SSPS. 2007. Puget Sound salmon recovery plan. Volume 1. Submitted to NMFS by the Shared Strategy for Puget Sound, Seattle, WA. 472 pages

U.S. Department of Commerce. 1995. American Indian and Alaska Native Policy. U.S. Department of Commerce, Washington, D.C. 5 pages.

Washington Fish and Wildlife Commission (WFWC). 2009. Washington Department of Fish and Wildlife hatchery and fishery reform. Policy Number C-3619. Olympia, WA. 3 pages.

WDFW. 2014a. Dungeness River Early Winter Steelhead Program. Hatchery and Genetic Management Plan. July 28, 2014. Fish Program. Washington Department of Fish and Wildlife. Olympia, WA.

WDFW. 2014b. Kendall Creek Winter Steelhead Program. Hatchery and Genetic Management Plan. July 28, 2014. Fish Program. Washington Department of Fish and Wildlife. Olympia, WA.

WDFW. 2014c. Whitehorse Ponds (Stillaguamish River) Winter Steelhead Hatchery Program. Hatchery and Genetic Management Plan. July 28, 2014. Fish Program. Washington Department of Fish and Wildlife. Olympia, WA.

Chapter 3 and Chapter 4

Amoss, P. T. 1987. The fish god gave us: the first salmon ceremony revived. Arctic Anthropology. 10 Volume 24, pages 56 to 66.

Ashbrook et al. in press Hook and release mortality.

Beamish, R.J. 1980. Adult biology of the river lamprey (Lampetra ayresi) and the Pacific lamprey (Lampetra tridentata) from the Pacific coast of Canada. Canadian Journal of Fisheries and Aquatic Sciences 37: 1906-1923.

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

Bergheim, Asbjørn and Torbjørn Åsgård. 1996. Chapter 3. Waste Production from Aquaculture. In: Aquaculture and Water Resource Management, Donald J. Baird, et al. (eds). Blackwell Science, Ltd. Oxford, England. Pages 50-80.

Boxall, A.B., L.A. Fogg, P.A. Blackwell, P. Kay, E.J. Pemberton, and A. Croxford. 2004. Veterinary medicines in the environment. Rev Environ Contam Toxicol. 2004: pages 1 to 91.

Buckley, R.M. 1999. Incidence of cannibalism and intra-generic predation by chinook salmon (Oncorhynchus tshawytscha) in Puget Sound, Washington. Technical Report # RAD 99-04. Fish Program, Resource Assessment Division. Washington Department of Fish and Wildlife. Olympia, WA.

CBFWA (Columbia Basin Fish and Wildlife Authority). 1996. Draft programmatic environmental impact statement. Impacts of artificial salmon and steelhead production strategies in the Columbia River basin. USFWS, NMFS, and Bonneville Power Administration. Portland, Oregon.

Cannamela, D. A. 1992. Potential impacts of releases of hatchery steelhead trout smolts on wild and natural juvenile chinook and sockeye salmon. Idaho Department of Fish and Game, Boise, Idaho.

Cardwell, R.D. and K.L. Fresh. 1979. Predation upon juvenile salmon. Draft No. 8. Washington Department of Fisheries. 21 p.

Cripps, S.J. 1995. Serial particle size fractionation and characterization of an aquacultural effluent. Aquaculture, 133: pages 323 to 339.

Crawford, B. A. 1979. The origin and history of the trout brood stocks of the Washington Department of Game. Olympia, WA. 76.

EDPU (Elwha-Dungeness Planning Unit). 2005. Elwha-Dungeness Watershed Plan, Water Resource Inventory Area 18 (WRIA 18) and Sequim Bay in West WRIA 17. May, 2005. Published by Clallam County. Volume 1: Chapters 1-3 and 15 appendices; Volume 2: Appendix 3-E.

EPA (Environmental Protection Agency). 1998. Reviewing for Environmental Justice: EIS and Permitting Resource Guide. EPA Review. Region 10 – Environmental Justice Office.

Ecology (Washington Department of Ecology). 1989. Quality and Fate of Fish Hatchery Effluents during the Summer Low Flow Season. Publication No. 89-17. Prepared by Will Kendra, Washington Department of Ecology, Environmental Investigations and Laboratory Services Program, Surface Water Investigations Section, Mail Stop PV-11, Olympia, Washington 98504. May 1989.

Ecology. 2014. 303(d) Category 5 Assessed Waters. http://www.ecy.wa.gov/services/gis/maps/wria/303d/w33-303d.pdf (accessed November 6 and 7, 2014).

Finger, T.R. 1982. Interactive segregation among three species of sculpins (Cottus). Copeia 1982: 680–694.

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

Gunther, E. 1950. The Indian background of Washington history. Pacific Northwest Quarterly. July, pages 189 to 202.

HSRG (Hatchery Scientific Review Group). 2005. Hatchery reform in Washington State: principles and emerging issues. L. Mobrand (chair), J. Barr, L. Blankenship, D. Campton, T. Evelyn, T. Flagg, C. Mahnken, R. Piper, P. Seidel, L. Seeb, and B. Smoker. Fisheries, 30(6): pages 1 to 23.

HSRG. 2009. Columbia River hatchery reform system wide report. Available from, http://www.hatcheryreform.us/hrp/reports/system/welcome_show.action.

Hard, J. J., J. M. Myers, M. J. Ford, R. G. Kope, G. R. Pess, R. S. Waples, G. A. Winans, B. A. Berejikian, F. W. Waknitz, P. B. Adams, P. A. Bisson, D. E. Campton, and R. Reisenbichler. 2007. Status review of Puget Sound steelhead (Oncorhynchus mykiss). U.S. Department of Commerce, NOAA Technical Memorandum. NMFS-NWFSC-81, 117 pages.

Hard, J. J., J. M. Myers, E. J. Connor, R. A. Hayman, R. G. Kope, G. Luchetti, A. R. Marshall, G. R. 26 Pess, and B. E. Thompson. 2014. Viability criteria for steelhead within the Puget Sound distinct 27 population segment. U.S. Department of Commerce, NOAA Technical Memorandum. NMFS-28 NWFSC-XXX, 390 pages.

Hartt, A. C. and M. B. Dell. 1986. Early oceanic migrations and growth of juvenile Pacific salmon and steelhead trout. International North Pacific Fisheries Commission. Bulletin Number 46. Vancouver, Canada. 105 pages.

Hastein and Lindstad 1991 – from DEIS or BiOp Risk of Disease Transfer Section

Hillman, T. W., and J. W. Mullan, editors. 1989. Effect of hatchery releases on the abundance of wild juvenile salmonids. Report to Chelan County PUD by D.W. Chapman Consultants, Inc., Boise, ID.

Hiss, J. 1993. Recommended Instream Flows for the Lower Dungeness River. U. S. Fish and Wildlife Service, Western Washington Fishery Resource Office. Lacey, Washington.

Hoffmann, A. 2015a. Spreadsheet from Hoffmann, A., WDFW, to C. Busack (NMFS); Beata Dungeness Gene Flow 6-24-14.xlsx. Mill Creek, Washington. February 27, 2015.

Hoffmann, A. 2015b. Spreadsheet from Hoffmann, A., WDFW, to C. Busack (NMFS); DRAFT Hoffmann 2014 Gene Flow 11-22-14.xlsx. Mill Creek, Washington. January 29, 2015.

Horner, N.J. 1978. Survival, densities and behavior of salmonid fry in stream in relation to fish predation. M.S. Thesis. University of Idaho, Moscow, Idaho. 132p.

Integrated Hatchery Operations Team (IHOT). 1995. Policies and procedures for Columbia Basin anadromous salmonid hatcheries. Annual report 1994. Bonneville Power Administration DOE/BP-60629. Portland, OR. 115 pages.

Kendra, W. 1991. Quality of Salmonid Hatchery Effluents during a Summer Low-Flow Season. Transactions of the American Fisheries Society, 120: 43-51.

Kolodziej, E.P., T. Harter, and D.L. Sedlak. 2004. Dairy wastewater, aquaculture, and spawning fish as sources of steroid hormones in the aquatic environment. Environ Sci Technol., 38:6377-6384.

Krohn, D.C. 1968. Production of the reticulate sculpin (Cottus perplexus) and its predation on salmon fry in three Oregon streams. M.S. Thesis, Oregon St. Univ., Corvallis. 78 p.

Light, J. T., C. K. Harris, and R. L. Burgner. 1989. Ocean distribution and migration of steelhead (Oncorhynchus mykiss, formerly Salmo gairdneri). FRI-UW-8912. Fisheries Research Institute, University of Washington, Seattle, WA. 50 pages.

Maret, T. R., C. Robinson, and G. Minshall. 1997. Fish Assemblages and Environmental Correlates in Least-Disturbed Streams of the Upper Snake River Basin. Transactions of the American Fisheries Society, 126:2, 200-216.

Martínez Bueno, M.J., M.D. Hernando, A. Agüera, and A.R. Fernández-Alba. 2009. Application of passive sampling devices for screening of micro-pollutants in marine aquaculture using LC-MS/MS. Talanta 77: 1518-1527.

Michael, J.H., Jr. 2003. Nutrients in salmon hatchery wastewater and its removal through the use of wetland constructed to treat off-line settling pond effluent. Aquaculture, 226: 213-225.

Missildine, B.R., R.J. Peters, G. Chin-Leo, and D. Houck. 2005. Polychlorinated biphenyl concentrations in adult Chinook salmon (Oncorhynchus tshawytscha) returning to coastal and Puget Sound hatcheries of Washington State. Environmental Science and Technology, Vol 39: 6944-6951.

Meyer Resources Inc. 1999. Tribal Circumstances and Impacts of the Lower Snake River Project on the Nez Perce, Yakama, Umatilla, Warm Springs and Shoshone Bannock Tribes. Prepared for Columbia River Intertribal Fish Commission, Portland, OR. 260 pages.

Myers, J. M., J. J. Hard, E. J. Connor, R. A. Hayman, R. G. Kope, G. Lucchetti, A. R. Marshall, G. R. Pess, and B. E. Thompson. 2014. Identifying historical populations of steelhead within the Puget Sound Distinct Population Segment. U.S. Dept. Commerce, NOAA Tech. Mem. NMFS-NWFSC, 154 p.

NMFS (National Marine Fisheries Service) 2014a. Final Environmental Impact Statement to Inform Columbia River Basin Hatchery Operations and the Funding of Mitchell Act Hatchery Programs. NMFS West Coast Regional Office, Sustainable Fisheries Division. Portland, Oregon.

NMFS 2014b. Draft Environmental Impact Statement on Two Joint State and Tribal Resource Management Plans for Puget Sound Salmon and Steelhead Hatchery Programs. NMFS West Coast Region, Sustainable Fisheries Division. Lacey, Washington.

NMFS 2011. Anadromous Salmonid Passage Facility Design. National Marine Fisheries Service - Northwest Region. July 2011. http://www.nwr.noaa.gov/Salmon-Hydropower/FERC/upload/Fish-Passage-Design.pdf

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

Pflug, D., E. Connor, B. Hayman, T. Kassler, K. Warheit, B. McMillan, and E. Beamer. 2013. Ecological, genetic and productivity consequences of interactions between hatchery and natural-origin steelhead of the Skagit watershed. Report prepared for the Skagit River System Cooperative, Saltonstall-Kennedy Grant Program funding number NMFS-FHQ-2008-2001011. La Conner, WA. 207 pages.

Phelps, S. R., S. A. Leider, P. L. Hulett, B. M. Baker, and T. Johnson. 1997. Genetic analysis of Washington steelhead: preliminary results incorporating 36 new collections from 1995 and 1996. Progress report. Washington Department of Fish and Wildlife, Olympia, WA. 29 pages.

Pouliquen, H., C. Thorin, J. Haury, M. Larhantec-Verdier, M.L. Morvan, R. Delépée, and H. Le Bris. 2008. Comparison of water, sediment and plants for the monitoring of antibiotics: a case study on a river dedicated to fish farming. Environ Toxicol Chem., 2008 Nov 3:1.

RIST (Recovery Implementation Science Team). 2009. Hatchery reform science: A review of some applications of science to hatchery reform issues. April 9, 2009. 93p.

SSPS 2005a – not sure if this should be 2005a or not. This is Nooksack one- check with Chapter 1 references. If this is not 2005a, change in text on page 25.

Scott, J. B., and W. T. Gill, editors. 2008. Oncorhynchus mykiss: Assessment of Washington State's steelhead populations and programs. Preliminary draft for Washington Fish & Wildlife Commission. 424p. Washington Department of Fish and Wildlife, Olympia, Washington.

Sparrow, R.A.H. 1981. Hatchery Effluent Water Quality in British Columbia. Bio-Engineering Symposium for Fish Culture (FCS Publ. 1): 162-166.

Stein, J. 2000. Exploring Coast Salish prehistory. University of Washington Press, Seattle, WA. 126 26 pages.

Stillaguamish. 2007. South Fork Stillaguamish Chinook Natural Stock Restoration Program-Hatchery and Genetic Management Plan. Stillaguamish Tribe. P.O. Box 277, Arlington, WA 98223. August 1, 2007. 50p.

USFWS. 2012. Washington Fish and Wildlife Office: Listed Species by County. http://www.fws.gov/wafwo/speciesmap_new.html (Accessed November 2014).

WDFW (Washington Department of Fish and Wildlife). 2008. Statewide steelhead management plan: Statewide policies, strategies, and actions. Olympia, Washington. February 29, 2008.

WDFW (Washington Department of Fish and Wildlife). 2013a. Wallace River Hatchery Summer Chinook Salmon. Hatchery and Genetic Management Plan. February 11, 2013. Fish Program. Washington Department of Fish and Wildlife. Olympia, WA.

WDFW 2014a. Dungeness River Early Winter Steelhead Program. Hatchery and Genetic Management Plan. July 28, 2014. Fish Program. Washington Department of Fish and Wildlife. Olympia, WA.

WDFW 2014b. Kendall Creek Winter Steelhead Program. Hatchery and Genetic Management Plan. July 28, 2014. Fish Program. Washington Department of Fish and Wildlife. Olympia, WA.

WDFW 2014c. Whitehorse Ponds (Stillaguamish River) Winter Steelhead Hatchery Program. Hatchery and Genetic Management Plan. July 28, 2014. Fish Program. Washington Department of Fish and Wildlife. Olympia, WA.

WDFW and WWTIT (Western Washington Treaty Indian Tribes). 1998 (Revised 2006). Salmonid disease control policy of the fisheries Co-Managers of Washington State. Washington Department of Fish and Wildlife and Western Washington Treaty Indian Tribes, Olympia Washington.

Wampler, P., and J. Hiss. Fish habitat analysis for the Dungeness River using the instream flow incremental methodology. 1991. U. S. Fish and Wildlife Service, Western Washington Fishery Resource Office. Lacey, Washington.

Warheit, K. I. 2014a. Measuring reproductive interaction between hatchery-origin and wild steelhead (Oncorhynchus mykiss) from northern Puget Sound populations potentially affected by segregated hatchery programs. Washington Department of Fish and Wildlife. Olympia, Washington. October 10, 2014.

Warheit, K. I. 2014b. Warheit, K. I., WDFW, to C. Busack (NMFS); Probability_PEHC_Greater_02.xlsx. Olympia, Washington. November 21, 2014.

Winans, G. A., M. L. McHenry, J. Baker, A. Elz, A. Goodbla, E. Iwamoto, D. Kuligowski, K. M. Miller, M. P. Small, P. Spruell, and D. VanDoornik. 2008. Genetic inventory of anadromous Pacific salmonids of the Elwha River prior to dam removal. Northwest Science. Volume 82 (Special Issue), pages 128 to 141.

Chapter 5

Barsh, R. L. 2003. The importance of human intervention in the evolution of Puget Sound ecosystems. In 20 Droscher, T. W. and D.A. Fraser, editors. Proceedings of the 2003 Georgia Basin/Puget Sound 21 Research Conference; March 31 to April 3, 2003, Vancouver, BC. Puget Sound Action Team, 22 Olympia, WA.

Beamish, R. J., B. E. Riddell, K. L. Lange, E. Farley Jr., S. Kang, T. Nagasawa, V. Radchenko, 24 O. Temnykh, and S. Urawa. 2009. The effects of climate on Pacific salmon – a summary of published 25 literature. North Pacific Anadromous Fish Commission (NPAFC) Special Publication No. 1, 26 Published Literature. 11 pages.

Beechie, T., H. Imaki, J. Greene, A. Wade, H. Wu, G. Pess, P. Roni, J. Kimball, J. Stanford, P. Kiffney, 28 and N. Mantua. 2013. Restoring salmon habitat for a changing climate. River Research and 29 Applications. Volume 29(8), pages 939 to 960.

British Columbia Ministry of Water, Land and Air Protection [BCMWLAP]. 2002. Environmental Trends 1 in British Columbia 2002. Available at http://wlapwww.gov.bc.ca/soerpt. Accessed December 2, 2 2012.

Center for Biological Diversity. 2005. The Puget Sound Basin: a biodiversity assessment. Center for 4 Biological Diversity, Portland, OR. 35 pages.

Environment Canada-U.S. Environmental Protection Agency (EPA). 2008. Joint statement of cooperation 6 on Georgia Basin and Puget Sound ecosystem 2008-2010: action plan initiatives for the Salish Sea. 7 16 pages.

Ford, M. J. 2011. Status review update for Pacific salmon and steelhead listed under the Endangered 9 Species Act: Pacific Northwest. U.S. Department of Commerce, NOAA Technical Memorandum. 10 NMFS-NWFSC-113, 281 pages.

Fraser River Estuary Management Program. 2012. Fraser River Management Plan. Available at 12 http://www.bieapfremp.org/main_fremp.html. Accessed December 2, 2012.

Glick, P., J. Clough, and B. Nunley. 2007. Sea-level rise and coastal habitats in the Pacific Northwest: an 14 analysis for Puget Sound, Southwestern Washington, and Northwestern Oregon. National Wildlife 15 Federation.

Greater Vancouver Regional District. 2005. Green Zone Issues and Policy Options. Metro Vancouver, 17 Vancouver, BC.

Halpern, B. S., C. V. Kappel, K. A. Selkow, F. Micheli, C. M. Ebert, C. Kontigs, C. M. Crain, R. G. 19 Martone, C. Shearer, and S. J. Teck. 2009. Mapping cumulative human impacts to California Current 20 marine ecosystems. Conservation Letters. Volume 2, pages 138 to 148.

Hamlet, A. F. 2011. Impacts of climate variability and climate change on transportation systems and 22 infrastructure in the Pacific Northwest. Climate Impacts Group, University of Washington, Seattle, 23 WA. 42 pages.

ISAB. 2007. Climate change impacts on Columbia River Basin fish and wildlife. ISAB Climate Change 25 Report. ISAB 2007-2. ISAB, Northwest Power and Conservation Council, Portland, OR. 136 pages.

Johannessen, S. C. and R. W. Macdonald. 2009. Effects of local and global change on an inland sea: the 27 Strait of Georgia, British Columbia, Canada. Climate Research. Volume 40, pages 1 to 21.

Lackey, R. T., D. H. Lach, and S. O. Duncan. 2006. Wild salmon in western North America; the historical 1 and policy context. Pages 13 to 55 in Lackey, R. T., D. H. Lach, and S. O. Duncan, editors. Salmon 2 2100: The future of wild Pacific salmon, American Fisheries Society, Bethesda, MD. 629 pages.

Littell, J. S., M. McGuire Elsner, L. C. Whitely Binder, and A. K. Snover, editors. 2009. The Washington 4 climate change impacts assessment – evaluating Washington's future in a changing climate – 5 executive summary. Climate Impacts Group, Center for Science in the Earth System, Joint Institute 6 for the Study of the Atmosphere and Oceans, University of Washington, Seattle, WA.

Lombard, J. 2006. Saving Puget Sound: a conservation strategy for the 21st century. American Fisheries 8 Society, Bethesda, MD. 320 pages.

MacKinlay, R., S. Lehmann, J. Bateman, and R. Cook. 2004. Pacific Salmon Hatcheries in British 10 Columbia. Pages 57 to 75 in Nickum, M., P. Mazik, J. Nickum, and D. MacKinlay, editors. 11 Propagated fish in resource management; June 2003. American Fisheries Society Symposium 44. 12 Bethesda, MD.

McElhany, P., M. H. Ruckelshaus, M. J. Ford, T. C. Wainwright, and E. P. Bjorkstedt. 2000. Viable 14 salmonid populations and the recovery of Evolutionarily Significant Units. U.S. Department of 15 Commerce, NOAA Technical Memorandum. NMFS-NWFSC-42, 156 pages.

Mantua, N., I. Tohver, and A. Hamlet. 2009. Impacts of climate change on key aspects of freshwater 17 salmon habitat in Washington State. Pages 217 to 253 (Chapter 6) in McGuire Elsner, M., J. Littell, 18 and L. Whitely Binder, editors. The Washington climate change impact assessment. Climate Impacts 19 Group, Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and 20 Oceans, University of Washington, Seattle, WA.

Metro Vancouver. 2013. Metro Vancouver 2040: shaping our future. Vancouver, BC. 22

NMFS. 2011a. 2011 Report to Congress: Pacific Coastal Salmon Recovery Fund FY 2000-2010. U.S. 23 Department of Commerce, NOAA, National Marine Fisheries Service. 12 pages.

NMFS. 2011b. 2011 implementation status assessment – final report. A qualitative assessment of 25 implementation of the Puget Sound Chinook Salmon Recovery Plan. Prepared by Millie M. Judge, 26 Lighthouse Natural Resource Consulting, Inc. for National Marine Fisheries Service, Northwest 27 Region. Portland, OR. 45 pages.

Natural Resources Canada (NRC). 2014. Municipal case studies: climate change and the planning 1 process. Available at http://www.nrcan.gc.ca/earth-sciences/climate-change/community-2 adaptation/municipalities/616. Accessed May 9, 2014.

Patrick, D. A., N. Boudreau, G. S. Carpenter, D. M. Langdon, S. R. LeMay, S. M. Martin, R. M. Course, 4 S. L. Prince, and K. M. Quinn. 2012. Effects of climate change on late-season growth and survival of 5 native and non-native species of watermilfoil (Myriophyllum spp.): implications for invasive 6 potential and ecosystem change. Aquatic Botany. Volume 103, pages 83 to 88.

Perry, I. 2009. Status of the Strait of Georgia. Pages 41 to 47 in Gallaugher, P. and L. Wood, editors. 8 Haig-Brown Symposium on Sustaining Wild Salmon: moving from words to actions; August 16 9 to 17, 2008, Campbell River, BC. Simon Fraser University, Burnaby, BC. 10

Puget Sound Action Team. 2007. State of the Sound. Office of the Governor, State of Washington, 11 Olympia, WA.

Puget Sound Nearshore Ecosystem Restoration Partnership. 2013. Puget Sound Nearshore Ecosystem 13 Restoration Project. Available at http://www.pugetsoundnearshore.org/index.html. Accessed on 14 December 30, 2013.

Puget Sound Partnership (PSP). 2010. 2009 state of the Sound: a report on Puget Sound ecosystem status 16 and a performance management system to track Action Agenda implementation. Puget Sound 17 Partnership, Olympia, WA.

PSP. 2012. Highlights of the 2012 Action Agenda for Puget Sound. Available at 19 http://www.psp.wa.gov/action_agenda_2011_update_home.php. Accessed December 2, 2012.

Puget Sound Regional Council (PSRC). 2009. Vision 2040 – the growth, management, environmental, 21 economic, and transportation strategy for the Central Puget Sound Region. Puget Sound Regional 22 Council, Seattle, WA.

PSRC. 2012. Population change and migration. Puget Sound trends index no. D7. Seattle, WA.

PSRC. 2013. 2012 regional macroeconomic forecast, July, 2013. Seattle, WA.

Quinn, T. 2010. An environmental and historical overview of the Puget Sound ecosystem. Pages 11 to 18 26 in Shipman, H., M. N. Dethier, G. Gelfenbaum, K. L. Gresh, and R. S. Dinocola, editors. Puget 27 Sound Shorelines and the Impacts of Armoring. Proceedings of a State of the Science Workshop; 28 May 16 to 19, 2009, Union, WA. U.S. Geological Survey Scientific Investigations Report 2015-5254.

Rogers, L. A., D. E. Schindler, P. J. Lisi, G. W. Holtgrieve, P. R. Leavitt, L. Bunting, B. P. Finney, D. T. 1 Selbie, G. Chen, I. Gregory-Eaves, M. J. Lisac, and P. B. Walsh. 2013. Centennial-scale fluctuations 2 and regional complexity characterize Pacific salmon population dynamics over the past five centuries. 3 Proceedings of the National Academy of Sciences. Volume 110(5), pages 1,750 to 1,755.

Sandher, J., R. Cook, and J. R. Irvine. 2010. Canadian enhanced salmonid production during 1978-2009 5 (1977-2008 brood years). North Pacific Anadromous Fish Commission Doc. 1258. 12 pages.

Stein, J. E. 2000. Exploring Coast Salish prehistory: the archaeology of San Juan Island. University of 7 Washington, Seattle. 126 pages.

U.S. Environmental Protection Agency (EPA). 2011. 2011 Salish Sea Ecosystem Conference 9 Proceedings. October 25 to 27, 2011, Vancouver, BC.

Washington Department of Ecology (Ecology). 2012a. Preparing for a changing climate: Washington 11 State's integrated climate response strategy. WDOE Publication No. 12-01-004. Olympia, WA. 12 203 pages, plus four appendices.

Ecology. 2012b. Saving Puget Sound, Puget Sound cleanup projects. Available at 14 http://www.ecy.wa.gov/puget_sound/index.html. Accessed December 2, 2012.

Washington Department of Natural Resources (DNR). 2005. Forest practices habitat conservation plan. 16 Olympia, WA. 274 pages, plus 15 appendices.

World Wildlife Fund. 2012. Puget lowland forests Ecoregion. Available at 18 http://worldwildlife.org/ecoregions/na0524. Accessed December 2, 2012.

8. APPENDIX A

Genetic effects analysis of early winter steelhead programs proposed for the Nooksack, Stillaguamish, and Dungeness Basins of Washington

Anadromous Production and Inland Fisheries Program
Sustainable Fisheries Division
NMFS West Coast Region
March 25, 2015

GENETIC EFFECTS OF EARLY WINTER STEELHEAD PROGRAMS

The hatchery programs under consideration in the Nooksack, Stillaguamish, and Dungeness Basins are segregated harvest programs that release fish that are not included in the Puget Sound steelhead DPS. Operators will use only early winter steelhead produced by the programs (identified by early return timing and presence of an adipose fin clip mark) as broodstock, and no natural-origin steelhead will be collected and spawned. The intent of management of these programs is to have relatively few returning fish in excess of broodstock needs escape to spawn in the wild. Those that do spawn in the wild are expected to have low reproductive success relative to the natural-origin fish because they spawn earlier than natural-origin fish, and thus are presumed to spawn under non-optimal conditions. They may also be less successful that natural-origin fish due to other aspects of domestication. To the extent they do reproduce and contribute to the next generation of natural-origin fish, however, they pose genetic risks to the population. In this section, we analyze the risks posed by this gene flow. NMFS considers three areas of effects caused by gene flow from hatchery-origin fish: within-population diversity, outbreeding effects, and hatchery-influenced selection.

Within-Population Diversity Effects

Risk to within-population diversity is much more of a concern in integrated programs than in segregated programs such as those in the Proposed Action, so we will deal with it briefly. Within-population diversity is influenced strongly by the effective size of the population. Population effective size could either increase or decrease from hatchery-origin fish spawning in the wild, depending on the effective number of breeders that produced the hatchery-origin and natural-origin fish, the relative spawning success of the hatchery-origin and natural-origin fish, and the background level of diversity in the natural-origin and hatchery-origin fish. Effective size changes are generally a concern only when the relative abundance of hatchery-origin fish on the spawning grounds far exceeds that of natural-origin fish, which is not the case with the three proposed programs. In addition, the background levels of genetic diversity are essentially identical in the hatchery and natural steelhead populations (Warheit 2014a). In general we would expect the risk posed by the Proposed Action to within-population diversity to be negligible.

However, one concern that has been raised in connection with these segregated steelhead programs is that due to the low expected reproductive success of early winter steelhead spawning in the wild, the reproductive potential of natural-origin fish that spawn with hatchery-origin fish is completely wasted. Loss of the reproductive output of these fish thus reduces the size of the spawning population and therefore the genetically effective size of the population. Although we do not consider this a realistic viewpoint, it is a useful analysis in highlighting how much lower than expected the actual amount of interbreeding between hatchery-origin and natural-origin may be. Figure 1 is a schematic of the expected distribution of hatchery-origin and natural-origin spawners over time. Although the difference varies from basin to basin, the early winter steelhead have an earlier spawn timing than natural winter steelhead. This means there will be a time during the spawning season when hatchery-origin steelhead can only spawn with other hatchery-origin steelhead (Region A), an overlap period when hatchery-origin and natural-origin steelhead can spawn amongst themselves or with each other (Region B), and a period when natural-origin steelhead can spawn only with natural-origin steelhead (Region C). Assuming random mating[9], the expected proportion of different mating types can easily be determined. In this case, since the only matings that are of interest

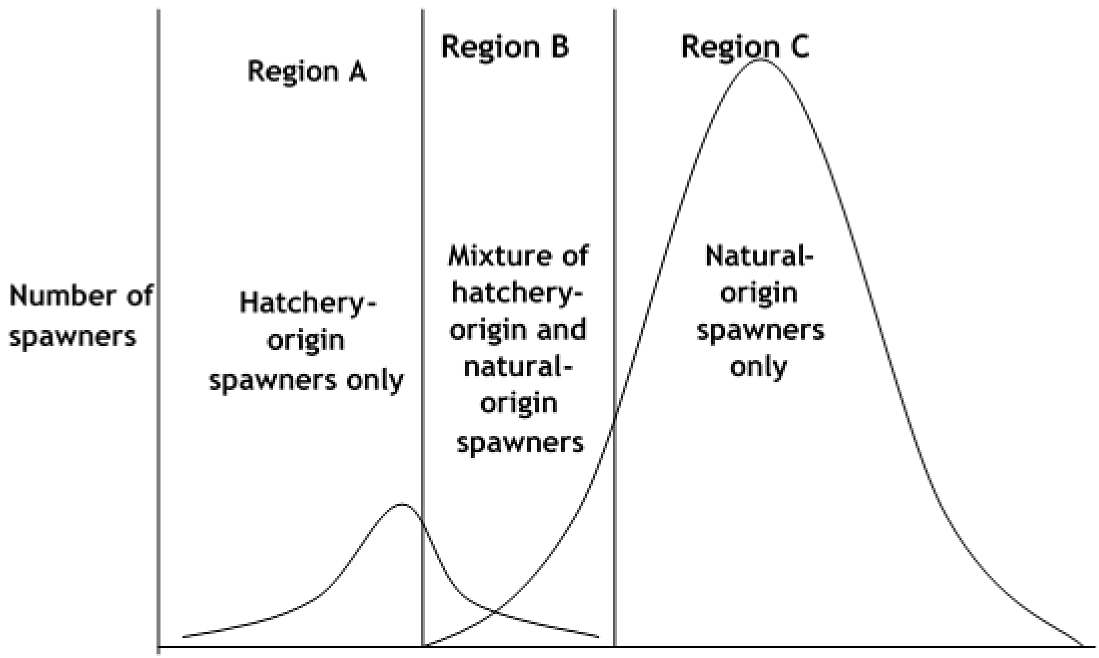

Figure A-2. Schematic of temporal spawning overlap between early winter hatchery steelhead and natural-origin winter steelhead. Shape, sizes and placement of curves is conceptual and is not meant to represent any specific situation ((Scott and Gill 2008, Fig. 4-7).

are those that occur in Region B, and of those, only the matings in which natural-origin fish mate with hatchery-origin fish are of interest. The expected proportion of the natural-origin escapement actually mating with hatchery-origin fish is given by:

$\frac{pHOS*O_N*O_H}{pHOS*O_H+(1-pHOS)*O_N}$ (1) , where pHOS is the proportion of natural spawners that are of hatchery origin, and O_N and O_H are the proportions of the natural-origin spawners, and the hatchery-origin spawners, respectively that spawn in region B. The proportion of the natural-

[9] Random mating is assumed in a number of basic population genetic models for mathematical simplicity. The models in this section are based on simple population genetic models, and use the random mating assumption for the same reason. Mating dynamics of steelhead and salmon is in fact non-random. but attempting to include all the deviations from random mating would be a major modelling exercise in itself. We assume that the results of our modelling is robust to the typical deviations from random mating found in nature.

origin spawners involved in HxN matings is expected to be very low under the proposed action, at most 0.006 in the Stillaguamish (Table 1). Thus, under the assumption that the reproductive output of a natural-origin fish mating with a hatchery-origin fish is a complete loss, the impact to the population in terms of demographic and effective population size would be less than 1%.

Table A-17. Expected proportion of natural-origin escapement involved in HxN matings for winter steelhead populations affected by the Proposed Action. Table 4 provides further details on metrics used in calculations.

	Population		
Metric/Data	Nooksack	Stillaguamish	Dungeness
O_N	0.0621	0.0125	0.0009
O_H	0.0838	0.1841	0.3238
Proposed Action pHOS	0.034	0.059	0.035
Expected proportion of natural-origin fish mating with hatchery-origin fish	.003	.006	0.001

All parameters of this model are subject to uncertainty, as will be discussed below. A simple evaluation of the effects of this uncertainty is presented in Figure 2, which shows the proportion of natural-origin fish participating in HxN matings as a function of pHOS and overlap. For simplicity, we assume that O_N and O_H are equal, which is a much higher level of overlap than has been observed (Table 1). Overlap and pHOS must be considerable before the proportion of natural-origin spawners in HxN matings reaches even 1%, and this proportion has a maximum value of pHOS if overlap is complete (equation 1).

A potential shortcoming of this “region” approach to spawning is that it assumes that all the spawners are returning adults. Resident *O. mykiss* (rainbow trout) and precocious residual hatchery juveniles may also be involved, both of which would not have been counted as part of the escapement. McMillan et al. (2007) noted both types of males participating in mating in the later part of the spawning season in an Olympic peninsula stream, but it is unclear what their net reproductive contribution was. Measurable reproductive success of non-anadromous males was noted in another Olympic peninsula stream that has no hatchery program (Seamons et al. 2004b). The relative abundance of anadromous and non-anadromous *O. mykiss* is not well known in most Puget Sound streams (Myers et al. 2014). Residualism rates for the programs in the proposed action are not known. A recent meta-analysis of steelhead programs found an average residualism rate of 5.6%, ranging from 0 to 17% (Hausch and Melnychuk 2012). Genetically, residual males are of no concern unless they are sexually mature. Although historically high rates of precocious maturation have been reported (e.g., Schmidt and House 1979) and groups can be generated with rates as high as 100% (e.g., Sharpe et al. 2010), the rate in WDFW steelhead releases tends to vary from 1 to 5% (Tipping et al. 2003).

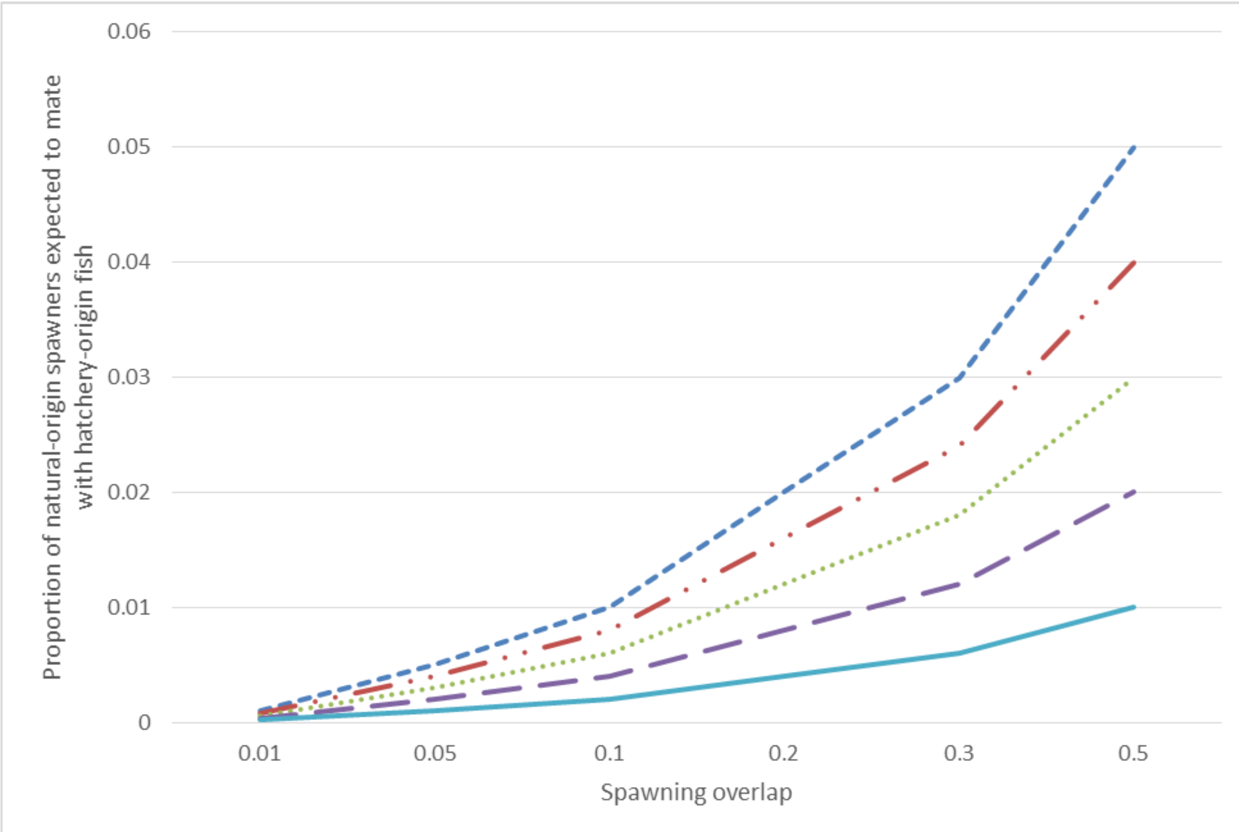

Figure A-3. Proportion of natural-origin fish expected to be involved in HxN matings as a function of pHOS, and proportion of spawners in overlap zone. For simplicity we have assumed that the overlap is the same for natural-origin and hatchery-origin fish; e.g., for the 0.05 level, ON=OH=0.05. Isopleths represent pHOS=0.1 (small dashes), 0.08 (dots and dashes), 0.06 (dots), 0.04 (large dashes), and 0.02 (solid).

This additional analysis of possible effective size reduction reinforces our original conclusion, of the proposed action having a negligible effect to within-population diversity.

Outbreeding Effects and Hatchery-Influenced Selection Effects

Although we conclude that the effects of the Proposed Action on within-population diversity will be negligible, the Proposed Action may pose non-negligible risks to natural steelhead populations through outbreeding effects and hatchery-influenced selection, however. Outbreeding effects are a concern whenever the hatchery-origin and natural-origin fish are from different populations, and this is certainly a case with the early winter hatchery steelhead and the natural populations considered in this consultation. In fact, the early winter steelhead are considered so diverged genetically from natural steelhead that they are not considered part of any steelhead DPS (NMFS 2003). The basis of this is the fact that they have been subjected to so many years of intense artificial selection for early smolting, which has resulted not only in smolting predominantly at one year of age, but also earlier spawning time (Crawford 1979). Of all the salmon and steelhead hatchery populations used on the West Coast, NMFS considers the early winter steelhead population the most altered by artificial selection.

Evaluation of outbreeding effects is very difficult. Under conditions of no selection and no genetic drift, and the best existing management guidance for avoiding out breeding effects remains the conclusion of the 1995 straying workshop (Grant 1997) that gene flow between populations (measured as immigration rates) should be under 5%. The HSRG (2009) generally recommended that for primary populations (those of high conservation concern) affected by segregated hatchery programs that the proportion of natural spawners consisting of hatchery-origin fish (pHOS) not exceed 5%, and more recently (HSRG 2014) have suggested that perhaps this level should be reduced. While not addressing them specifically in their guidelines, the HSRG earlier discussed risks posed highly diverged hatchery populations such as the early winter steelhead, concluding that "…if non-harvested fish spawn naturally, then these segregated programs can impose significant genetic risks to naturally spawning populations. Indeed, any natural spawning by fish from these broodstocks may be considered unacceptable because of the potential genetic impacts on natural populations" (HSRG 2004, Appendix B). WDFW used the Ford (2002) model to evaluate the hatchery-influenced selection risk of early winter segregated steelhead programs, and concluded they posed less risk than integrated native-stock programs at pHOS levels below 2%, but greater risk at levels above that (Scott and Gill 2008). WDFW's statewide steelhead management plan states that segregated programs will result in average gene flow levels of less than 2% (WDFW 2008).

NMFS concludes, based on the present level of empirical and theoretical information currently available on the subject, that the proposed maximum gene flow levels of 2%, into natural Puget Sound steelhead populations of high conservation concern, will not pose unacceptable genetic risk, subject to two criteria. First, that an appropriate gene flow metric is used and second, that the gene flow level is known with a reasonably high level of certainty.

Gene flow from hatchery fish into natural populations is referred to in many NMFS documents and elsewhere 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 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. WDFW has developed such a metric based on genetic data, which is called proportionate effective hatchery contribution (*PEHC*) (Warheit 2014a). NMFS has accepted it as an appropriate measure of gene flow for evaluation of these proposed segregated hatchery programs (Jones Jr. 2014). WDFW also has developed an alternative demographic method, hereafter called the Scott-Gill method, for calculating the expected gene flow that is not based on genetic data (Scott and Gill 2008). NMFS also considers the metric generated by the Scott-Gill method, called gene flow by WDFW, an appropriate metric for estimating the 2% criterion, subject to subsequent verification through genetic data (Warheit method). We discus certainty in Section 1.3.

Estimation of gene flow using genetic data

Warheit method

Detection of PEHC estimates in Puget Sound steelhead is difficult because, in terms of genetic markers that can currently be analyzed on a production scale, the differences between the hatchery-origin fish and natural-origin fish are slight, because of common ancestry and possibly gene flow in the past. WDFW has struggled with this problem for several years, and Dr. Ken Warheit, director of the Molecular Genetics Laboratory at WDFW, has developed a method for estimating *PEHC* in situations like this. The method is new, still undergoing refinement, and that reason has received limited peer review[10]. Because of this, and because the method is so critical to current and future steelhead consultations, during this consultation 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.

Although Structure is the basic analytical engine of the Warheit method, the full method is far more complex than the basic structure analysis. Realizing that assignment portions of an individual genome to populations must involve error if the genetic distance between the populations involved in the admixture is small, Warheit first investigated this assignment uncertainty in a study of genetic effects of early winter steelhead Skagit winter steelhead[11]. He simulated populations of hatchery-origin and natural-origin fish and their hybrids, then applying

[10] Warheit is currently developing a manuscript for submission to a peer-reviewed journal.

[11] We refer to the Skagit report only for presenting the historical development of the method. Any results presented have been superseded by Warheit (2014a) (Warheit, pers comm.)

Structure to determine how well the program classified fish of known ancestry (Warheit 2013). He found that depending on the situation, the proportion of hybrid fish could either be seriously over- or underestimated, and concluded that he lacked sufficient power with 15 microsatellite loci to reliably quantify introgression from early winter steelhead into the wild Skagit River winter steelhead populations, or reliably identify pure unmarked hatchery-origin or hatchery-ancestry fish. Warheit's current (2014a) method applies and extends the lessons learned in the Skagit work. The data set consists of genotypes from up to 192 single-nucleotide polymorphism (SNP) loci. Simulation methods were refined to better model the genetic composition of populations. In addition, Warheit used a likelihood approach to adjust the *Structure*-based assignment proportions, based on the assignment error from analysis of the simulated populations.

NMFS Northwest Fisheries Science Center (NWFSC) staff reviewed a report provided to us in March 2014 that described the method and the results of its application to several Puget Sound steelhead populations (Warheit 2014d). They commented extensively on many aspects of the document (Hard 2014). Because of these comments and additional discussion with SFD staff, the method was refined and the document extensively revised. WDFW provided NMFS with the new draft (Warheit 2014a) in October 2014, which we submitted to NWFSC for review, along with a document by Warheit (Warheit 2014c) detailing his responses to the earlier review. The NWFSC responded with a new review in January 2015 (Ford 2015).

Briefly, the NWFSC reviewers found Warheit's method to be a reasonable, thoughtful and innovative effort to address genetic introgression from closely related hatchery populations. Importantly, Warheit's approach demonstrated that a naïve application of the *Structure* program would provide misleading results, probably overestimating introgresion. However, they were concerned, as in their previous review, that Warheit's approach may overstate the precision and possibly the accuracy of the estimates. In other words, the confidence intervals may be larger than reported, and point estimates may be biased. They singled out two potential sources of uncertainty. The first was uncertainty associated with sampling, which did not seem to have been taken into account. The second was sensitivity to the many assumptions and choices about model parameters that Warheit used.

These NWFSC comments were expected. The Warheit approach is an innovative complex method that attempts something very difficult, and necessarily involves many assumptions and sources of uncertainty. NMFS staff and Warheit discussed the method and revisions to it extensively during the consultation process. Confidence intervals were developed, in fact, and the urging of NMFS staff, with the full understanding that they were underestimates. NMFS considers that although sensitivity analysis is necessary, which may spur further refinement of the technique, the Warheit method is not only a reasonable approach to measuring gene flow in this situation, but the best method available.

Application of Warheit method to Nooksack and Stillaguamish steelhead populations

WDFW has applied the Warheit method to the Nooksack and Stillaguamish steelhead populations, as well as several other Puget Sound steelhead populations, but has not yet applied it to the Dungeness population because of lack of genetic data. Table 1 reports *PEHC* information provided by WDFW (Warheit 2014a) on the Nooksack and Stillaguamish steelhead populations, the estimates of PEHC and sampling details. The HGMPs present the same information, but numbers vary. Given that Warheit (2014a) was finalized after the HGMPs, we assume the values therein are more up to date and have based analysis on them. Also included in the Table is additional information on confidence intervals provided by Warheit (2014b), specifically the probability that *PEHC* exceeded 0.02.

Table A-18. *PEHC* estimates from early winter steelhead hatchery programs and sampling details for the Nooksack and Stillaguamish steelhead populations (Warheit 2014a).

Basin	Listed Population	Sample size and details	*PEHC* and 90% CI	P (*PEHC*>0.02)
Nooksack	Nooksack (W)	246 (2009-2013 adults and juveniles)	0.00 (0.00-0.02)	0.10
	SF Nooksack (S)	66 (2010-2011 adults)	0.00 (0.00-0.02)	0.13
Stillaguamish	Stillaguamish (W)	86 (2006 smolt trap samples)	0.00 (0.00-0.07)	0.52
	Deer Cr. (S)	157 (1995+2013 juveniles, few 2012-2013 adults)	0.00 (0.00-0.01)	0.02
	Canyon Cr. (S)	96 (2013 juveniles)	0.00 (0.00-0.02)	0.06

Assuming that sample pooling had no effect on the results, *PEHC* appears to be under 0.02 in both Nooksack steelhead populations with high confidence. Since the proposed programs are essentially the same size as the existing programs, we expect these values to remain under 0.02. It is interesting that the PEHC information is virtually identical for the Nooksack summer and winter steelhead populations, given that the summer steelhead are thought to spawn only in areas inaccessible to winter steelhead (WDFW 2014b). The result may suggest this spatial separation is not absolute, or may reflect an insensitivity in analysis. *PEHC* estimates for the Stillaguamish summer steelhead populations are also very low, even though, unlike the situation in the Nooksack, summer and winter steelhead spawning are not spatially segregated in the Stillaguamish.

The point estimate for PEHC in Stillaguamish winter steelhead population was also 0.0, but the confidence interval ranged to 7%, with the probability that *PEHC* exceeds 0.02 is 0.52. Warheit (2014a) noted that the Stillaguamish was the most poorly represented system in his analysis. No true sample of naturally produced Stillaguamish winter steelhead was available, and no samples of the hatchery fish released into the Stillaguamish were used in the analysis. The WDFW analysis was based on sampling outmigrating smolts at a lower basin smolt trap that undoubtedly collects fish from multiple populations, and is many years old now, so may not be a good representation of current gene flow conditions anyway. Thus, both the *PEHC* estimate and confidence interval for Stillaguamish winter steelhead are more uncertain than for other populations.

We have included the sample information in Table 1 to highlight the fact that Warheit's analysis largely used pooled samples from multiple years, and multiple life stages. Given the difficulties inherent in sampling steelhead, pooling seems reasonable, but it may have implications for *PEHC* estimates. We discuss this in detail in the section below.

Genetic monitoring

A key part of the Proposed Action is a genetic monitoring plan described in Anderson et al. (2014), which is intended to verify that *PEHC* is being maintained at or below stipulated levels. The plan includes sampling in several Puget Sound basins. Table 2 presents sampling details for the Nooksack, Stillaguamish, and Dungeness Basins.

Table A-19. Genetic sampling plans for Nooksack, Stillaguamish, and Dungeness steelhead (Anderson et al. 2014).

Basin	Sample site	Life stage	N	Population(s) sampled
Nooksack	Mainstem Nooksack R.	Smolts	≤ 100 annually	Nooksack (W) and (S)
	SF Nooksack R.	Adults	≤ 50 every third year	SF Nooksack (S)
Stillaguamish	Mainstem Stillaguamish R.	Smolts	≤ 100 annually	Stillaguamish (W), Canyon Cr. (S), Deer Cr. (S)
	Deer Cr.	Adults	≤ 50 every third year	Deer Cr. (S)
Dungeness	Mainstem Dungeness R.	Smolts	≤ 100 annually	Dungeness (S/W)

This level of sampling is impressive, especially coupled with sampling efforts elsewhere in Puget Sound. But the plan lacks important details. The plan commits to sampling a maximum specified number of either smolts or adults on a regular basis, but the numbers are the same in all basins, so it appears to that there is no link between sample size and analytical power. In the Dungeness River, for example, is a sample of 100 smolts large enough to generate a *PEHC* estimate of the desired precision and accuracy? It is also unclear, given that the specified sample sizes are maxima, how many samples can actually expected to be collected in a season at the various locations. This is especially an issue with the Nooksack and Stillaguamish smolt traps, which will collect smolts from multiple populations.

Based on the sample pooling evident in the Warheit report (Warheit 2014a), it seems likely that either analytical demands or sampling difficulties that samples will be pooled. The implications of this procedure are unclear. If *PEHC* is constant over time, then unweighted pooling seems reasonable in principle. However, *PEHC* will undoubtedly vary to some degree, possibly necessitating weighting of samples. In addition, sample sizes may vary widely from year to year. Perhaps samples should be weighted based on size. Finally, it makes sense that in a given population, a *PEHC* estimate based on adults could differ from one based on smolts, simply because the progeny of hatchery-origin are expected to be less fit than the progeny of natural-origin fish and thus some of them may die before they can be sampled as adults. What are then the implications of pooling adult and juvenile samples?

We also note that there is no directed sampling of the Canyon Cr. summer steelhead population. Summer steelhead are at low levels in the Stillaguamish basin, with no available escapement estimates, but intrinsic potential estimates of capacity for Deer Cr. may be ten times higher than that for Canyon Cr. Canyon Cr. fish can be expected to be sampled at low rates at the smolt trap, but at this point sampling this population effectively seems very difficult. In the monitoring plan WDFW has chosen to sample the Deer Cr. population intensively to represent Stillaguamish summer steelhead. This not really a deficiency, but the monitoring plan should deal with this issue in more detail.

Estimation of gene flow using demographic methods

Methodology

The Scott-Gill method is also based on the schematic diagram presented in Figure 1. The Scott-Gill method assumes random mating, and uses estimates of the proportion of spawners that are of hatchery origin (pHOS[12]), 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. Dr. Craig Busack (NMFS) developed the equation in 2006 when he worked at WDFW. Although the

[12] Symbolized by *q* in the equation in WDFW documents.

value produced by the equation seems to us to be analytically identical to *PEHC*, we will call it *Gene_Flow* to prevent confusion as to which metric we are discussing, and to distinguish the metric from the concept.

Hoffmann (2014) presents Scott-Gill estimates for *Gene_Flow* for several Puget Sound winter steelhead populations, including the Nooksack and Stillaguamish populations, along with details on estimation of parameters. Considerable effort went into population-specific development of the overlap parameters, especially in modeling the timing of natural spawning. Because spawning distributions are not known with precision for either the early winter hatchery or natural steelhead populations in most cases, basin specific information on overlap was bracketed with information from the Tokul Creek hatchery population, the best studied winter steelhead hatchery population, and the natural winter steelhead populations in Snow Creek and Clearwater River. Hoffmann used literature values for the RRS of early winter hatchery steelhead, including a range for HxH matings. The parameter most susceptible to error is pHOS, which was estimated from spawning ground surveys and from hatchery-origin fish returning to the hatchery. The total number of fish returning to the hatchery was assumed to be 70-80% of the escapement. This assumption of 20-30% of the hatchery-origin escapement remaining in the river to spawn was considered to be conservative in comparison to earlier estimates by the HSRG of 10-20% (Hoffmann 2014). The Dungeness population was also analyzed but the Scott-Gill method in the HGMP (WDFW 2014a), but using slightly differing assumptions about proportion of hatchery-origin escapement remaining in the river, and RRS.

During the consultation an algebraic error was discovered in the Scott-Gill equation (Busack 2014), so all previously published *Gene_Flow* values were slightly inaccurate. Table 3 presents updated *Gene_Flow* values for steelhead populations in the Nooksack, Stillaguamish, and Dungeness Basins computed with the same assumed values about RRS (0.13 for HxH matings and 0.54 for HxN), and pHOS as proportion of hatchery-origin escapement (30%) (Hoffmann 2015a; 2015b). Because these populations are not monitored (WDFW 2014b), and thus no abundance or timing data exists, no analysis was possible for the summer steelhead populations in the Nooksack and Stillaguamish Basins.

Table A-20. *Gene_Flow* values generated from the Scott-Gill equation for the Nooksack, Stillaguamish, and Dungeness winter steelhead populations (Hoffmann 2015a; 2015b). For historical pHOS and *Gene_Flow* , means are reported with maxima in parentheses. Proposed Action pHOS values are back-calculated approximations from the *Gene_Flow* values using the Scott-Gill Equation. All data have had the correction to the equation applied.

	Population		
Metric/Data	Nooksack	Stillaguamish	Dungeness
Escapement years	2009-12	2000-12, except 2006-7	2010-11, 2012-13
O_N	0.0621	0.0125	0.0009
O_H	0.0838	0.1841	0.3238
Historical pHOS	0.030 (0.035)	0.052 (0.108)	0.020 (0.029)
Historical *Gene_Flow* (%)	0.50 (0.58)	0.93 (1.87)	0.30 (0.42)
Proposed Action pHOS	0.034	0.059	0.035
Proposed Action *Gene_Flow(%)*	0.57	1.05	0.50

The Scott-Gill results indicate that gene flow into the natural steelhead winter populations in the Nooksack and Stillaguamish Basins, and the summer/winter population in the Dungeness Basin has been and will continue to be (under the Proposed Action) well under the 2% threshold. These results agree with the *PEHC* analysis.

The Scott-Gill approach offers a look at the mechanics of the gene flow process that makes these estimates more understandable. For the five-year period 2007-2012, post-harvest survival rate for returning hatchery fish in the Stillaguamish River was 0.0016 (averaging 216 from an average release of 131,840)(WDFW 2014a). Of the estimated 216 fish returning, 151 would return to the hatchery and 65 would remain on the spawning grounds (30%). The natural spawning escapement averaged 1217. So average pHOS was 0.05. Because of temporal segregation only 1.25% of the natural-origin fish and 18.4% of the hatchery-origin fish coincided temporally (15 natural-origin and 12 hatchery-origin). The other 1202 natural-origin fish would spawn among themselves, as would the other 53 hatchery-origin fish. Assuming random mating, this would be expected to result in 94.5% NxN matings, 1% NxH matings, and 4.5% HxH matings. Only 11 natural-origin fish (0.9%) would be expected to mate with hatchery-origin fish. Assuming no differences in success of these matings, the initial proportion of the progeny gene pool originating from hatchery-origin fish would be 5.0%. However, because of the expected low RRS of the hatchery-origin fish (e.g., Araki et al. 2008), this percentage would be reduced to 1.1% (assuming RRS of 0.54 for NxH matings and 0.18 for HxH).

The example above also illustrates well the chain of logic in using modeled parameter values to generate the *Gene_Flow* values. Whatever error exists in the *Gene_Flow* 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 4. Hoffmann (2014) used a sensitivity analysis to evaluate the effects of parameter uncertainty on the Scott-Gill results. This was a general rather than a basin- or population-specific analysis. Average parameter values for overlap, pHOS, and RRS[13] over all the Puget Sound steelhead populations analyzed in the document to arrive at an average *Gene_Flow*, then varied each parameter individually up and down 50% (Table 5) and observed the effect on that average *Gene_Flow* (Figure 3). Based on this analysis, results seem most sensitive to pHOS, but are reasonably sensitive to RRS and overlap values. Although this sensitivity analysis is informative, additional sensitivity analysis needs to be done to improve the level of certainty of the *Gene_Flow* estimates. First, although basing the analysis on average values makes sense in several ways, it should be done on a population specific basis as well, as the situation for a particular population may deviate considerably from average. Second, multiple parameters should be varied simultaneously. We realize that varying combinations of parameters presents a huge number of options, but this can be limited by focusing on those subject to greatest uncertainty or variability. Third, variation should be done on a biologically realistic basis rather than using an arbitrary scale such as 150% and 50%, because some variables are more subject to variability/uncertainty than others. Biological reality may require the dissection of the input parameters into components and investigating their individual variability/uncertainty. An excellent example is pHOS, which is obviously a function of the estimated number of hatchery-origin and natural-origin fish on the spawning grounds. The former is assumed to be a constant proportion of the escapement, calculated from the known number returning to the hatchery, and the latter is based on redd counts and assumptions about the proportion of the run that spawns before redd surveys begin, itself an input parameter to the Scott-Gill equation. Given this, it is unclear that sensitivity analysis based on varying pHOS up and down 50% actually adequately captures all the uncertainty/variability in pHOS. Possibly the major source of imprecision and bias is in the redd counts, which are well known to be potentially subject to error. Another obvious candidate for closer scrutiny for biological reality is overlap. Seamons et al. (2004a) and Seamons et al. (2012) showed that assumptions about temporal separation between a natural steelhead population and early winter hatchery steelhead can be misleading.

[13] Hoffmann used two values for the RRS of HxH matings (0.02 and 0.13), so used an average of 0.07 in the sensitivity analysis.

Table A-21. Input parameter values used in sensitivity analysis of Scott-Gill method applied to Puget Sound steelhead populations (from Table 11 of Hoffmann (2014))

Input Parameter	Average value over watersheds and cases	Parameter value at a 50% increase	Parameter value at a 50% decrease
O(n)	3.63%	5.44%	1.81%
O(h)	12.19%	18.29%	6.10%
K1	0.07	0.11	0.04
K2	0.54	0.81	0.27
On Station pHOS	5.05%	7.58%	2.53%

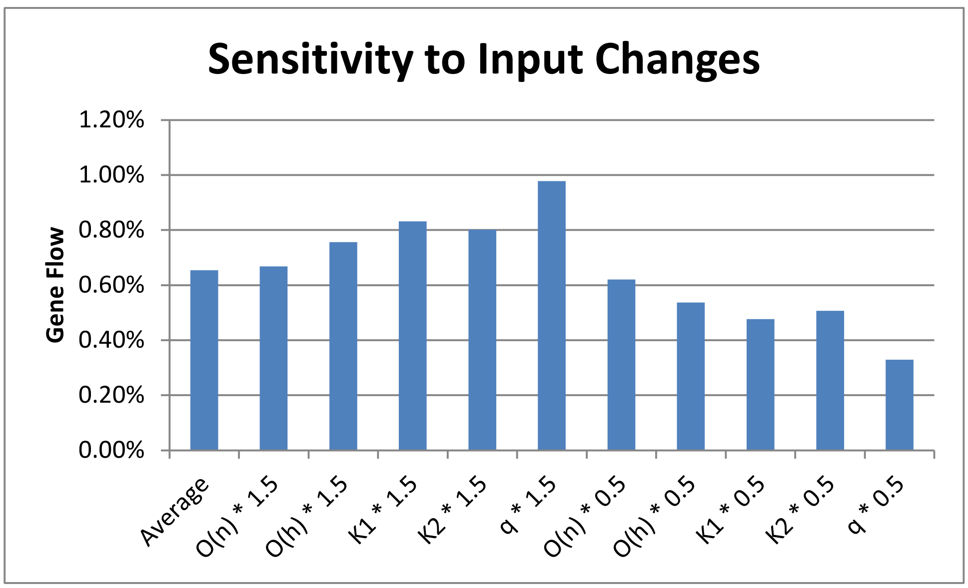

Figure A-4. Gene flow values when varying each Scott-Gill parameter in isolation by a 50% increase and a 50% decrease over the input value averaged over all watersheds and all cases (from Fig. 11 in Hoffmann 2014).

Summary

Above we have discussed at length the need for additional work on the Warheit method and associated sampling plans, and the need for a considerably more thorough sensitivity analysis of the input parameters used in the Scott-Gill method. The space devoted to detailing those issues should not overshadow the fact that for these three proposed programs, two credible and independent approaches indicate that gene flow, measured either as *PEHC* or *Gene_Flow*

Table A-22. Summary of analyses of gene flow from early winter hatchery steelhead into listed Nooksack, Stillaguamish, and Dungeness steelhead populations. (data from Table 2 and Table 4)

Basin	Listed Population	*PEHC*	*Gene_Flow*
Nooksack	Nooksack (W)	0.00 (0.00-0.02)	0.57%
	SF Nooksack (S)	0.00 (0.00-0.02)	-
Stillaguamish	Stillaguamish (W)	0.00 (0.00-0.07)	1.05%
	Deer Cr. (S)	0.00 (0.00-0.01)	-
	Canyon Cr. (S)	0.00 (0.00-0.02)	-
Dungeness	Dungeness (S/W)	-	0.50%

should be under the 2% level in all the steelhead populations affected by the three programs in the Proposed Action. And although there are concerns about the precision of the genetically based results, and concerns about both precision and bias of the demographically based results, we conclude that there would have to have been unreasonably large errors in methods or parameter estimation to have achieved these results if the gene flow was larger than 2%. Thus, while NMFS cannot rule out exceedance of 2%, we are sufficiently confident that the gene flow levels are below this threshold. On the basis of this determination, NMFS concludes that the proposed action does not pose unacceptable risk through gene flow to Puget Sound steelhead.

However, NMFS also feels that this conclusion must be validated as indicated above by (1) further development of the Warheit method to produce improved confidence intervals, (2) further development of the genetic monitoring plan, and (3) expanded sensitivity analysis of the Scott-Gill method.

Literature Cited

Anderson, J., K. I. Warheit, and B. Missildine. 2014. Genetic monitoring of hatchery-wild introgressive hybridization in Puget Sound steelhead. Washington Department of Fish and Wildlife. Olympia, Washington. December 2, 2014.

Araki, H., B. A. Berejikian, M. J. Ford, and M. S. Blouin. 2008. Fitness of hatchery-reared salmonids in the wild. Evolutionary Applications. 1(2): 342-355.

Busack, C. 2014. Error in Scott-Gill equation for gene flow. NMFS, WCR, SFD. Portland. November 3, 2014. 2.

Crawford, B. A. 1979. The origin and history of the trout brood stocks of the Washington Department of Game. Olympia, WA. 76.

Ford, M. 2015. Memorandum from Ford, M., NMFS Northwest Fisheries Science Center,, to Busack, C. . Review of updated Warheit steelhead report. Seattle, Washington. January 9, 2015.

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

Grant, W. S. 1997. Genetic effects of straying of non-native hatchery fish into natural populations: Proceedings of the workshop. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-NWFSC-30. 130p.

Hard, J. 2014. Memorandum from Hard, J., NMFS Northwest Fisheries Science Center,, to Tynan, T.

Jones, R. Review of "Summary of hatchery-wild introgressive hybridization for northern Puget Sound steelhead (*Oncorhynchus mykiss*) populations affected by segregated hatchery programs". Unpublished Washington Department of Fish and Wildlife report by Kenneth I. Warheit, dated March 2014. April 16, 2014.

Hausch, S. J., and M. C. Melnychuk. 2012. Residualization of hatcheyr steelhead: a meta-analysis of hatchery practices. North American Journal of Fisheries Management. 32: 905-921.

Hoffmann, A. 2014. Estimates of gene flow for Puget Sound hatchery steelhead programs. Washington Department of Fish and Wildlife. Mill Creek, Washington. October 10, 2014.

Hoffmann, A. 2015a. Spreadsheet from Hoffmann, A., WDFW, to C. Busack (NMFS); Beata Dungeness Gene Flow 6-24-14.xlsx. Mill Creek, Washington. February 27, 2015.

Hoffmann, A. 2015b. Spreadsheet from Hoffmann, A., WDFW, to C. Busack (NMFS); DRAFT Hoffmann 2014 Gene Flow 11-22-14.xlsx. Mill Creek, Washington. January 29, 2015.

HSRG. 2004. Hatchery reform: Principles and recommendations of the Hatchery Scientific Review Group. April 2004.

HSRG. 2009. Columbia River Hatchery Reform Project Systemwide Report. Appendix A. White paper 1. Predicted Fitness Effects of Interbreeding Between Hatchery and Natural Populations of Pacific Salmon and Steelhead. 38p

HSRG. 2014. On the Science of Hatcheries: An updated perspective on the role of hatcheries in salmon and steelhead management in the Pacific Northwest. A. Appleby, H.L. Blankenship, D. Campton, K. Currens, T. Evelyn, D. Fast, T. Flagg, J. Gislason, P. Kline, C. Mahnken, B. Missildine, L. Mobrand, G. Nandor, P. Paquet, S. Patterson, L. Seeb, S. Smith, and K. Warheit. June 2014. 160p.

Jones Jr., R. P. 2014. letter from Jones Jr., R. P., NMFS Sustainable Fisheries Division, to Anderson, P. (WDFW)

Loomis, L. (NWIFC). Sufficiency of five updated HGMPs for early winter steelhead programs. Portland, Oregon. November 12, 2014.

McMillan, J. R., S. L. Katz, and G. R. Pess. 2007. Observational evidence of spatial and temporal structure in a sympatric anadromous (winter steelhead) and resident rainbow trout mating system on the Olympic Peninsula, Washington. Transactions of the American Fisheries Society. 136: 736–748.

Myers, J. M., J. J. Hard, E. J. Connor, R. A. Hayman, R. G. Kope, G. Lucchetti, A. R. Marshall, G. R. Pess, and B. E. Thompson. 2014. Identifying historical populations of steelhead within the Puget Sound Distinct Population Segment. U.S. Dep. Commer., NOAA Tech. Mem. NMFS-NWFSC-XXX, 154pp.

NMFS. 2003. Hatchery Broodstock Summaries and Assessments for chum, coho, and Chinook salmon and steelhead stocks within Evolutionarily Significant Units listed under the Endangered Species Act. Salmon Steelhead Hatchery Assessment Group. National Marine Fisheries Service, Northwest Fisheries Science Center. Seattle, Washington.

Pritchard, J. K., M. Stephens, and P. Donnelly. 2000. Inference of population structure using multilocus genotype data. Genetics. 155: 945-959.

Pritchard, J. K., X. Wen, and D. Falush. 2010. Documentation for *structure* software: Version 2.3.

Schmidt, S. P., and E. W. House. 1979. Precocious sexual development in hatchery-reared and laboratory maintained steelhead trout (*Salmo gairdneri*). Journal of the Fisheries Research Board of Canada. 36: 90-93.

Scott, J. B., and W. T. Gill, editors. 2008. Oncorhynchus mykiss: Assessment of Washington State's steelhead populations and programs. Preliminary draft for Washington Fish & Wildlife Commission. 424p. Washington Department of Fish and Wildlife, Olympia, Washington.

Seamons, T. R., P. Bentzen, and T. P. Quinn. 2004a. The effects of adult length and arrival date on individual reproductive success in wild steelhead trout (*Oncorhynchus mykiss*). Canadian Journal of Fisheries and Aquatic Sciences. 61: 193-204.

Seamons, T. R., P. Bentzen, and T. P. Quinn. 2004b. The mating system of steelhead, *Oncorhynchus mykiss*, inferred by molecular analysis of parents and progeny. Environmental Biology of Fishes. 69: 333-344.

Seamons, T. R., L. Hauser, K. A. Naish, and T. P. Quinn. 2012. Can interbreeding of wild and artificially propagated animals be prevented by using broodstock selected for a divergent life history? Evolutionary Applications. 5(7): 705-719.

Sharpe, C. S., P. L. Hulett, C. W. Wagemann, M. P. Small, and A. R. Marshall. 2010. Natural reproductive success of first-generation hatchery steelhead spawning in the Kalama River: a progress report. W. D. o. F. a. Wildlife. Olympia, WA.

Tipping, J. M., A. L. Gannam, T. D. Hilson, and J. B. Poole. 2003. Use of size for early detection of juvenile hatchery steelhead destined to become precocious males. North American Journal of Aquaculture. 65: 318-322.

Warheit, K. I. 2013. Introgressive hybridization. Pages 88-119 *in* D. Pflug, editor. Ecological, genetic and productivity consequences of interactions between hatchery and natural-origin steelhead of the Skagit watershed. Report to Saltonstall-Kennedy Grant Program (NOAA).

Warheit, K. I. 2014a. Measuring reproductive interaction between hatchery-origin and wild steelhead (*Oncorhynchus mykiss*) from northern Puget Sound populations potentially affected by segregated hatchery programs. Washington Department of Fish and Wildlife. Olympia, Washington. October 10, 2014.

Warheit, K. I. 2014bWarheit, K. I., WDFW, to C. Busack (NMFS); Probability_PEHC_Greater_02.xlsx. Olympia, Washington. November 21, 2014.

Warheit, K. I. 2014cWarheit, K. I., Washington Department of Fish and Willdife,. Response to comments by Northwest Fisheries Science Center, NOAA, dated April 16, 2014. Olympia, Washington. November 10, 2014.

Warheit, K. I. 2014d. Summary of hatchery-wild introgressive hybridization for northern Puget Sound steelhead (*Oncorhynchus mykiss*) populations affected by segregated hatchery programs. Washington Department of Fish and Wildlife. Olympia, Washington. March 2014.

WDFW. 2008. Statewide steelhead management plan: Statewide policies, strategies, and actions. Olympia, Washington. February 29, 2008.

WDFW. 2014a. Dungeness River early winter steelhead hatchery program (segregated) HGMP. July 28, 2014.

WDFW. 2014b. Kendall Creek winter steelhead hatchery program (segregated) HGMP. July 28, 2014.