PROPOSED RECOVERY PLAN
FOR THE
PUGET SOUND STEELHEAD
DISTINCT POPULATION SEGMENT

(Oncorhynchus mykiss)

West Coast Regional Office
National Marine Fisheries Service
National Oceanic and Atmospheric Administration

Cover photo of first natural-origin steelhead radio tagged in the Elwha River after dam removal, by John McMillan of NOAA Fisheries.

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(Oncorhynchus mykiss)

Prepared by:

Office of Protected Resources and West Coast Region
National Marine Fisheries Service

Approved: ____________________________

Chris W. Oliver
Assistant Administrator for Fisheries
National Oceanic and Atmospheric Administration

Date: ______________________________

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LITERATURE CITATION SHOULD READ AS FOLLOWS:

NMFS (National Marine Fisheries Service). 2018. Proposed Recovery Plan for the Puget Sound Steelhead Distinct Population Segment (*Oncorhynchus mykiss*). National Marine Fisheries Service. Seattle, WA.

ADDITIONAL COPIES MAY BE OBTAINED FROM:

National Marine Fisheries Service
West Coast Regional Office, Oregon Washington Coastal Area Office 7600 Sand Point Way NE Seattle, WA 98115

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http://www.westcoast.fisheries.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/puget_sound/puget_sound_salmon_recovery_domain.html

Acknowledgments

The Recovery Plan for the Puget Sound Steelhead DPS builds on the significant body of published work and expert knowledge regarding Puget Sound steelhead. The National Marine Fisheries Service gratefully acknowledges the contributions and dedicated efforts of numerous people and organizations over many years, and would like to thank the individuals, organizations, and agencies listed below (alphabetically) for their contributions to the Plan.

NMFS Puget Sound Steelhead Recovery Lead
Elizabeth Babcock, NOAA Fisheries, West Coast Region, Oregon Washington Coastal Office

Principal Authors
David Price, NOAA Fisheries, West Coast Region, Oregon Washington Coastal Office
Rob Walton, NOAA Fisheries, West Coast Region, Oregon Washington Coastal Office (retired)

Contributing Authors

Joseph Anderson	Washington Department of Fish and Wildlife
Ed Connor	Seattle City Light
Ken Currens	Northwest Indian Fisheries Commission
Jeff Hard	NOAA Northwest Fisheries Science Center
Neala Kendall	Washington Department of Fish and Wildlife
Susan O'Neil	Long Live the Kings
Barbara Taylor	NOAA Fisheries Contractor

NMFS Contributors and Reviewers

Alison Agness	NOAA Pacific Salmon Commission
Laurie Beale	NOAA Office of the General Counsel
Barry Berejikian	NOAA Northwest Fisheries Science Center
Craig Busack	NOAA Fisheries, West Coast Region
Therese Conant	NOAA Fisheries, Office of Protected Resources
James Dixon	NOAA Fisheries, West Coast Region
Jeff Hard	NOAA Northwest Fisheries Science Center
Damon Holzer	NOAA Northwest Fisheries Science Center
Christina Iverson	NOAA Fisheries, West Coast Region
Kim Kratz,	NOAA Fisheries, West Coast Region
Steve Leider	NOAA Fisheries, West Coast Region
Richard Morse	NOAA Fisheries, West Coast Region
Jim Myers	NOAA Northwest Fisheries Science Center
George Pess	NOAA Northwest Fisheries Science Center

Puget Sound Steelhead Recovery Team

Joseph Anderson	Washington Department of Fish and Wildlife
Elizabeth Babcock	NOAA Fisheries, West Coast Region
Ed Connor	Seattle City Light
Ned Currence	Nooksack Indian Tribe

Ken Currens	Northwest Indian Fisheries Commission
Jeanette Dorner	Puget Sound Partnership
Jeff Hard	NOAA Northwest Fisheries Science Center
Neala Kendall	Washington Department of Fish and Wildlife
Susan O'Neil	Long Live the Kings
Tristan Peter-Contesse	Puget Sound Partnership
Scott Powell	Seattle City Light
David Price	Washington Department of Fish and Wildlife and NOAA Fisheries, West Coast Region
Stacy Vynne	Puget Sound Partnership
Rob Walton	NOAA Fisheries, West Coast Region

Consultant Support

Claire Chase	Triangle Associates
Robert Wheeler	Triangle Associates
Barbara Taylor	Contract Scientist, Writer, Editor

Other Contributors and Reviewers

Recovery Implementation Technical Team

State and Tribal Co-Managers

Puget Sound Partnership

Governor's Salmon Recovery Office

Puget Sound Salmon Recovery Council

Local Governments and Organizations

Other Contributors and Reviewers

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Acronyms and Abbreviations

AQI	Aquatic Inventories Project
BLM	Bureau of Land Management
BMP	Best Management Practice
BRT	Biological Review Team
CAO	Critical Area Ordinance
CIG	Climate Impact Group
CREP	Conservation Reserve Enhancement Program
CWA	Clean Water Act
DIP	Demographically Independent Population
DNR	Washington State Department of Natural Resources
DPS	Distinct Population Segment
DSS	Decision Support System
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
FBRB	Fish Barrier Removal Board
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FFFPP	Family Forests and Fish Passage Program
FMEP	Fishery Management Evaluation Plan
FPDSI	Fish Passage and Diversion Screening Inventory
FRN	Federal Register Notice
GAO	U.S. Government Accountability Office
GSRO	Governor's Salmon Recovery Office
GMA	Washington State Growth Management Act
HCP	Habitat Conservation Plan
HGMP	Hatchery Genetic Management Plan
HPA	Hydraulic Project Approval
HUC	Hydrologic Unit Code
IP	Intrinsic Potential
IPCC	Intergovernmental Panel on Climate Change
LE	Lead Entity
LiDAR	Light Detection and Ranging remote sensing method
MMPA	Marine Mammal Protection Act
MPG	Major Population Group
N/A	Not Applicable
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration (NOAA Fisheries)
NRCS	National Resources Conservation Service
NWFP	Northwest Forest Plan
NWFSC	Northwest Fisheries Science Center

NWR	Northwest Region (of NOAA Fisheries) (Merged with Southwest Region to form West Coast Region on 10/1/13)
O&M	Operation and Maintenance
PBDE	Polybrominated diphenyl ethers
PCSRF	Pacific Coast Salmon Recovery Funds
PDO	Pacific Decadal Oscillation
PFMC	Pacific Fisheries Management Council
PSAR	Puget Sound Acquisition and Restoration
PSP	Puget Sound Partnership
PSSRC	Puget Sound Salmon Recovery Council
PSSTRT	Puget Sound Steelhead Technical Recovery Team
R/S	Recruits per Spawner
RCO	Recreation and Conservation Office
RMAP	Road Maintenance and Abandonment Plan
RM&E	Research, Management and Evaluation
SEPA	State Environmental Policy Act
SMA	Shoreline Management Act
SRFB	Salmon Recovery Funding Board
TMDL	Total Maximum Daily Load
TRT	Technical Recovery Team
UGA	Urban Growth Area
USACE	U.S. Army Corps of Engineers (or Corps')
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
USFWS	U.S. Fish and Wildlife Service
VSP	Viable Salmonid Population
WDFW	Washington Dept. Fish and Wildlife
WDOE	Washington Dept. of Ecology (or Ecology)
WSDOT	Washington Dept. of Transportation

Preface

This proposed recovery plan (Plan) has been developed pursuant to the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 et seq.). This Plan will be published for public review and comments received during the review period will be considered during preparation of the final plan.

Congress passed the Endangered Species Act of 1973 (16 USC 1531 et. seq.) to provide a means to conserve the ecosystems upon which endangered and threatened species depend, to provide a program for the conservation of such endangered and threatened species, and to take such steps as may be appropriate to achieve the purposes of the treaties and conventions that conserve such species. The National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service share responsibilities for the administration of the ESA. NMFS is responsible for most marine and anadromous species, including the Puget Sound Steelhead (*Oncorhynchus mykiss*) Distinct Population Segment (DPS).

To help identify and guide recovery needs for listed species, section 4(f) of the ESA directs the secretaries to develop and implement recovery plans for listed species. A recovery plan must include, to the maximum extent practicable: (1) a description of site-specific management actions necessary to conserve the species; (2) objective, measurable criteria that, when met, will allow the species to be removed from the endangered and threatened species list; and (3) estimates of the time and funding required to achieve the plan's goals.

The goals and objectives of this recovery plan can be achieved only if a long-term commitment is made to support the actions recommended herein. Achievement of these goals and objectives will require the continued cooperation of the governments of the United States and other nations. Within the United States, the shared resources and cooperative involvement of federal, state, tribal, and local governments, industry, academia, nongovernmental organizations, and individuals will be required throughout the recovery period.

Executive Summary

Introduction

This recovery plan (Plan or recovery plan) provides guidance for the protection and recovery of Puget Sound steelhead, which are currently listed as a threatened species under the federal Endangered Species Act (ESA). NOAA's National Marine Fisheries Service (NMFS) recognizes Puget Sound steelhead as a distinct population segment (DPS)[1] of steelhead *(Oncorhynchus mykiss).* The Puget Sound steelhead DPS (shown in Figure ES-1) includes all naturally spawned steelhead originating below natural and manmade impassable barriers from rivers flowing into Puget Sound from the Elwha River (inclusive) eastward, including rivers in Hood Canal, South Sound, North Sound, and the Strait of Georgia. The DPS also includes steelhead from six artificial propagation programs.

At one time rivers, streams, and estuaries along the shores of Puget Sound teemed each year with steelhead returning from the Pacific Ocean to their natal spawning grounds. The historical abundance of the fish is unknown, but commercial catch records and news articles from the early 1800s indicate that 409,000 to 930,000 adult steelhead returned each year to Puget Sound at the turn of the 19th Century. These runs played an integral role in the lives of Indian tribes that lived in the region, as well as for many of the people who later settled in the area.

The once healthy and abundant runs of steelhead began to decline in the late 1800s and continued to decline through the 1900s. In recent years, significantly fewer steelhead have returned to Puget Sound; the current run is less than 5–10 percent of its historical size, and productivity continues to decline (Hard et al. 2015; NMFS 2016). To stop the decline, NMFS listed Puget Sound steelhead as a threatened species under the ESA in 2007 (72 FR 26722, May 11, 2007). Since then, repeated NMFS reviews of the species' status have determined that the "threatened" classification remained appropriate.

This recovery plan aims to recover the species to the point that it can be self-sustaining in the natural environment over the long term. To achieve full recovery, steelhead populations in Puget Sound need to be robust enough to withstand natural environmental variation and some catastrophic events, and they should be resilient enough to support harvest and habitat loss due to human population growth. The recovery plan provides guidance to improve the viability of the Puget Sound steelhead DPS by addressing the factors that contribute to the current condition — including habitat loss and degradation, water withdrawals, declining water quality, fish passage barriers, dam operations, harvest, hatcheries, climate change effects, and reduced early marine survival. As directed by Section 4(f) of the ESA, the Plan describes: (1) recovery goals and objective, measurable criteria which, when met, will result in a determination that the species be removed from the threatened and endangered species list; (2) site-specific management actions necessary to achieve the Plan's goals; and (3) estimates of the time required and cost to carry out the actions. NMFS intends to use the recovery plan to organize and coordinate recovery of the species in partnership with state, tribal, and federal resource managers.

[1] A DPS is a group of steelhead that is discrete from other groups of the same species and that represents an important component of the evolutionary legacy of the species. Under the ESA, a DPS is treated as a species.

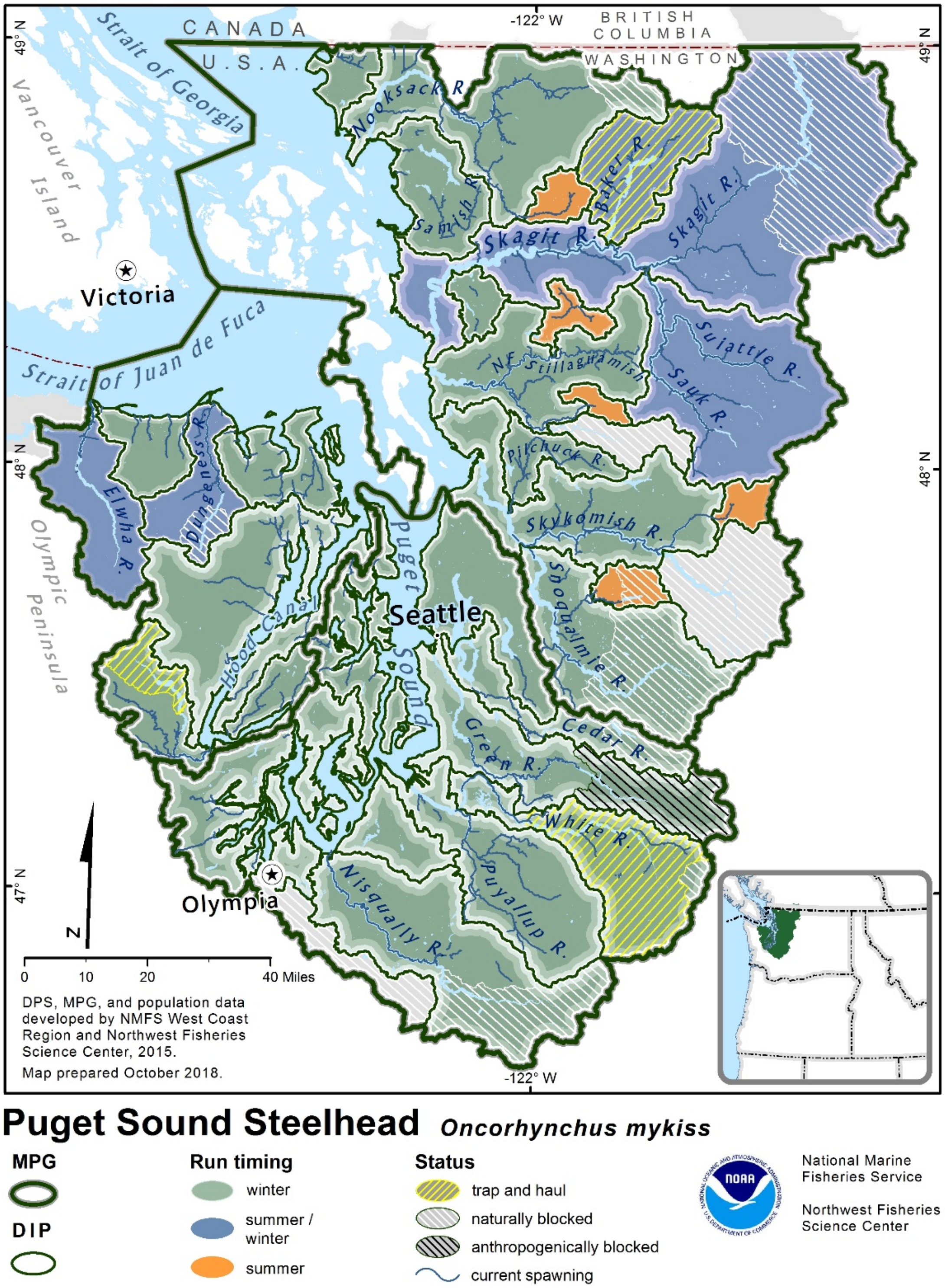

Figure ES-1. Puget Sound steelhead DPS and associated Major Population Groups (MPGs) and Demographically Independent Populations (DIPs).

Steelhead Life History and Habitat Requirements

Steelhead use a wide variety of freshwater habitats throughout Puget Sound watersheds, often migrating into upper tributary reaches to spawn. Also, unlike salmon species, steelhead are iteroparous, capable of repeat spawning in successive years, and they have a resident life-history form (rainbow trout) that is capable of producing anadromous offspring and interbreeding with anadromous life forms.

Adult Puget Sound steelhead commonly arrive from the ocean after two to three years and return to spawning and rearing habitats in independent tributaries that flow into Puget Sound, Hood Canal, and the Strait of Juan de Fuca. Steelhead generally reside longer in freshwater than salmon species (commonly 1-4 years) and use diverse tributary habitats with cool, clean water. Channel features such as side channels, adjacent small tributaries and floodplains, and abundant large wood and coarse substrate (boulders and cobble) provide important habitat for juvenile steelhead, including as cover from predators and as refuge from fall and winter floods.

While steelhead show a high degree of diversity in their life-history traits, they exhibit two general types of life-history strategies: Winter-run steelhead return from the ocean in the fall and typically spawn within a few weeks; summer-run steelhead migrate into natal streams from the ocean during the late spring and summer, and hold for up to nine months in stream and river habitats with deep pools, diverse instream cover, and cool water before spawning in late-winter/early spring of the following year. Their early migration allows them upstream access through canyons and other confined channel areas that become flow barriers to winter-run steelhead later in the year. Most summer steelhead spawning areas in the Puget Sound are located in headwater areas above narrow canyons. However, because the habitat features needed to sustain summer-run steelhead populations are uncommon in most Puget Sound watersheds, winter-run steelhead populations are the predominant life-history strategy. Figure ES-2 shows the different stages in the life history cycle of winter-run steelhead in Puget Sound.

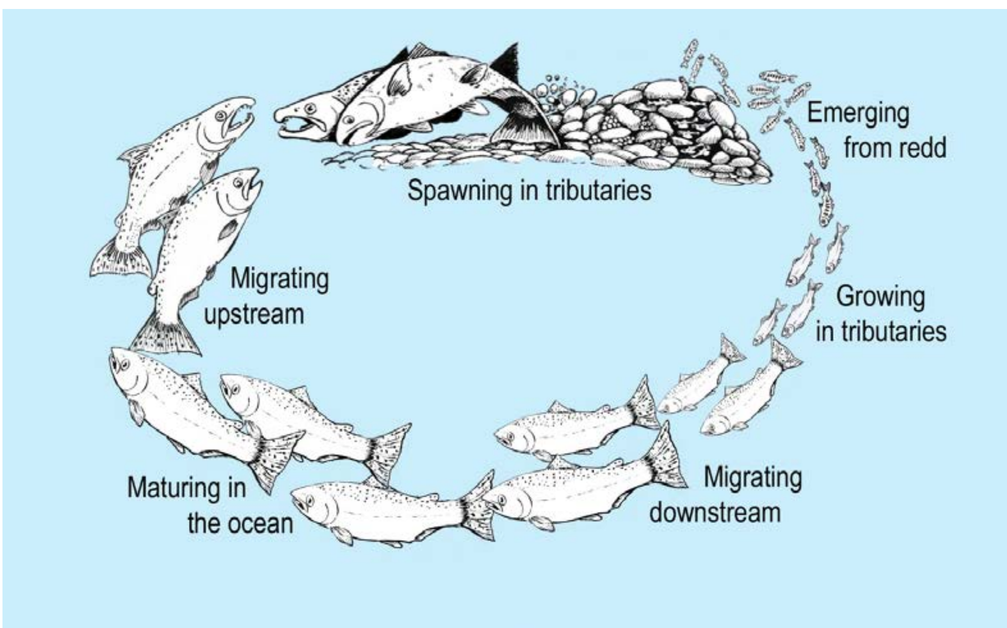

Figure ES-2. Winter-run steelhead life history cycle.

Factors Leading to ESA-Listing and Remaining Pressures

At the time of listing, NMFS identified several factors that led to the decline of Puget Sound steelhead and the determination that listing the species as threatened was warranted: widespread declines in abundance and productivity for most natural steelhead populations in the DPS — including the populations in the Skagit and Snohomish Rivers, which previously were considered steelhead strongholds; the low abundance of several summer-run populations; and the sharply diminishing abundance of some steelhead populations, especially in south Puget Sound, Hood Canal, and the Strait of Juan de Fuca. Continued releases of out-of-DPS hatchery fish from Skamania-derived summer run were considered a major concern for diversity in the DPS (Hard et al. 2007).

The Puget Sound steelhead viability evaluation (Hard et al. 2015) found that while harvest and hatchery production of steelhead in Puget Sound were currently at low levels and not likely to increase substantially in the foreseeable future, some unfavorable environmental trends existed and were expected to continue. Habitat utilization by steelhead has been most affected by the degradation and fragmentation of freshwater habitats, with consequential effects on connectivity. Large dams in some watersheds have affected steelhead populations and their distribution. In addition to eliminating accessibility to habitat, dams affect habitat quality through changes in river hydrology, temperature profile, downstream gravel recruitment, and the movement of large woody debris. Many of the lower reaches of rivers and their tributaries in Puget Sound have been dramatically altered by urban development. Urbanization and suburbanization have resulted in the loss of historical land cover in exchange for large areas of imperious surface (buildings, roads, parking lots, etc.). The human-related pressures have resulted in severe consequences for steelhead freshwater habitat and the species' abundance and productivity.

During the planning process, the Puget Sound Steelhead Recovery Team identified 10 primary pressures associated with the listing decision for Puget Sound steelhead and subsequent affirmations of the listing. These "pressures" are human activities and natural events that cause or contribute to the species' decline in viability. The 10 primary pressures are: fish passage barriers at road crossings; dams, including fish passage and flood control; floodplain impairments, including agriculture; residential, commercial, industrial development (including impervious runoff); timber management activities; water withdrawals and altered flows; ecological and genetic interactions between hatchery and wild fish; harvest pressures (including selective harvest) on wild fish; juvenile mortality in estuary and marine waters of the Puget Sound; and climate change. These pressures are described in Section 1.2.3 and addressed by the recovery strategies and actions for the species in Chapter 3.

Recovery Goals and Criteria

The recovery plan provides NMFS' recovery goals for the Puget Sound steelhead DPS in Chapter 2 and criteria for delisting in Chapter 4. The direction reflects agreements made through a collaborative process initiated by NMFS and strengthened through wide regional and local participation.

ESA Recovery Goals

- The Puget Sound steelhead DPS achieves biological viability and the ecosystems upon which the DPS depends are conserved such that it is sustainable and persistent and no longer needs federal protection under the ESA, and
- The five listing factors from the ESA, section 4(a)(1), are addressed.

Recovery (Delisting) Criteria

NMFS uses two types of criteria to determine whether a species can be delisted:

Viability Criteria are the criteria NMFS will consider in determining whether the species has achieved a biological status consistent with recovery. The overarching viability criterion for Puget Sound steelhead is that the DPS "has a negligible risk of extinction due to threats from demographic variation, local environmental variation, and genetic diversity changes over a 100-year time frame" based on the status of major population groups (MPGs) and demographically independent populations (DIPs), and supporting ecosystems (McElhany et al. 2000). A self-sustaining viable population has a negligible risk of extinction due to reasonably foreseeable changes in circumstances affecting its abundance, productivity, spatial structure, and diversity characteristics and achieves these characteristics without dependence upon artificial propagation (see Section 4.2.2.1 for specific viability delisting criteria).

Listing Factor Criteria are the criteria that NMFS will evaluate to determine whether the underlying causes of steelhead decline have been addressed and mitigated and are not likely to re-emerge in the foreseeable future. The criteria address the five listing factors from the ESA section 4(a)(1): (A) the present or threatened destruction, modification, or curtailment of the species' habitat or range; (B) over-utilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) inadequacy of existing regulatory mechanisms; and (E) other natural or human-made factors affecting the species' continued existence (see Section 4.3 for specific listing factor delisting criteria).

Recovery Strategies and Actions

The recovery strategies for Puget Sound steelhead primarily focus on protecting and restoring ecosystem functions and freshwater habitat and improving juvenile survival in Puget Sound waters. Complementary strategies ensure that fisheries management (harvest and hatcheries) is consistent with recovery, and where possible, improve viability. Collectively, these strategies address the 10 primary pressures (discussed earlier) that threaten Puget Sound steelhead recovery. They also describe research, monitoring,

**Primary Pressures
Affecting Puget Sound Steelhead Recovery**

- Fish passage barriers at road crossings
- Dams, including fish passage and flood control
- Floodplain impairments, including agriculture
- Residential, commercial, industrial development (including imperious runoff)
- Timber management activities
- Water withdrawals and altered flows
- Ecological and genetic interactions between hatchery and natural-origin fish
- Harvest pressures (including selective harvest) on natural-origin fish
- Juvenile mortality in estuary and marine waters of Puget Sound
- Climate change

and evaluation needs. Chapter 3 and Appendix 4 describe the site-specific strategies and associated actions.

Recovery Strategies

Strategies to Improve Fish Passage

1. Maintain and increase support for the Fish Barrier Removal Board and related programs.
2. Highlight and remedy programmatic gaps in fish passage removal programs.
3. Provide funding and resources for fish barrier removal.
4. Increase the education, social science, and social marketing programs that support fish passage barrier removal.
5. Align fish passage correction programs to ensure consistency between federal, state, cities, counties, private entities.
6. Prohibit new fish passage barriers.
7. Increase monitoring, data collection, information sharing, and reporting of fish passage correction progress.
8. Incorporate the benefits of beaver in barrier removal programs.

Strategies to Address Effects of Dams

1. Identify opportunities and priorities for dam removal in watersheds where steelhead migration has been blocked.
2. Provide funding and resources for dam removal.
3. Remove high priority dams that block or impair steelhead migration into historical spawning and rearing areas.
4. Construct or improve fish passage facilities at dams, locks, and water diversions where steelhead migration is blocked or impaired. Reduce passage injuries and mortalities at these facilities.
5. Increase education, social science, and social marketing.
6. Dis-incentivize new dams, locks, and water diversion structures.
7. Improve instream flows downstream of hydroelectric dams and water storage reservoirs.
8. Use mitigation/restoration to improve habitat conditions downstream of dams and water storage reservoirs.
9. Improve temperature and water quality conditions downstream of hydroelectric dams and water storage reservoirs.

Strategies to Improve Floodplain Connectivity and Condition

1. Protect intact floodplains using effective land use regulations and enforcement.
2. Identify and protect floodplains and freshwater wetlands for steelhead through funding and implementing farm-fish-flood integrated planning programs at the local level.
3. Reduce levee impacts through setbacks and improved vegetation management.
4. Reduce bank armoring and other habitat stressors in steelhead river systems.
5. Educate the community to reduce bank armoring and other habitat stressors in steelhead river systems.

Strategies to Address Effects of Residential, Commercial, Industrial Development

1. Reduce impediments to infill and redevelopment in Urban Growth Areas.
2. Improve local implementation and enforcement of Growth Management Act existing regulations that protect streams and wetlands from residential/ commercial/ industrial development.
3. Incentivize protection of priority habitat areas beyond those covered via regulations.
4. Ensure and improve effectiveness of mitigation to offset impacts of development.
5. Improve federal and state highway maintenance and management to reduce impacts to steelhead.
6. Improve county and city road maintenance and new road development.
7. Align infrastructure improvements with steelhead recovery at the federal, state and local level.
8. Consider climate change impacts in planning and permitting.

Strategies to Address Effects of Timber Management

1. Develop and perform an independent and comprehensive review of forest practices rule compliance and effectiveness.
2. Collaborate on water temperature monitoring and modeling.
3. Prioritize forest riparian restoration with Clean Water Act (CWA) 303d listings.
4. Explore potential funding and financial incentives for discussions with timber companies.
5. Improve accuracy of water type classifications to ensure steelhead habitats.

6. Improve fish passage at artificial barriers.
7. Implement best science practices on other private forest protection needs.
8. Manage the Northwest Forest Plan (U.S. Forest Service for federally managed forestlands).

Strategies to Improve Instream Flows during Critical Periods

1. Identify, protect, and preserve instream flows for steelhead.
2. Maintain, restore, or improve instream flow by protecting tribal, state, and federal water rights by enforcing regulations and improving transparency, efficiency, and accountability.
3. Develop and implement incentive programs to protect and restore instream flows for steelhead.
4. Protect uplands to improve hydrological characteristics of watersheds; protect groundwater recharge areas to improve infiltration of precipitation and runoff into aquifers.
5. Improve instream flow protections and water rights for fish on federal lands.
6. Through the Habitat Conservation Plan process, provide long-term protections and conservation measures for steelhead instream flows.
7. Restore instream flows for steelhead in over-allocated watersheds.
8. Identify, develop, and fund habitat restoration projects that result in improved streams.

Strategies to Reduce Negative Effects and Improve the Conservation Benefits of Hatchery Programs

1. Be intentional in the purpose of the hatchery program.
2. Be accountable for reducing risks of hatchery programs on natural-origin steelhead.
3. Adapt to new information and challenges in the operation and management of hatcheries.

Strategies to Reduce Harvest Pressures on Natural-Origin Fish

1. Coordinate harvest among all co-managers to ensure that the collective impacts to each population are consistent with recovery goals, and associated management plans and biological opinions.
2. Consistent with habitat protection strategies, develop and manage harvest plans to ensure adequate escapement and abundance of breeding adults and execute plans and actions in such a way that key aspects of phenotypic and genetic diversity are maintained or enhanced in the population throughout a watershed (i.e., minimizing the selectivity of fisheries). Examples of key diversity elements include the extent of run and spawn timing; spatial distribution; variability in size, age, and sex ratio of spawners; and the abundance and condition of kelts.

Strategies to Reduce Early Marine Mortality and Predation

1. Continue predation research and monitoring, with a focus on areas of greatest steelhead early marine mortality.
2. Assess and test the effectiveness of specific actions to alter harbor seal behavior at locations associated with high steelhead mortality. Thoroughly assess whether predator distribution will be adequately altered and evaluate unexpected consequences.
3. Implement regional actions to allow for testing the effectiveness of site-specific marine mammal management in support of steelhead recovery.
4. Support efforts to recover or enhance the abundance of forage fish as buffer prey.
5. Support efforts to recover or enhance the abundance of other prey historically important to harbor seals and other predators of concern (e.g. hake, cod, rockfish).
6. Address high steelhead mortality at the Hood Canal Bridge through structural modifications or through management approaches to facilitate steelhead passage or alter predator behavior during the steelhead outmigration period.
7. Determine if hatchery fish act as a predator attractant and/or buffer prey in relation to steelhead early marine survival.
8. Implement actions to address *Nanophyetus salmincola* in watersheds where the parasite is prevalent and at high enough intensities to influence the health and survival of out-migrating juvenile steelhead.
9. Implement actions to identify and reduce/or eliminate contaminants suspected of affecting steelhead smolt condition.
10. Implement long-term monitoring protocol to continue to assess steelhead early marine mortality rates and distribution, and compare to freshwater and later ocean mortality.

Strategies to Reduce Impacts of Climate Change

1. By watershed, identify and prioritize climate change adaptation strategies and recovery actions that explicitly include climate change as a risk to steelhead.

2. Increase strategies or actions in other parts of the recovery plan that increase freshwater and fish connectivity, and thus increase life-history diversity, for populations and MPGs across Puget Sound.
3. Increase strategies and actions in other parts of the recovery plan that address stream temperatures and instream flows suitable for Puget Sound steelhead to maximize resiliency of aquatic systems to climate change.
4. Incorporate climate change adaptations into other steelhead recovery strategies and actions where appropriate.
5. At the MPG or population scale, use decision support tools available to prioritize and fund projects for both the 4-year work plan and annual funding rounds. All restoration projects submitted for funding should be required to demonstrate how they consider climate change and how they are designed to ensure, as much as possible, desired outcomes given future climate projections.
6. Monitor steelhead abundance, productivity, diversity, and spatial scale to detect specific impacts of climate change.

Strategies to Integrate Research, Monitoring, and Evaluations

1. Significantly improve status and trends monitoring to estimate steelhead freshwater productivity and marine survival.
2. Develop and maintain a long-term program to monitor the status and trends of steelhead habitat in Puget Sound.
3. Maintain and advance research programs intended to quantify the population viability benefits from recovery actions.
4. Identify linkages between steelhead life-history diversity and population viability.
5. Implement long-term monitoring protocol to continue to assess steelhead early marine mortality rates and distribution, and compare to freshwater and later ocean mortality.

Implementation

Ultimately, the recovery of Puget Sound steelhead depends on the commitment and dedicated actions of the many entities, tribes, agencies, and individuals who share responsibility for the species' future. Together, we need to bring the species to a level where we are confident that it is viable and naturally self-sustaining.

During implementation of the recovery plan, NMFS anticipates the continued execution of ongoing programs, management actions and regulations, as well as the implementation of many new actions proposed in this Plan to address pressures on steelhead viability across the Puget Sound region. Importantly, the Plan includes an adaptive management process so we learn as we go, and adjust our efforts accordingly. Implementation of the adaptive management process will help us target actions based on best available science, monitor to improve the science, and update actions effectively based on new knowledge to achieve DPS recovery and delisting.

Implementing strategies and actions will require close coordination among restoration partners and co-managers (see Sections 1.3 and 1.4). NMFS will work with recovery partners to develop and integrate Plan implementation into existing recovery forums, such as the Puget Sound Salmon Recovery Council (PSSRC) and the Washington State Salmon Recovery Funding Board (SRFB). NMFS intends to work closely with these and other entities in the Puget Sound basin to integrate a Plan implementation framework to facilitate sharing of research and monitoring information and to coordinate decisions regarding the prioritization and implementation of recovery actions. Once fully developed, NMFS will make the implementation framework available on our web site.

Time and Cost Estimates

The time needed to recover Puget Sound steelhead will likely depend on how much funding and resources are delivered to recovery efforts, and how the strong influence of early marine survival is ultimately addressed. Under any scenario, the time to recovery will take many decades and will depend on several variables: the continued implementation of ongoing actions, including actions that benefit Puget Sound Chinook and Chum salmon recovery; the implementation of regulatory mechanisms to protect habitat; the adequacy of funding for adaptive management to inform key uncertainties; the response of natural-origin steelhead to hatchery management improvements; the effectiveness of actions to improve early marine survival; and the effects of emerging large-scale ecological factors, such as the shifting ocean currents, increasing temperatures and acidity and sea level rise associated with climate change. Overall, since habitat protection and restoration efforts comprise the largest potential gains for steelhead viability — and needed improvements in habitat conditions can take decades to achieve — it may be 100 years before full protection and restoration efforts would lead to recovery.

NMFS believes that it is most appropriate to focus on the first ten years of action implementation. We will rely on the adaptive management framework's structured process to conduct monitoring to improve the science, and on periodic plan reviews to evaluate the status of the species and add, eliminate, or modify actions based on new knowledge. Section 5.2 of the Plan provides 10-year cost estimates for Puget Sound steelhead recovery. In general, the cost estimates for Puget Sound steelhead build on the costs projected to recovery Puget Sound Chinook and Hood Canal summer Chum salmon. According to 2016 cost estimates provided by the Washington Governor's Salmon Recovery Office, the total estimated cost (capital and non-capital costs) to implement the Puget Sound Chinook and Chum salmon recovery plans is approximately $200 million per year, or $2 billion total over the next 10 years (GSRO 2016). The cost estimates for Puget Sound steelhead recovery assume that related actions for salmon recovery are fully funded and implemented. NMFS recognizes, however, that there are additional costs that apply more directly to steelhead recovery and less to Chinook and Chum salmon. These costs include correcting fish passage barriers at road crossings, providing passage at (or removing) dams, addressing early marine survival impediments, and additional monitoring and adaptive management. We estimate that $437 million will be needed over the next ten years to provide fish passage (culverts and dams) to historic reaches of Puget Sound steelhead habitat that are not used by Chinook or Chum salmon. In addition, we estimate that $44 million will be needed to monitor and adaptively manage steelhead for the next ten years. Additional funds will be needed to remedy early marine survival impacts to steelhead, but these costs are currently unknown. As adaptive management continues to improve our understanding of early marine migration impediments to recovery, costs will be developed and included with future iterations of this planning effort.

1. Introduction

This is an Endangered Species Act (ESA) recovery plan (Plan or recovery plan) for Puget Sound steelhead *(Oncorhynchus mykiss)*. NOAA's National Marine Fisheries Service (NMFS) is required, pursuant to section 4(f) of the ESA, to develop and implement recovery plans for species listed under the ESA. The Plan focuses on steelhead that spawn and rear in tributaries of the Puget Sound basin.

The Plan provides direction for the protection and conservation of the Puget Sound steelhead distinct population segment (DPS). A DPS is a group of salmon or steelhead that is discrete from other groups of the same species and that represents an important component of the evolutionary legacy of the species. Under the ESA, a DPS is treated as a species. The Puget Sound steelhead DPS is considered threatened under the ESA — signaling that it is likely to become endangered in the foreseeable future unless actions are taken to improve its viability. By extension, a viable DPS is one that is unlikely to be at risk of extinction in the foreseeable future (Hard et al. 2015).

1.1 Purpose of the Plan

This recovery plan is intended to guide the effort to improve the viability of the Puget Sound steelhead DPS and address the factors that contributed to the current condition. The Plan aims to recover the species to the point that it is self-sustaining in the wild and no longer requires protection under the ESA. To achieve full recovery, steelhead populations in Puget Sound need to be robust enough to withstand natural environmental variation and even some catastrophic events, and they should be resilient enough to support harvest and habitat loss due to human population growth (Hard et al. 2015). This Plan identifies guidance and specific planning targets to achieve recovery of Puget Sound steelhead at three hierarchical spatial scales (see Myers et al. 2015). The three levels in the hierarchy are defined below:

- **Distinct Population Segment (DPS):** A steelhead DPS is a distinctive group of steelhead that is uniquely adapted to a particular area or environment. Two criteria define a DPS of steelhead listed under the ESA: (1) discreteness of the population segment in relation to the remainder of the species to which it belongs, and (2) significance of the population segment to the species to which it belongs. DPSs may contain multiple populations that are connected by some degree of migration, and hence may have a broad geographic range across watersheds, river basins, and political jurisdictions.
- **Major Population Group (MPG):** Within a DPS, independent populations can be grouped into larger aggregates that share similar genetic, geographic, and/or habitat characteristics (McClure et al. 2003). MPGs are groupings of populations that are isolated from one another over a longer time scale than that defining the individual populations, but retain some degree of connectivity greater than that between different DPSs. An MPG is considered a "recovery unit" (see Interim Recovery Planning Guidance for Threatened and Endangered Species: https://www.fisheries.noaa.gov/national/endangered-species-conservation/endangered-species-act-guidance-policies-and-regulations) within a DPS and must be conserved to ensure the long-term viability of the species (Myers et al. 2015;

Hard et al. 2015). In the context of Puget Sound steelhead recovery, all three MPGs must be viable for the DPS to be recovered (see Chapter 2).

- **Demographically Independent Populations (DIP):** McElhany et al. (2000) defined an independent population as: "…a group of fish of the same species that spawns in a particular lake or stream (or portion thereof) at a particular season and which, to a substantial degree, does not interbreed with fish from any other group spawning in a different place or in the same place at a different season." For purposes of this Plan, not interbreeding to a "substantial degree" means that two groups are considered to be independent populations if they are isolated to such an extent that exchanges of individuals among the populations do not substantially affect the population dynamics or extinction risk of the independent populations over a 100-year time frame.

Figure 1 shows the Puget Sound steelhead DPS and associated MPGs and DIPs. Table 1 identifies the DIPs by numbers referenced in Figure 1.

DIPs exhibit different population attributes that influence their abundance, productivity, spatial structure, and diversity. They are the management units that will be combined to form alternative recovery scenarios for MPG and DPS viability. Ultimately, except for the regional focus of Puget Sound marine waters, DIPs are the scale of recovery efforts (Myers et al. 2015). Each DIP, however, is not necessarily essential for the conservation of the species or necessarily included in the recovery scenarios (see Chapter 4).

This recovery plan is intended to communicate recovery guidance to a variety of audiences, including but not limited to:

- Co-managers (Tribes and Washington Department of Fish and Wildlife (WDFW)
- NMFS
- Puget Sound Partnership Leadership Council
- Puget Sound Partnership Ecosystem Coordination Board
- Puget Sound Partnership Science Panel
- State agencies
- Government land use managers (local, state, federal)
- Industrial landowners (agriculture, forestry, transportation)
- Water managers, flood control districts, and hydroelectric utilities
- Watershed policy bodies for implementing salmonid recovery plans
- Funders
- Governor's Salmon Recovery Office
- Salmon Recovery Funding Board
- Puget Sound Salmon Recovery Council (PSSRC)
- Steelhead fishing community
- Project sponsors
- Conservation community
- Citizens and private landowners
- Scientists (steelhead, marine, habitat, and others)
- U.S. Fish and Wildlife Service (USFWS)

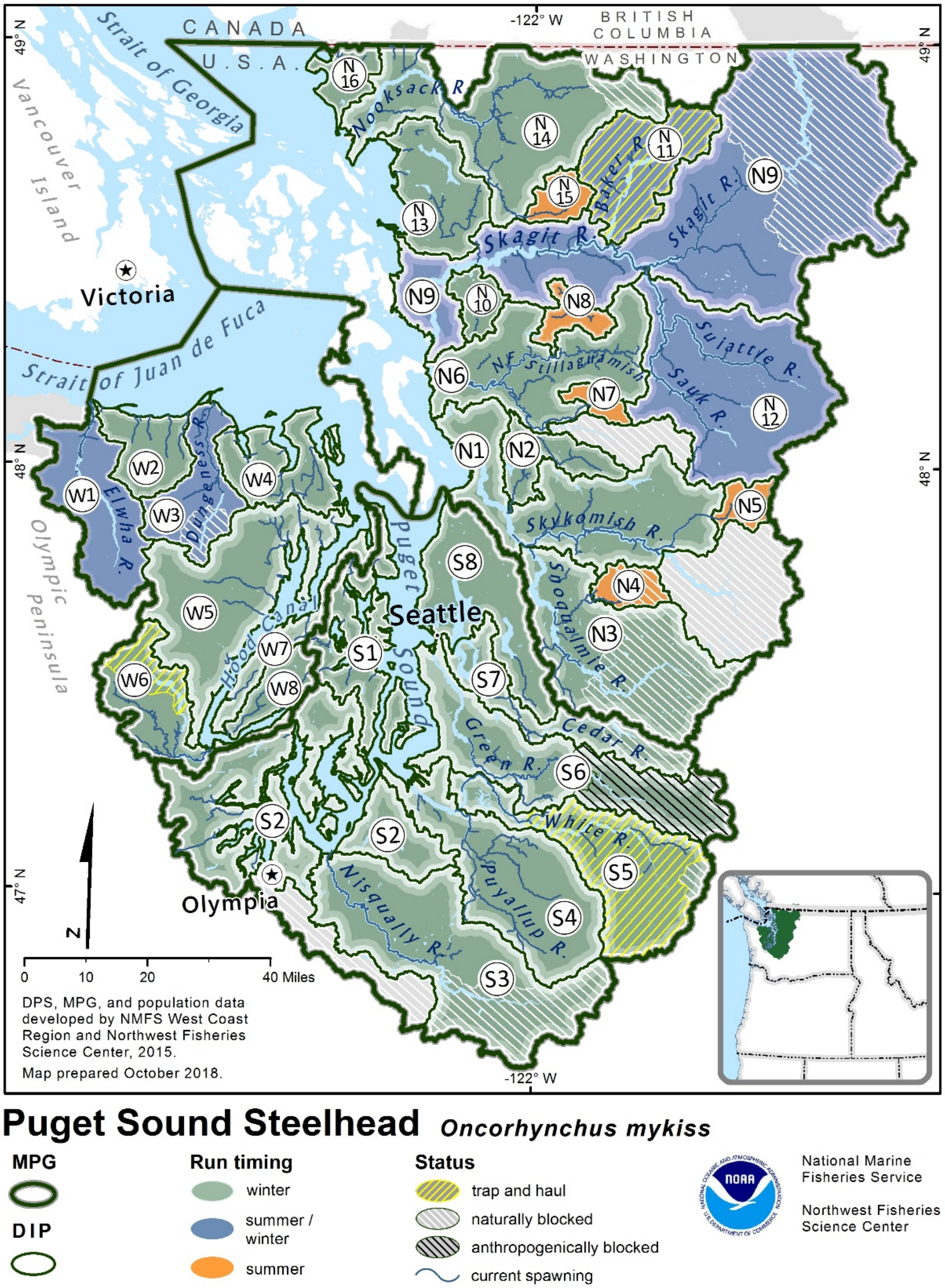

Figure 1. Puget Sound Steelhead DPS and associated major population groups (MPGs) and demographically independent populations (DIPs). Table 1 identifies the DIPs associated with the numbers referenced on the map.

Table 1. Puget Sound steelhead demographically independent populations (DIPs) by MPG, and DIP numbers referenced in Figure 1.

Figure 1 Reference	Demographically Independent Population by MPG
Northern Cascades (South Salish Sea) MPG	
N1	Snohomish/Skykomish Rivers Winter Run
N2	Pilchuck River Winter Run
N3	Snoqualmie River Winter Run
N4	Tolt River Summer Run
N5	North Fork Skykomish River Summer Run
N6	Stillaguamish River Winter Run
N7	Canyon Creek Summer Run
N8	Deer Creek Summer Run
N9	Skagit River Summer Run and Winter Run
N10	Nookachamps Creek Winter Run
N11	Baker River Summer Run and Winter Run
N12	Sauk River Summer Run and Winter Run
N13	Samish River winter run
N14	Nooksack River Winter Run
N15	South Fork Nooksack River Summer Run
N16	Drayton Harbor Tributaries Winter Run
Central and South Puget Sound MPG	
S1	East Kitsap Peninsula Tributaries Winter Run
S2	South Puget Sound Tributaries Winter Run
S3	Nisqually River Winter Run
S4	Puyallup/Carbon Rivers Winter Run
S5	White River Winter Run
S6	Green River Winter Run
S7	Cedar River Winter Run
S8	North Lake Washington and Lake Sammamish Winter Run
Hood Canal and Strait of Juan de Fuca MPG	
W1	Elwha River Summer Run and Winter Run
W2	Strait of Juan de Fuca Tributaries Winter Run
W3	Dungeness River Summer Run and Winter Run
W4	Sequim/Discovery Bays Tributaries Winter Run
W5	West Hood Canal Tributaries Winter Run
W6	Skokomish River Winter Run
W7	East Hood Canal Tributaries Winter Run
W8	South Hood Canal Tributaries Winter Run

1.2 Why Puget Sound Steelhead are Listed as Threatened

At one time, rivers, streams, and estuaries along the shores of Puget Sound teemed each year with steelhead returning from the Pacific Ocean to their natal spawning grounds. These runs played an integral role in the lives of Indian tribes that lived in the region, as well as for many of the people who later settled in the area.

The historical abundance of Puget Sound steelhead is impossible to estimate precisely. However, based on commercial catch records and news articles produced at the time, approximately 409,000 to 930,000 adult steelhead are estimated to have returned to Puget Sound streams at the turn of the 19th Century (Myers et al. 2015; Hard et al. 2015). The current abundance of Puget

Sound steelhead is less than 5–10 percent of historical abundance, with productivity continuing to decline (Hard et al. 2015; NMFS 2016). These once mighty runs began to decline in the late 1800s largely due to overfishing. However, numerous factors contributed to the decline of Puget Sound steelhead including habitat loss and degradation, water withdrawals and declining water quality, fish passage barriers, dam operations, harvest, hatcheries, climate change effects, and early marine survival factors. This Plan addresses each of these factors while identifying paths toward steelhead recovery across Puget Sound.

To address the proximal factors contributing to the decline of Puget Sound steelhead, we describe the life-history characteristics of steelhead and the pressures that limit their productivity and abundance in Puget Sound. Chapter 3 identifies strategies and actions to ameliorate those pressures. Appendix 4 describes the specific strategies and actions in more detail. As watershed-specific planning activities are developed, NMFS will include those plans on our web page.

Puget Sound steelhead are listed under the ESA as:

"Naturally spawned anadromous *O. mykiss* (steelhead) originating below natural and manmade impassable barriers from rivers flowing into Puget Sound from the Elwha River (inclusive) eastward, including rivers in Hood Canal, South Sound, North Sound and the Strait of Georgia. Also, steelhead from six artificial propagation programs: the Green River Natural Program; White River Winter Steelhead Supplementation Program; Hood Canal Steelhead Supplementation Off-station Projects in the Dewatto, Skokomish, and Duckabush Rivers; and the Lower Elwha Fish Hatchery Wild Steelhead Recovery Program." (72 FR 26722, 11 May 2007).

1.2.1 Ecosystem/Habitat Requirements of Steelhead

Steelhead display a wide range of life-history traits and use a wide variety of freshwater habitats throughout Puget Sound watersheds. Unlike the salmon species of the same genus *Oncorhychus*, steelhead are iteroparous — capable of repeat spawning in successive years. Steelhead also have a resident life-history form (rainbow trout), that is capable of producing anadromous offspring and interbreeding with anadromous life forms. Their run timing (return to freshwater from ocean residency) can span nine months or more. Steelhead are known to ascend small tributaries that are inaccessible to salmon. They use independent tributaries that flow directly into Puget Sound, Hood Canal, and the Strait of Juan de Fuca, unlike Chinook salmon which are largely isolated to major rivers. Adult steelhead also have a leaping ability that exceeds salmon (Reiser and Peacock 1985), which allows the distribution of steelhead to frequently extend far into the headwater reaches of watersheds. Lastly, juvenile steelhead commonly reside longer in freshwater than salmon species (1-4 years). The high degree of diversity and plasticity in the steelhead life history makes this species unique among salmonids in Puget Sound.

Steelhead use diverse habitats while rearing in freshwater streams. Like other salmonids, steelhead require cool, clean water to survive. Because steelhead are exothermic, they cannot regulate their body temperature in elevated stream temperature environments without a source of cool water (e.g., ground water, seeps, and hyporheic sources). Juvenile steelhead begin losing competitive interactions with non-salmonids and increase their susceptibility to disease and parasites at 20°C (Reeves et al. 1987), and face lethal conditions when temperatures reach 24-

26°C (Brett 1952; Bell 1986; McCullough 1999). Adult summer-run steelhead returning to spawn are even more susceptible to elevated temperatures. McCullough 1999 found that adult steelhead in the Columbia River died when exposed to stream temperatures of 21°C. The physiological effects of elevated temperatures on summer-run adult steelhead is profound as they must endure up to nine months in streams (including summer months) before spawning.

Because steelhead rear in rivers and streams for extended periods, their habitat requirements change as they grow and compete for resources and refugia. They need shallow stream margins, side channels, and other slow-moving channel features as emergent fry (Frissell 1992; Hines et al. 2017). Within the summer of their first year, they begin to move toward the center of the channel and, unlike salmon, juvenile steelhead develop territorial behaviors in diverse habitats that include pools, riffles, and cascades (Hartman 1965). Cover is an important component of juvenile habitat selection. Channel features such as side channels, adjacent small tributaries and floodplains, and abundant large wood and coarse substrate (boulders and cobble) provide important habitat for juvenile steelhead seeking cover from predators and refuge from fall and winter floods (Bustard and Narver 1975; Sedell et al. 1990; Fausch 1993; Ligon et al. 2016).

Unlike most salmonids in Puget Sound, steelhead do not rear extensively in estuaries or nearshore habitats. Nevertheless, as steelhead migrate to sea as smolts, diverse channels with abundant wood and complex river deltas help protect them from predation, largely from marine mammals and birds (Simenstad et al. 1982; Gonor et al. 1988). Steelhead smolts typically migrate directly from natal freshwater streams and rivers to the ocean very rapidly, spending only a few days to a couple of weeks in Puget Sound. Despite their rapid migration into and through Puget Sound, recent research advances have revealed alarming mortality rates of steelhead during this life stage (Moore et al. 2010; Moore et al. 2015).

After commonly two to three years at sea, maturing steelhead return to native rivers and streams to spawn. The habitat requirements for adult summer-run steelhead are notably more stringent than for winter-run steelhead. Summer-run steelhead are an early migratory life-history form that migrate into natal streams from the ocean during the late spring and summer, and hold for up to nine months in streams and rivers. Summer steelhead typically do not feed extensively during this time and must conserve energy while their gametes mature. They commonly hold in habitats with deep pools, high quality instream cover, and cool water before spawning in late-winter/early spring of the following year (Hard et al. 2007). The early migration of adult summer steelhead may provide this life-history form upstream access through canyons and other confined channel areas that become flow barriers to winter steelhead later in the year (Busby et al. 1996). Most summer steelhead spawning areas in the Puget Sound are located in headwater areas above narrow canyons, including those for the North Fork Nooksack River, Canyon Creek, Deer Creek, North Fork Skykomish River, and Tolt River DIPs (Hard et al. 2015). Because the habitat features needed to sustain summer-run populations of steelhead are uncommon in most Puget Sound watersheds, winter-run populations of steelhead are the predominant life-history strategy. Figure 2 shows the winter-run steelhead life history cycle. Winter-run steelhead return in fall or winter and typically spawn within a few weeks.

Both summer- and winter-run adult steelhead require diverse channel features to provide access to suitable spawning gravel. Steelhead migrate upstream and spawn during the winter and spring when stream flows are relatively high, and therefore require velocity refuge provided by log jams, deep pools, and boulders. Multi-threaded channels, islands, large wood, streamside vegetation, and interconnected floodplains help ensure reproductive success by providing and maintaining clean gravels and protecting incubating eggs from floods. The importance of diverse habitats and cool, clean water to steelhead cannot be overstated. Indeed, the loss and degradation of habitat is the principle cause of the decline and ultimate ESA-listing of Puget Sound steelhead (72 Federal Register 26722).

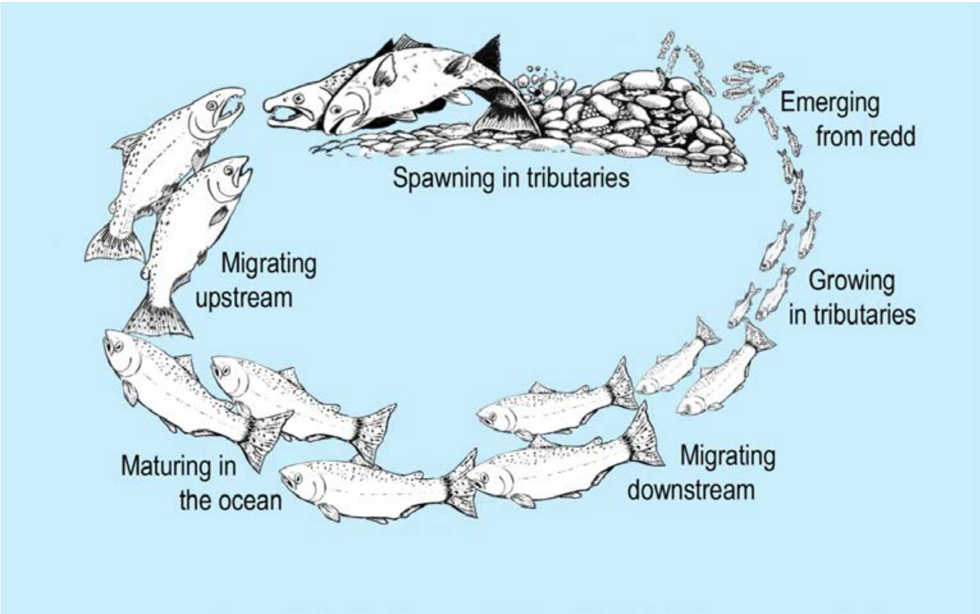

Figure 2. Winter-run steelhead life history cycle.

1.2.2 Population Status and Listing Decisions

In 2004, NMFS formed the Puget Sound Steelhead Biological Review Team in response to a petition to list Puget Sound steelhead as threatened under the ESA. The following excerpts from the Biological Review Team report (Hard et al. 2007), described in the text box below, provide a summary of the factors that led to the decline of Puget Sound steelhead and the determination that listing as threatened was warranted (Ford 2011).

Factors Leading to ESA-Listing Decision for Puget Sound Steelhead

The Puget Sound Steelhead Biological Review Team (Hard et al. 2007) considered the major risk factors facing Puget Sound steelhead to be widespread declines in abundance and productivity for most natural steelhead populations in the DPS, including those in Skagit and Snohomish Rivers, previously considered strongholds for steelhead in the DPS; the low abundance of several summer-run populations; and the sharply diminishing abundance of some steelhead populations, especially in south Puget Sound, Hood Canal, and the Strait of Juan de Fuca. Continued releases of out-of-DPS hatchery fish from Skamania-derived summer run were a major concern for diversity in the DPS.

The Biological Review Team observed that most of the other populations in the DPS are small, especially those in Hood Canal and the Strait of Juan de Fuca. Declining trends in abundance have occurred despite widespread reductions in direct harvest of natural steelhead in this DPS since the mid-1990s. Natural run sizes (sum of harvest and escapement) for most populations show even more marked declining trends than indicated by escapements, meaning the substantially reduced harvest rates for natural fish since the early 1990s have not resulted in a rebound in steelhead production in Puget Sound.

For many of the Puget Sound steelhead populations, the decline in adult recruits-per-spawner has been precipitous. In addition, the Biological Review Team was concerned about the status of the summer-run populations of steelhead in the DPS. Populations of summer-run steelhead occur throughout the Puget Sound DPS but are concentrated in the northern Puget Sound area, are generally small, and are characterized as isolated populations adapted to streams with distinct attributes.

Habitat utilization by steelhead has been most affected by reductions in habitat quality and by fragmentation. A number of large dams in Puget Sound basins have affected steelhead populations and their distribution. In addition to eliminating accessibility to habitat, dams affect habitat quality through changes in river hydrology, temperature profile, downstream gravel recruitment, and the movement of large woody debris. Many of the lower reaches of rivers and their tributaries in Puget Sound have been dramatically altered by urban development. Urbanization and suburbanization have resulted in the loss of historical land cover in exchange for large areas of imperious surface (buildings, roads, parking lots, etc.).

Eight years after the ESA-listing decision, a status assessment of the DPS found that the status of Puget Sound steelhead regarding risk of extinction had not changed (NMFS 2016; 81 FR 33468).[2] Scientists on the 2011 Biological Review Team identified degradation and fragmentation of freshwater habitat, with consequential effects on connectivity, as the primary limiting factors and threats facing the Puget Sound steelhead DPS. The Biological Review Team determined that most of the steelhead populations within the DPS continued to show downward trends in estimated abundance, with a few sharp declines (Ford 2011). Further, the NMFS' 2016 5-Year Review (NMFS 2016) concluded:

> "The biological risks faced by the Puget Sound steelhead DPS have not substantively

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[2] 81 Federal Register 33468, 05/26/2016. Five-year reviews available for listed Pacific salmon, steelhead, and eulachon as required by the ESA. These reviews evaluate whether the listing classifications of these species remains accurate or should be changed.

changed since the listing in 2007, or since the 2011 status review. Furthermore, the Puget Sound steelhead Technical Recovery Team (TRT) recently concluded that the DPS was at very low viability, as were all three of its constituent MPGs, and many of its 32 DIPs (Hard et al. 2015)."

1.2.3 Pressures and Factors Affecting the Decline of Steelhead

The loss of steelhead habitat in many areas of the Puget Sound has been staggering, especially in those areas that have undergone extensive urban and residential development. Puget Sound riverscapes once featured extensive riparian forests, braided and unimpeded stream channels, unconstrained and spatially complex floodplains with abundant flows and cool water, fully functioning stream hydrology with large wood and intact wetlands, and productive estuaries with abundant prey (Sedell et al. 1988; Collins et al. 2002; Simenstad et al. 2011).

Today, many Puget Sound rivers and streams are simplified and degraded. Since the 1970s, Puget Sound has experienced rapid human population growth with as many as 1 million new inhabitants per decade influencing Puget Sound streams, rivers, and estuaries (Booth 1991; USCB 2010). The human-related pressures have resulted in severe consequences for steelhead habitat and their abundance and productivity (Hard et al. 2015).

> **Pressures** are human activities or natural events (e.g., road building, floodplain development, fish harvest, hatchery influences, or floods) that cause or contribute to a decline in species' viability.

During the recovery planning process, NMFS identified 10 primary pressures that were associated with the listing decision for Puget Sound steelhead and subsequent affirmations of the listing: fish passage barriers at road crossings; dams, including fish passage and flood control; floodplain impairments, including agriculture; residential, commercial, industrial development (including impervious runoff); timber harvest management; altered flows and water withdrawals; ecological and genetic interactions between hatchery and natural-origin fish; harvest pressures (including selective harvest) on natural-origin fish; juvenile mortality in estuary and marine waters of the Puget Sound; and climate change. The recovery strategies identified in the Plan (Chapter 3) address these pressures for Puget Sound steelhead.

Fish Passage Barriers at Road Crossings

Artificial stream barriers are pervasive in the Puget Sound basin as a result of the conversion of forest lands to urbanizing environments. Roads account for the large majority of barriers in Puget Sound. As many as 8,000 culverts block access to steelhead habitats in Puget Sound (WDFW 2009; GAO 2001; WDFW 2018). Impassable culverts limit the upstream extent of spawning, which restricts the abundance of steelhead that can be produced in streams. Blocking culverts also reduce access to juvenile refuge habitat in tributaries and floodplain channels during floods, which reduces spatial structure and survival during catastrophic events. Culverts may limit genetic diversity in some stream systems. Impassable culverts have caused genetic variation among isolated fish populations within a single watershed (Wofford et al. 2005). Steelhead abundance and productivity is limited by access to suitable habitats above fish barrier culverts throughout the Puget Sound. See Section 3.2 for additional information on fish passage.

Dams, including Fish Passage and Flood Control

Like culverts, dams can block steelhead access to upstream habitats that were historically used for spawning and juvenile rearing. In fact, reservoirs created behind dams often cover historic spawning and rearing habitat. Some dams have fish ladders (i.e., fishways) or trap-and-haul facilities to accommodate passage, but the success and efficiency of these facilities is highly variable. Providing upstream adult steelhead passage at dams is a formidable challenge, but often the greatest passage obstacle is in securing the downstream passage of juvenile and adult (kelts) steelhead (Wertheimer and Evans 2005). The continuously changing flows created by filling and draining the reservoirs disorients juvenile fish migrating downstream. Juvenile fish successfully finding the fishway may be subjected to supersaturated gas and predators at the outlet below the dam. Juveniles that exit through dam turbines can encounter high mortality rates.

Dams affect steelhead and their habitats in many ways. Operations at some dams can create artificial floods that scour eggs and alevins from redds (Gendaszek et al. 2017). Dam operations can alter instream flows, which can reduce the quantity and quality of rearing habitat below the dam. Daily fluctuations in river flows caused by increasing power to meet demands during the day and reduced power demands at night can dry out redds, and strand and kill fry and juvenile fish along the channel shoreline (Nagrodski et al. 2012). Altered flows from dam operations can limit access to mainstem side-channel and off-channel rearing habitats, thus reducing abundance and productivity of steelhead, as is currently the case below Howard Hansen Dam on the Green River (WRIA 9 2000). Dams limit sediment and wood transport to downstream reaches, which effectively limits the formation of rearing and spawning habitat below the dam (Kondolf 1997). Dams can also create elevated temperature regimes in streams by increasing exposure to solar radiation and delaying flow through the reservoir. Steelhead react to warmer temperatures by avoiding the area affected, or by delaying their migrations (Caudill et al. 2013). Finally, dams often provide communities with flood relief and comfort, which often leads to rapid increases in urban development below the dams in historic floodplains (Beck et al. 2012). See Section 3.3 for additional information on dams.

Floodplain Impairments, including Agriculture

As previously described, diverse habitats and channel features are important for a variety of steelhead life-history stages. Dikes and levees adjacent to rivers and streams often restrict channels to single, featureless threads that are isolated from the productive floodplain. Approximately 254 miles of Puget Sound streams, rivers and delta channels are narrowed and armored with dikes and levees (PSP 2012). Beamer et al. (2002) estimated that Skagit River delta habitats, including channels, sloughs, and intertidal habitats, have decreased by 72 percent from historic conditions. Dikes and levees greatly reduce or eliminate the opportunity for steelhead spawning in those reaches. Dikes and levees also isolate floodplain rearing habitats for steelhead, which may hasten the entry of pre-smolt juvenile steelhead to marine waters. See Section 3.4 for additional information on floodplain impairments.

Residential, Commercial, and Industrial Development (Urban Development)

Urbanization and residential development have led to dramatic changes on the landscape and, perhaps more than any other pressure, have reduced steelhead habitat and population abundance. In addition to fostering other pressures, such as increasing fish passage barriers at road crossings and increasing the armoring of stream banks with dikes and levees, increased urban development has resulted in major increases in the area of watershed covered by impervious surfaces (e.g., roads, parking lots, and roofs), which has reduced groundwater inflows and instream flows during the summer and fall. The reduction in summer flows reduces available habitat directly for juvenile steelhead, and also indirectly elevates stream temperatures which leads to increased susceptibility to disease, predation, and a degraded aquatic invertebrate forage base. Urbanization and resulting increases in impervious surfaces also increase stormwater run-off during fall and winter months, which can scour steelhead redds and pollute water quality. See Section 3.5 for additional information on residential, commercial, and industrial development.

Timber Management

Although historically abundant throughout Puget Sound, many riparian forests are now confined to upper headwater reaches of Puget Sound streams. Timber management is widespread throughout the region, and timber harvest practices can affect steelhead habitat by limiting the recruitment of instream features (especially large wood), reducing shade by harvesting riparian trees (which moderates stream temperature), increasing road construction (which result in fish passage barriers and delivers fine sediment), and increasing the frequency of landslides which are a major source of stream sediments. Without adequate riparian shade, stream temperatures in Puget Sound streams increase during summer months. As described above under the Fish Passage Barriers at Road Crossings pressure, fish-blocking culverts are pervasive on the landscape, including forested landscapes. Forest roads also deliver fine sediment to streams, which is a source of redd and emergent fry mortality. Sediment runoff from roads and landslides associated with timber harvest can also degrade the habitat quality for juvenile steelhead by filling in pools, reducing habitat cover provided by cobbles and boulders, and reducing the aquatic invertebrate food supply. Timber management has improved over the last several decades, but the adequacy of current riparian buffers is in question (Ecology 2018). The adequacy of road management practices requires improved monitoring and potential adaptive management because failed fish passage repair projects are common in Puget Sound (Price et al. 2010). See Section 3.6 for additional information on timber management.

Water Withdrawals and Altered Flows

The construction of diversions and resulting water withdrawals from streams in the Puget Sound Basin began in the mid-1800s (Palmisano et al. 1993). Water withdrawals and flow modifications occur through several activities. Water withdrawals can occur through the exercise of an individual or municipal water right, either by diverting stream flows directly to drinking water facilities, or by pumping groundwater that has hydrologic connectivity to streams. Water is also diverted for agricultural use in many areas of the Puget Sound. Water withdrawals for human consumption (domestic and municipal water use, agricultural irrigation) have reduced flows in some Puget Sound streams. Together, these different withdrawals have reduced summer flows in many rivers in the Puget Sound basin. Concerns for Puget Sound steelhead also exist regarding the diminished flows resulting from hydrologically connected exempt wells. In addition to water withdrawals, altered flows can also affect the steelhead. Altered flows occur when stream flows are stored in stormwater systems or a reservoir on a seasonal basis and then released at a later time. Water withdrawals and altered flows can reduce spawning and rearing habitat quality for steelhead. Reduced instream flows have a number of secondary impacts to steelhead as well, including increased water temperatures and degraded water quality conditions, and reductions to the invertebrate food base of juvenile fish. See Section 3.7 for additional information on water withdrawals and altered flows.

Climate Change

Climate change will exacerbate the current ecosystem pressures currently facing steelhead (Battin et al. 2007). Hydrologically, many snowmelt-based streams in Puget Sound are expected to become rain dominated by the end of this century (Isaak et al. 2012). This change will mean that steelhead will be especially vulnerable during summer low flows and elevated peak flows during winter (Wade et al. 2013). The period of peak snowmelt runoff will occur earlier in the year, which may impact spawning timing of adults and outmigration timing of smolts. A higher magnitude and frequency of peak winter flows caused by climate change will reduce overwinter survival rates of juvenile steelhead throughout the region (Wade et al. 2013). Because less water will be retained as snow over the winter, summer flows in areas affected by snowmelt runoff are expected to substantially drop below current base flows conditions. These reductions in base flows may become a critical factor limiting the carrying capacity for juvenile steelhead during the summer and fall in many areas. Hydrologic factors could decrease steelhead habitat capacity and population abundance by shifting available flows away from the times when the fish most need it. Climate change will also warm stream temperatures in the summer (Isaak et al. 2012). Because many steelhead streams are already nearing elevated temperature thresholds, riparian habitat management efforts will need to meaningfully improve to ameliorate the effects of climate change. See Section 3.11 for additional information on climate change.

Ecological and Genetic Interactions between Hatchery and Natural-Origin Fish

Steelhead hatchery programs have been used to boost harvest opportunities for recreational and tribal fisheries. However, the adverse effects from the use of some hatchery operations and management have become well known over the last two decades. Reductions in the diversity and fitness of native steelhead populations have resulted from the use of out-of-basin stocks (i.e., Skamania Hatchery summer-run steelhead; see Hard et al. 2007 and Warheit 2014), which has precluded the stocks from being included in the DPS (73 FR 55451). Similarly, the wide-spread use of Chambers Creek Hatchery early winter-run stocks (a hatchery stock originating in the Puget Sound) have caused deleterious genetic and ecological effects to native steelhead populations throughout the region (Myers et al. 2015). Ecological interactions can negatively impact natural-origin steelhead when hatchery releases result in competition for food and habitat resources, or when hatchery fish attract predators that then forage on natural-origin steelhead. Recently, integrated and conservation hatchery programs have sought to protect against loss of diversity and bolster the productivity of native stocks. See Section 3.8 for additional information on hatcheries.

Harvest Pressures on Natural-Origin Fish

Harvest of steelhead was an early factor in the historic decline of abundance from Puget Sound rivers, and impacts of overfishing to steelhead were evident in the early 1900s (Gayeski et al. 2011). Directed commercial harvest has not occurred for many decades, however, and the current level of recreational and tribal harvest is not considered to be a prominent factor in the current decline of Puget Sound steelhead (Hard et al. 2015; NMFS 2016). Still, especially where population abundances have become precariously low, harvest can become a meaningful pressure, even in catch and release fisheries. See Section 3.9 for additional information on harvest.

Early Marine Survival

Recent work by the Salish Sea Marine Survival Project has revealed that the mortality of juvenile steelhead during the early marine life stage in Puget Sound has increased to the point where it is significantly impacting Puget Sound steelhead abundance and productivity. In recent years, survival has been measured from several river mouths through the Strait of Juan de Fuca. Survival of smolts ranged from 0.8 percent to over 39 percent over a few weeks. This means that a large percentage of steelhead smolts are not surviving the relatively short outmigration period through the marine waters of the Puget Sound, and that this may be major bottleneck to the productivity of steelhead populations throughout the region. Human activities have fostered the increase of marine mammal populations, which have been observed preying on steelhead smolts and kelts (post-spawn adults). Other early marine survival limitations may be affected by increased risk of diseases, which may inhibit outmigration success, and increased infrastructure in the marine environment (e.g., Hood Canal Bridge) that likely alters the migration behavior and survival of juvenile steelhead. See Section 3.10 and Appendix 3 for more information on early marine survival.

1.3 Planning Approach

The Plan is based on the best available scientific and commercial information and focuses on DPS-wide actions for Puget Sound steelhead, concentrating on addressing the ESA listing factors that continue to hinder the long-term sustainability and persistence of the species and its habitat. It also addresses other ESA requirements.

The recovery strategy in this Plan aims to improve the viability of Puget Sound steelhead so that the species is self-sustaining in the natural environment. A viable DPS is one that is sufficiently abundant, productive, and diverse and likely to persist in the long term, defined as the next 100 years.

The overarching approach for recovery of Puget Sound steelhead is to focus primarily on protecting and restoring ecosystem functions and freshwater habitats, and improving juvenile survival in Puget Sound waters. Complementary strategies ensure that hatchery and harvest management do not impede recovery; and where possible, contribute to recovery.

1.3.1 Plan Development ─ Collaboration with Recovery Planning Partners

This recovery plan is the product of a collaborative process initiated by NMFS and strengthened through regional and local participation. The goal was to produce a recovery plan that would meet NMFS' ESA requirements for recovery plans, as well as recognizing broader needs. Throughout the recovery planning process, NMFS collaborated with the state of Washington, tribes, other federal agencies, local governments, representatives of industry and environmental groups, other stakeholders, and the public.

The collaborative process reflects NMFS' belief that ESA recovery plans for salmon and steelhead should be based on state, regional, tribal, local, and private conservation efforts already underway throughout the region. Local support of recovery plans by those whose activities directly affect the listed species, and whose actions will be most affected by recovery efforts, is essential to plan implementation.

The following text box identifies the primary partners in recovery planning efforts for Puget Sound steelhead and summarizes their responsibilities. The Acknowledgments section also lists a number of the stakeholders who joined NMFS in developing this recovery plan. These groups provided vital input during the planning process, and their continued involvement during Plan implementation is critical to the success of our joint efforts to recover Puget Sound steelhead. While NMFS is responsible for recovery planning for salmon and steelhead, and for decisions to list and delist marine and anadromous species as endangered or threatened, it recognizes that continued local support of recovery plans — by those whose activities directly affect the listed species, and whose activities are most affected by recovery requirements — is essential to their successful implementation.

Ultimately, NMFS will assist state agencies, tribes, and Lead Entities in the development of watershed-scale plans. As watershed-specific plans are developed, NMFS will include those plans in the implementation strategy, and make that information available on our web site. NMFS will assist and encourage the use of multidisciplinary teams (presumably led by the Lead Entities) from multiple jurisdictions to develop and implement watershed plans. As with other recovery planning efforts in Puget Sound, organization, adaptive management, and tracking progress through time will be important.

Recovery Planning Partners and Responsibilities

Puget Sound Steelhead Technical Recovery Team (PSSTRT): Appointed by NMFS, this panel of scientific experts from federal, state, tribal, and academic organizations provides a solid scientific foundation for recovery planning. The team developed a recommended scientific framework and DPS biological recovery criteria for the species. The PSSTRT also provides scientific support to local and regional recovery efforts, and providing scientific evaluations of proposed recovery plans (Hard et al. 2015; Myers et al. 2015).

Puget Sound Steelhead Recovery Team: NMFS convened the Puget Sound Steelhead Recovery Team to assist in preparing the draft recovery plan in 2014. The team includes participants from the Washington Department of Fish and Wildlife, Northwest Indian Fisheries Commission, Puget Sound Partnership, Seattle City Light, Long Live the Kings, Nooksack Indian Tribe, NMFS, and NMFS Northwest Fisheries Science Center.

State and Tribal Co-Managers: Puget Sound Tribes and the Washington Department of Fish and Wildlife have been actively involved in the preparation of comprehensive harvest management plans and hatchery genetic management plans for listed species across the region. They work toward the integration of habitat, harvest and hatchery considerations in watershed and regional levels, monitors fish populations including steelhead, and play an integral role in recovery planning efforts.

Puget Sound Partnership (PSP): The Puget Sound Partnership is the state agency leading the region's collective effort to restore and protect Puget Sound. The Partnership works with its Leadership Council, Salmon Recovery Council, Ecosystem Coordination Board, Science Panel, local stakeholders and communities, Indian tribes, businesses, and state and federal agencies to identify, sequence, prioritize, and implement projects and programs to recover salmon.

Recovery Planning Partners and Responsibilities (cont'd)

Lead Entities: Lead entities are local, citizen-based organizations established by Washington State law that develop watershed-scale recovery strategies and coordinate salmon recovery efforts in their watersheds. Per statute (RCW 77.85.050), lead entities are tasked with establishing a committee made up of habitat recovery interests in their area and developing a list of habitat restoration projects. A Lead Entity is commonly led by a coordinator (usually from a county, conservation district, or tribe) and includes a committee of technical experts, a committee of local citizens, and often a grant administrator. In Puget Sound, lead entities work with local and state agencies, tribes, citizens, and other community groups to adaptively manage their watershed recovery plans to recover salmon and ensure that salmon recovery actions are implemented on the ground. To date, only two lead entities, Nisqually and Skagit have a locally written steelhead recovery strategy/chapter. Others are underway for Hood Canal and East Kitsap populations (West Sound).

Puget Sound Partnership Leadership Council: The Leadership Council is the governing body of the Puget Sound Partnership, and provides region-wide direction and guidance on Puget Sound recovery. Its seven members are leading citizens appointed by the Governor. In 2008, Washington State designated the Council as the regional salmon recovery organization under the Puget Sound Partnership Act. The Act designated the Council as the lead for implementing the Puget Sound Salmon Recovery Plan, which was developed by the Shared Strategy, a non-profit organization, and approved by NOAA in 2007. The Leadership Council is supported by the Puget Sound Partnership, which administers the Council's direction, by the Ecosystem Coordination Board, which implements Leadership Council policy direction, and the Science Panel, which provides technical and scientific expertise to the Council.

Puget Sound Salmon Recovery Council (PSSRC): The Puget Sound Salmon Recovery Council (PSSRC) serves as an advisory body to the Leadership Council and the Puget Sound Partnership. This group consists of representatives from each of the 16 Puget Sound watersheds, environmental and business communities, Indian tribes, and state and federal agencies involved in salmon recovery. The PSSRC meets regularly to help set priorities for the types of recovery work to conduct, determine the issues to focus on, and provide recommendations for future projects and funding.

Puget Sound Partnership Ecosystem Coordination Board (ECB): The primary role of the ECB is to advise the Leadership Council in carrying out its responsibilities. The ECB is made up of 27 individuals representing specific interests around the Sound and who act as the main implementers of policy initiatives to recover the Puget Sound.

Puget Sound Partnership Science Panel: The Science Panel provides expertise and advice to the Leadership Council and informs the Puget Sound Partnership's efforts to develop a comprehensive, science-based plan to restore Puget Sound. Science Panel members are appointed by the Leadership Council and are chosen from among the top scientists in Washington.

Puget Sound Task Force: The Puget Sound Federal Task Force is composed of nine federal agencies and cabinet departments who have agreed to enhance Puget Sound recovery by strengthening coordination among federal agencies, tribes, state and local governments, and private efforts, strengthening the integration of federal activities in the Puget Sound Action Agenda, contributing scientific and technical expertise, fulfilling federal trust responsibilities to Puget Sound federally recognized tribal governments, and creating and maintaining a standing federal venue through which to share information. The Puget Sound Federal Task Force developed an Action Plan that supports the Puget Sound Action Agenda.

1.3.2 Recovery at Multiple Scales ─ DPS to Watersheds

For this recovery plan to be effective, it requires a multi-faceted effort with coordination between federal, state, and local agencies and the private sector, and linked efforts at the watershed/ population, major population group, and DPS levels. Our long-term approach needs to be watershed process-oriented for freshwater strategies, and regionally oriented for marine strategies to increase smolt survival.

Since changes in land use associated with human development continue to apply pressures on stream and marine ecosystems throughout the DPS, an important element in our Plan is to identify watershed-level efforts that could, if implemented, address indirect threats — the root causes of ecosystem impairment. We intend to integrate these efforts, working with landowners, businesses, and non-governmental and governmental organizations to find ways to accomplish multiple goals.

Concurrently, early marine survival has emerged as a serious pressure on steelhead survival. Our approach includes strategies and actions to understand and ameliorate factors that are causing the unsustainable decline of steelhead in the Puget Sound marine ecosystem, including freshwater factors that may inhibit the health and performance of young steelhead as they transition to the marine environment.

1.3.3 Relationship to Other Recovery Efforts

Three other ESA-listed salmonid species spawn and rear within the Puget Sound area: Puget Sound Chinook and Hood Canal Summer-run Chum salmon, which are managed by NMFS, and bull trout (Coast Recovery Unit), managed by USFWS. Recovery plans have already been completed for these ESA-listed species.[3] This Plan only addresses steelhead recovery in the Puget Sound DPS, but is intended to complement the plans for the other listed species. Where possible and appropriate, actions should be taken to benefit the recovery of multiple species.

Similarly, NMFS intends for the Puget Sound steelhead recovery plan to be consistent and collaborative with state, tribal, and co-manager recovery plans. Scott and Gill (2008) outline recovery actions planned and undertaken by Washington State. A framework developed by WDFW and the Puget Sound Partnership (2011) provides a structure for steelhead recovery planning at local (watershed) planning levels. NMFS encourages the use of diverse approaches in the recovery of Puget Sound steelhead, and will continue to work collaboratively with partners toward that end.

Technical Recovery Teams

For each recovery domain, NMFS appointed a team of scientists who have geographic and species expertise to provide a solid scientific foundation for recovery plans. The technical recovery team for Puget Sound steelhead DPS is the Puget Sound Steelhead Technical Recovery Team (PSSTRT). The PSSTRT includes biologists from NMFS, state agencies, tribes, and academic institutions.

[3] https://www.westcoast.fisheries.noaa.gov/protected_species/salmon_steelhead/salmon_and_steelhead.html
https://www.fws.gov/pacific/bulltrout/

The PSSTRT and other NMFS technical recovery teams used a common set of biological principles in developing their recommendations for species and population viability criteria. The biological principles are described in NMFS' technical memorandum, "Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units" (McElhany et al. 2000). Viable salmonid populations (VSP) are defined in terms of four population parameters: abundance, population productivity or growth rate, population spatial structure, and diversity. Each technical recovery team made recommendations using the VSP framework. The recommendations also reflect data availability, the unique biological characteristics of the species and habitats in the domain, and the members' collective experience and expertise. NMFS has encouraged the technical recovery teams to develop species-specific approaches to evaluating viability, while using the common VSP scientific foundation (See Myers et al. 2015; Hard et al. 2015).

Puget Sound Steelhead Recovery Team

Using the PSSTRT's scientific guidance as the foundation for our work, NMFS convened a new Puget Sound Steelhead Recovery Team (Team) to assist the agency in preparing this draft recovery plan for Puget Sound steelhead. This Team will develop implementation tools, monitoring and adaptive management plans, and facilitate the development of watershed-scale activities to advance steelhead recovery at the DIP scale.

Relationship to Puget Sound Chinook Salmon, Hood Canal Summer-run Chum Salmon, and Bull Trout Recovery

NMFS and our recovery planning partners agree that Puget Sound steelhead recovery planning should be consistent with the regional and watershed strategies used for Puget Sound Chinook salmon, Hood Canal summer-run Chum salmon, and bull trout (NMFS 2007). NMFS and the recovery planning partners identified recovery actions and developed this Puget Sound steelhead recovery plan concurrent with ongoing implementation of the Puget Sound Chinook and Hood Canal summer-run Chum salmon plans. NMFS recognizes that recovery planning for other species is ongoing at the watershed-level and ultimately, there will be watershed-level plans for steelhead as well, or plans that integrate multiple listed species. The Puget Sound Salmon Recovery Council and the Puget Sound Partnership oversee the implementation of the Chinook Recovery Plan. The Hood Canal Coordinating Council is the regional partner organization for Summer Chum salmon recovery and oversees implementation of the recovery plan. Several regional Chinook salmon recovery plans have been or are undergoing updates using a consistent recovery framework and language.

This steelhead plan was developed using the same approach, but tailored to the unique life histories and habitat use of the species. While steelhead occupy habitats and a geography that overlaps both Chinook and Hood Canal summer Chum salmon, they also use smaller tributaries further up in the watersheds and independent tributaries that drain directly into Puget Sound, which are not otherwise included in Chinook recovery planning. Also, unlike Chinook and summer-run Chum salmon, steelhead do not reside extensively in estuary/nearshore areas; therefore, while the different plans need to provide consistency and be compatible for overall recovery of Puget Sound salmon and steelhead, this Plan has unique elements that are specific to the geography, life histories, and current science of Puget Sound steelhead. For example, this

Plan represents the first in Puget Sound to identify strategies and actions necessary for survival in open marine waters, as neither Chinook nor summer Chum salmon recovery plans addressed pressures outside the estuary or nearshore environment.

The final bull trout recovery plan was completed by the USFWS in 2015. The Coastal Recovery Unit for bull trout includes the Puget Sound, Olympic Peninsula, and portions of western Oregon. Bull trout and steelhead share many of the same habitat requirements (clean and cold freshwater habitat conditions), and the distribution of both species extends into the headwater areas of Puget Sound watersheds. Thus, many of the same habitat factors and threats identified in the bull trout recovery plan also apply to steelhead. Primary threats to bull trout in the Puget Sound streams and rivers include degradation to upland and riparian lands, timber harvest, degraded water quality, impaired connectivity caused by fish passage barriers (culvert and dams), altered instream flows form dams and diversions, altered migration and declining survival in the marine waters of the Puget Sound, and climate change (USFWS 2015). Accordingly, many of the recovery actions identified in this Plan will also benefit bull trout populations in the region.

This Plan for Puget Sound steelhead builds on efforts implemented through the Shared Strategy, a collaborative initiative that began in 1999 concurrent with the ESA-listing of Puget Sound Chinook salmon and Hood Canal summer Chum as threatened and USFWS listed coastal/Puget Sound bull trout as threatened. Representatives of federal, state, tribal, and local governments, business, the agriculture and forestry industries, conservation and environmental groups, and local watershed planning groups met to shape “one strategy shared by many” for salmon recovery. A key objective defined in this process was to “(B)uild a scientifically robust, practical, cost-effective recovery plan by June 2005 that defines the strategies and actions necessary to recover naturally spawning Chinook salmon, bull trout, and Hood Canal summer Chum salmon to self-sustaining and harvestable levels within the context of a prosperous economy and sustainable growth (Volume I, Chapter 1).” Many actions and processes being implemented under the Chinook and Chum salmon plans are consistent with this steelhead recovery plan.

Relationship to the Puget Sound Action Agenda

The Puget Sound Leadership Council provides policy direction and guidance in the recovery of Puget Sound. Their vision: Beyond 2020 – Our Vision and Commitment for a Resilient Puget Sound outlines the principles that are used to recover the Puget Sound ecosystem of which, steelhead are a major part. These principles include:

- Act with Urgency.
- Inspire and Engage.
- Make Science-informed Decisions.
- Continuously Learn and Adapt.
- Apply a Holistic Approach.
- Look Forward Together.

The Puget Sound Partnership (PSP) is a state agency serving as the backbone organization for coordinating and generally guiding Puget Sound recovery under the direction of the Leadership Council. The PSP oversees development of and updates to the Puget Sound Action Agenda, which charts the course to recovery of our nation’s largest estuary by identifying the goals and strategies for recovery, and by describing how the work of many partner organizations contributes to improving the health of Puget Sound. The 2018-2022 update to the Action Agenda articulates a vision for Puget Sound as a resilient ecosystem that can adapt to the impacts of climate change and the pressures of a growing human population, while meeting the needs of its native species. The Puget Sound Steelhead Recovery Team used the 2016 Action Agenda and the final and draft Implementation Strategies that were relevant and available at the time of plan development as the basis for addressing specific threats. Rather than reinventing the wheel, the team looked to the latest efforts on land development, floodplains, and shoreline armoring and considered them to build out steelhead-specific strategies and actions from there.

Other regional and statewide processes were also used as a basis for strategy development, such as the Long Live the King’s Salish Sea Marine Survival Project, WDFW’s Fish Barrier Removal Board, and Department of Ecology’s 303(d) list and total maximum daily load. In addition, the Action Agenda and Puget Sound Federal Task Force, specifically call out the need for supporting several long-term elements of the Salish Sea Marine Survival Project adopted in this Plan for recovery of steelhead, such as addressing increased predation, monitoring the marine food web, including zooplankton and forage fish efforts. The Action Agenda also calls out specific strategies to address pollution from stormwater runoff at local jurisdiction and regional scales.

1.4 Tribal Trust and Treaty Responsibilities

Northwest Indian tribes have legally enforceable treaty rights reserving to them a share of the harvestable salmon. Achieving the basic purposes of the ESA such that the species no longer needs the protection of the Act may not by itself fully meet these rights and expectations, although it will lead to major improvements in the current situation. Ensuring a sufficient abundance of salmon to sustain harvest is an important element in fulfilling trust responsibilities and treaty rights as well as garnering public support for these plans. It is NMFS policy that recovery of salmonid populations should achieve two goals: (1) the recovery and delisting of salmonids listed under the provisions of the ESA, and (2) the restoration of the meaningful exercise of tribal fishing rights.

Thus, it is appropriate for recovery plans to take these considerations into account and plan for a recovery strategy that includes harvest. In some cases, the desired abundances for harvest may come about through increases in the naturally spawning population. In others, the recovery strategy may include appropriate use of hatcheries to support a portion of the harvest. So long as the overall plan is likely to achieve the biological recovery of the listed DPS under the ESA, it will be acceptable as a recovery plan.

Pacific salmon and steelhead have been harvested both historically and in modern times, and there is a strong public interest in restoring them to harvestable levels. Because listed salmon and steelhead often migrate with non-listed fish, the listings not only constrain the harvest of listed fish but also have become factors limiting the harvest of other non-listed fish. Fisheries affecting both salmon and steelhead are co-managed by Washington State, Puget Sound Tribes, and Federal agencies, under the principles of the Pacific Salmon Treaty (PST), the Magnuson-Stevens Act (MSA), *U.S. v. Washington*, and United States treaties with Puget Sound Tribes.

Historically, the steelhead that returned to streams and rivers in the Puget Sound region played an integral role in the lives of Native Americans. At one time as many as 50 different tribes resided along the shores of the Puget Sound and its rivers. Today, a smaller number of tribes live along Puget Sound, but these tribes continue to retain strong spiritual and cultural ties to salmon and steelhead. These ties reflect thousands of years of use for tribal religious and cultural ceremonies, subsistence, and commerce.

A complex history of treaties, executive orders, legislation, and court decisions culminated in the recognition of tribes as co-managers who share management responsibilities and rights for fisheries in the Puget Sound. The Secretarial Order *American Indian Tribal Rights, Federal-Tribal Trust Responsibilities, and the Endangered Species Act* of 1997 acknowledges the federal trust responsibility to, and treaty rights of, the tribes, as well as the government-to-government relationship. NMFS acknowledges and accepts its obligations to integrate its ESA responsibilities with its trust responsibilities for the Western Washington federally recognized tribes.

Western Washington Treaty Tribes include:

- Jamestown S’Klallam Tribe,
- Lower Elwha Klallam Tribe,
- Port Gamble S’Klallam Tribe,
- Lummi Nation,
- Muckleshoot Tribe,
- Nisqually Tribe,
- Nooksack Tribe,
- Puyallup Tribe of Indians,
- Sauk-Suiattle Tribe,
- Skokomish Tribe,
- Squaxin Island Tribe,
- Stillaguamish Tribe,
- Suquamish Tribe,
- Swinomish Tribe,
- Tulalip Tribes,
- Upper Skagit Indian Tribe,
- Hoh Tribe,
- Quinault Indian Nation,
- Makah Tribe, and
- Quileute Indian Tribe.

ESA and tribal trust responsibilities complement one another. Both depend on a steady upward trend toward ESA recovery and delisting in the near term, while making aquatic habitat, harvest, and land management improvements for the long term.

Relationship to Treaty Rights at Risk Initiative

In 2011, the Western Washington Treaty Tribes launched the Treaty Rights at Risk Initiative to encourage the federal government to bring the suite of government agencies and programs affecting salmon and steelhead into a more coordinated, effective approach to recovery.

The tribes have a treaty-reserved right to harvest salmon and steelhead to sustain tribal cultures, communities, and economies. The federal government has the responsibility to protect this right. However, after years of constraining harvest and investing millions of dollars in salmon and steelhead recovery efforts in Puget Sound, salmon and steelhead continue to decline in abundance. The Treaty Rights at Risk Initiative focuses on the federal responsibility to help reverse this trend and protect the tribes' rights.

The cornerstone strategy of the Treaty Rights at Risk Initiative[4] is to reverse the negative trend in suitable habitat for salmon and steelhead. Numerous scientific assessments show that despite many local efforts to recover habitat, concerns remain regarding habitat loss and conversion rates in areas that are important to steelhead and salmon throughout Puget Sound. However, some studies may indicate that protection strategies may be slowing the degradation of floodplains, estuaries, and mainstem rivers (Bartz et al. 2015).

1.5 How NMFS Intends to Use the Plan

NMFS intends to use this recovery to inform federal, state, and local agencies and interested stakeholders about what will be needed to recover Puget Sound steelhead to the point where they can be removed from the list of threatened and endangered species. Although recovery plans are not regulatory, and their implementation is voluntary, they are important tools that help to do the following:

- Provide context for regulatory decisions;
- Guide decision making by federal, state, tribal, and local jurisdictions;
- Organize, prioritize, and sequence recovery actions;
- Guide research, monitoring, and evaluation efforts; and
- Provide a framework for the use of adaptive management.

NMFS makes a commitment to implement the actions in the Plan for which it has authority, and to work cooperatively on implementation of other actions. NMFS encourages other federal agencies and non-federal jurisdictions to use recovery plans as they make decisions and allocate their resources including:

- Actions carried out to meet federal ESA section 7(a)(1) obligations to use their programs in furtherance of the purposes of the ESA and to carry out programs for the conservation of threatened and endangered species;
- Actions that are subject to ESA sections 4d, 7(a)(2), or 10;
- Hatchery and Genetic Management Plans and permit requests;
- Harvest plans and permits;

[4] http://treatyrightsatrisk.org/

- Selection and prioritization of sub-basin planning actions;
- Development of research, monitoring, and evaluation programs;
- Revision of land use and resource management plans, including critical Area Ordinance evaluation and modification; and
- Other natural resource decisions at the federal, state, tribal, and local levels.

We will emphasize recovery plan information in ESA section 7(a)(2) consultations, section 10 permit development, and application of the section 4(d) rule by considering:

- The nature and priority of the effects that will occur from an activity;
- The level of effect to, and importance of, individuals and populations within the DPS;
- The level of effect to, and importance of, the habitat for recovery of the species;
- The cumulative effects of all actions to species and habitats at a population scale; and
- The current status of the species and habitat.

In implementing these programs, recovery plans will be used as a reference for best available science and a source of context for evaluating the effects of actions on listed species, expectations, and goals. Recovery plans and recovery plan actions do not pre-determine the outcomes of any regulatory reviews or actions. We expect that agencies and others will use this recovery plan as a reference and a source of context, expectations, and goals. We will encourage federal agencies to describe in their biological assessments how their proposed actions will affect specific populations and limiting factors identified in the recovery plans, and to describe any mitigating measures and voluntary recovery activities in the action area.

2. Recovery Goals and Overarching Strategic Approach

This chapter describes the ESA recovery goals and the overarching strategy for recovery of Puget Sound steelhead. Chapter 3 describes the recovery strategies and site-specific actions that NMFS recommends in order to implement the strategic approach and achieve the recovery goals. Chapter 4 describes specific criteria for delisting and how NMFS intends to consider the biological status along with the five listing factors when deciding if delisting is warranted.

2.1 ESA Recovery Goals

Our primary goals are:

- The Puget Sound steelhead DPS achieves biological viability and the ecosystems upon which the DPS depends are conserved such that it is sustainable and persistent and no longer needs federal protection under the ESA, and
- The five listing factors from the ESA, section 4 (a)(1) are addressed.

Achieving Viability

Section 4.2 describes in detail the viability criteria for NMFS to consider in determining whether or not the species has achieved a biological status consistent with recovery. When evaluating whether the species has reached a recovered condition, we review the best available information, including that regarding steelhead viability. In order for the DPS to achieve recovery, NMFS' review would need to support a determination that the DPS has abundance, population growth rate, population spatial structure, and diversity that meet the biological recovery goals described in this chapter. The criteria for Puget Sound steelhead include the requirement that Puget Sound steelhead achieve viability at the DIP, MPG, and DPS scales, as described in detail in Chapter 4.

Addressing the Listing Factors

The same five listing factors identified in ESA section 4(a)(1) apply to all ESA-listed species; however, the relative importance of each factor varies from species to species. There is no set threshold for these five listing factors, so there are many different possible combinations of effort and results that could lead to a determination that Puget Sound steelhead have been recovered. This is discussed in more detail in Section 4.3.

The criteria for addressing the five listing factors from the ESA, section 4(a)(1), include:

A. The present or threatened destruction, modification, or curtailment of the species' habitat or range;
B. Over-utilization for commercial, recreational, scientific, or educational purposes;
C. Disease or predation;
D. Inadequacy of existing regulatory mechanisms; and
E. Other natural or human-made factors affecting the species' continued existence.

2.2 Overarching Strategic Approach

The ESA requires that recovery plans, "…to the maximum extent practicable…, incorporate … a description of such site-specific management actions as may be necessary to achieve the plan's goal for the conservation and survival of the species…" The overarching approach for recovery of Puget Sound steelhead is to focus primarily on protecting and restoring ecosystem functions and freshwater habitat and improving juvenile survival in Puget Sound waters. A complementary and important strategy is to ensure that fisheries management (harvest and hatcheries) is consistent with recovery, and to the extent practicable, improves viability of the DPS.

NMFS' overarching strategic approach to Puget Sound steelhead recovery includes the application of NMFS regulatory and non-regulatory tools in combination with those of tribal, state, local government and stakeholders and, to the extent practicable, to "protect the best and restore the rest." Species recovery in Puget Sound's biologically diverse geography — which includes the full spectrum of rural to urban human environments and terrestrial to marine ecosystems — requires the exercise of government regulatory measures as well as non-regulatory funding, restoration and conservation actions. NMFS is committed to working with managers, agencies, recovery practitioners, and stakeholders to expedite Puget Sound steelhead recovery through the use of all necessary and relevant recovery instruments.

This recovery plan is a guidance and planning document. It provides a suggested roadmap to recovery. The proposed strategies and actions presented in the Plan will, if implemented, lead to recovery of the listed DPS. There are a variety of combinations of these strategies and actions that could lead to recovery under the ESA (See Chapter 4 for more detail).

In this Plan, we present the strategies and management actions at the DIP, MPG, and DPS levels for all listing factors in Chapter 3 and Appendix 4. We recognize, however, that additional and more-refined actions are needed at the DIP level, and to assess the collective and relative effectiveness of our efforts and to evaluate uncertainties. Additional activities and implementation strategies within each MPG to address watershed-specific pressures will be identified through future planning efforts with recovery partners and presented on our web site as they are developed. Accordingly, NMFS will periodically update the Recovery Action Mapping Tool[5] to record project completion. In conjunction with this focus on habitat, it will be necessary to continue to implement fishery management systems that support steelhead recovery. NMFS will continue to work closely with the tribal and state co-managers on hatchery and harvest management at the DPS, MPG, and DIP scales to ensure consistency with recovery and to improve viability of the DPS.

Because overall viability of Puget Sound steelhead is a function of survival in each life stage, significant improvement in survival in one life stage might expedite recovery more than improvements in other life stages. When considering recovery actions, it is important to assess which life stage is limiting species recovery and where the greatest improvements are needed to

[5] http://www.westcoast.fisheries.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/recovery_action_mapping_tool.html

move the species onto a trajectory toward recovery. In some cases, there can be trade-offs between investments and species responses. Thus, there can be flexibility in selecting and implementing strategies and actions, depending on which issues and steelhead life-history stage(s) presents the greatest recovery opportunity.

To be successful in the overall effort, for all life stages, it will be important that NMFS, co-managers and recovery partners implement a coordinated “All H” approach. Policy and technical staff working on the “four Hs” — habitat, hatcheries, harvest, and hydro (dams) — will need to collaborate to maximize species benefits and recovery potential. Examples include aligning hatchery management with harvest goals and local habitat conditions, and integrating the best available science on habitat capacity and density dependence into habitat restoration, hatchery, and harvest actions as described in Chapter 3 and Appendix 4.

2.3 Integrating Management

The major factors that affect the abundance, productivity, and diversity of steelhead occur in different major management sectors. Each of these sectors has different economies, is subject to different authorities and regulations, and can make day-to-day decisions to achieve long-term strategies without much interaction with other sectors. Four broad categories of management sectors affecting steelhead are habitat, hydropower, harvest, and hatcheries (the “four Hs”). Although management within these sectors can occur independently, recovery of steelhead and other salmonids depends on making choices in all these management sectors that benefit populations.

“H-Integration” is the process of identifying, choosing, and implementing strategies and suites of actions that are coherent and logical in timing, sequences, locations, and outcomes so that they are predicted to achieve population and ESU/DPS viability based on the best scientific understanding of responses of fish populations to these actions. Characteristics of H-integration are:

- It includes all activities in habitat, harvest, hatchery, and hydropower management sectors that could affect the status and viability of fish habitat and populations.
- It addresses the interrelated effects of these actions on viability characteristics (such as diversity, abundance, productivity, and spatial distribution).
- It is consistent with the causal hypotheses, protection and recovery strategies, and population goals.
- It produces no lasting (permanent) pathological effects on population viability.
- It is efficient (the allocation of resources, timing, sequence, and location of activities increases the expected rate of recovery towards achieving population and ESU goals.)
- It requires difficult trade-offs between competing economic and social objectives.
- It increases public support for salmon recovery.

To achieve H-integration, it is necessary to approach the problem as an adaptive challenge rather than a technical challenge. Adaptive challenges are defined by solutions that can only occur through changes in people's priorities, beliefs, habits, and loyalties. These solutions are often difficult to identify (and easy to deny), have unclear boundaries, have no quick fixes but require experimentation and learning, and arise from the people most affected by potential solutions (Heifetz et al. 2009). Management authority and expertise for many of these different "Hs", for example, rests with different federal, tribal, state, county, city agencies, and private landowners with often competing values and beliefs.

Over the last decade, considerable research has been focused on the role of leadership in adaptive challenges (BBCSS 2015). This work suggests that successful H-integration has five characteristics:

- Getting the right science.
- Getting the science right.
- Getting the right participation.
- Getting the participation right.
- Developing an accurate, balanced, and informative synthesis.

"Getting the right science" means that the technical analysis addresses the combined effects of all the Hs on salmon populations. "Getting the science right" means that the analysis meets rigorous scientific standards for data, analytical methods, and the treatment of uncertainty and the results are communicated accurately. Together these enhance credibility, relevance, and legitimacy of the effort. Getting the "right science right" poses several technical challenges. We must be able to understand (or predict) the effects of the individual "H" actions and their joint effects on population viability characteristics over the life of the actions, including:

- Comparing the short-term and long-term effects on VSP of the various "H" actions for directionality (+, -), magnitude, lag, and persistence. (This requires one or more "common denominators" for translating the effects of actions in the different management sectors on population viability characteristics);
- Timing (when do you do it) of the actions keeping in mind the status of population VSP attributes and desired VSP outcomes (the "first things first" principle);
- Sequencing (what order do you do it) and location of actions that minimizes the risk to the population while maximizing the cost-effectiveness and probability of achieving viability; and
- Communicating the effects of choosing different scenarios (suites of actions) and the uncertainty in language that is accessible to decision makers and the public.

"Getting the right participation" means that the process includes all those affected by the decisions and with authority to implement actions in each of the Hs and considers their different perspectives. "Getting the participation right" means that the process is responsive to the needs of the participants by recognizing their needs, rights, and viewpoints and it incorporates their abilities to implement change. Developing the opportunities, political values, processes and institutional support to manage this as an adaptive challenge is much more challenging than the technical issues listed earlier because the authorities involved in recovery planning have little experience with this kind problem solving.

Each of these steps is essential. The result should be a synthesis that identifies:

- a suite of actions that can be practically implemented as is consistent and predicted to move salmon populations towards short, moderate, and long-term recovery goals;
- the relative uncertainty of the suite of actions; and
- an approach to incorporate learning during the process to improve success.

To apply these principles within each watershed, agencies and governments that make decisions that affect habitat quantity and quality, hatchery operations, and fisheries must align the expected consequences and sequences of their actions so that taken in whole they represent the most efficient way to recover steelhead.

3. Recovery Strategies and Actions

The ESA requires that recovery plans; "…shall, to the maximum extent practicable …, incorporate … a description of such site-specific management actions as may be necessary to achieve the plan's goal for the conservation and survival of the species…" This chapter describes the recovery strategies and site-specific management actions that NMFS recommends for the conservation and recovery of Puget Sound steelhead. These strategies and actions are based on the best scientific data available and designed to help meet the goals described in Chapter 2 and the delisting criteria in Chapter 4. The chapter also presents an adaptive management framework and describes the potential parts of an implementation framework that will be developed to guide recovery plan implementation.

The biological status of Puget Sound steelhead has been impacted by numerous human activities over the last 150 years. The Puget Sound Steelhead Recovery Team considered the "pressures" (human activities and natural events) associated with each of the five ESA Listing Factors and developed the strategies and actions found in this chapter and further described in Appendix 4.

The recovery team followed an Open Standards for the Practice of Conservation approach[6] to identify the highest priority pressures that threaten steelhead, develop strategies to reduce or remove these pressures, and define strategies and actions to restore key habitat types that have been previously damaged. The highest priority pressures for steelhead were arrived at through analysis of several lines of evidence rather than a single pressure assessment. Initial work included the Puget Sound Pressure Assessment, a tool developed and used by the Puget Sound Partnership to assess (terrestrial and marine) threats to various species and habitats. Results of the assessment were organized by MPG, but the team found the results to be insufficient because steelhead were not one of the species included in the original analysis, and some steelhead-specific threats were not well understood or included when the tool was developed in 2014. In addition, both the cause and effect were often combined in the regional list. Thus, the team attempted a series of multivariate analyses to separate cause (e.g. timber harvest) from effect (e.g. sedimentation). These analyses found that many of the individual pressures identified in the assessment covaried strongly across the DPS, and that pressures and stressors (conditions that apply stress on the fish and limit viability) were sometimes confounded. The team also found that the potential impacts on steelhead from the stressors differed appreciably among the three steelhead MPGs in Puget Sound. Defining specific strategies to reduce the impact of stressors through mitigation of pressures is challenging for steelhead and other migratory fish with complex life cycles because simple action pathways are often not possible to identify.

Beyond the Puget Sound Pressures Assessment, the team also looked to the original listing factors for steelhead in 2007, as well as the 2015 Northwest Fisheries Science Center status review for listed Pacific salmon and steelhead (NWFSC 2015) to round out a steelhead-specific list of high-priority pressures to address to reach recovery. Figure 3 shows how the team separated pressures from stressors, and the relationships between pressures and stressors in the

[6] Developed by the Conservation Measures Partnership, this is a publicly available approach to project design, management, and monitoring that aims to help practitioners improve the practice of conservation. The approach provides a general process for the successful development and implementation of conservation projects.

two groups. In most cases, the strategies were developed for each pressure. However, some pressures, such as roads and culverts, were split up and addressed as “fish passage barriers at road crossings” and as part of other pressures such as “residential, commercial, industrial development” (for paved roads) and “timber harvest” (for unpaved roads).

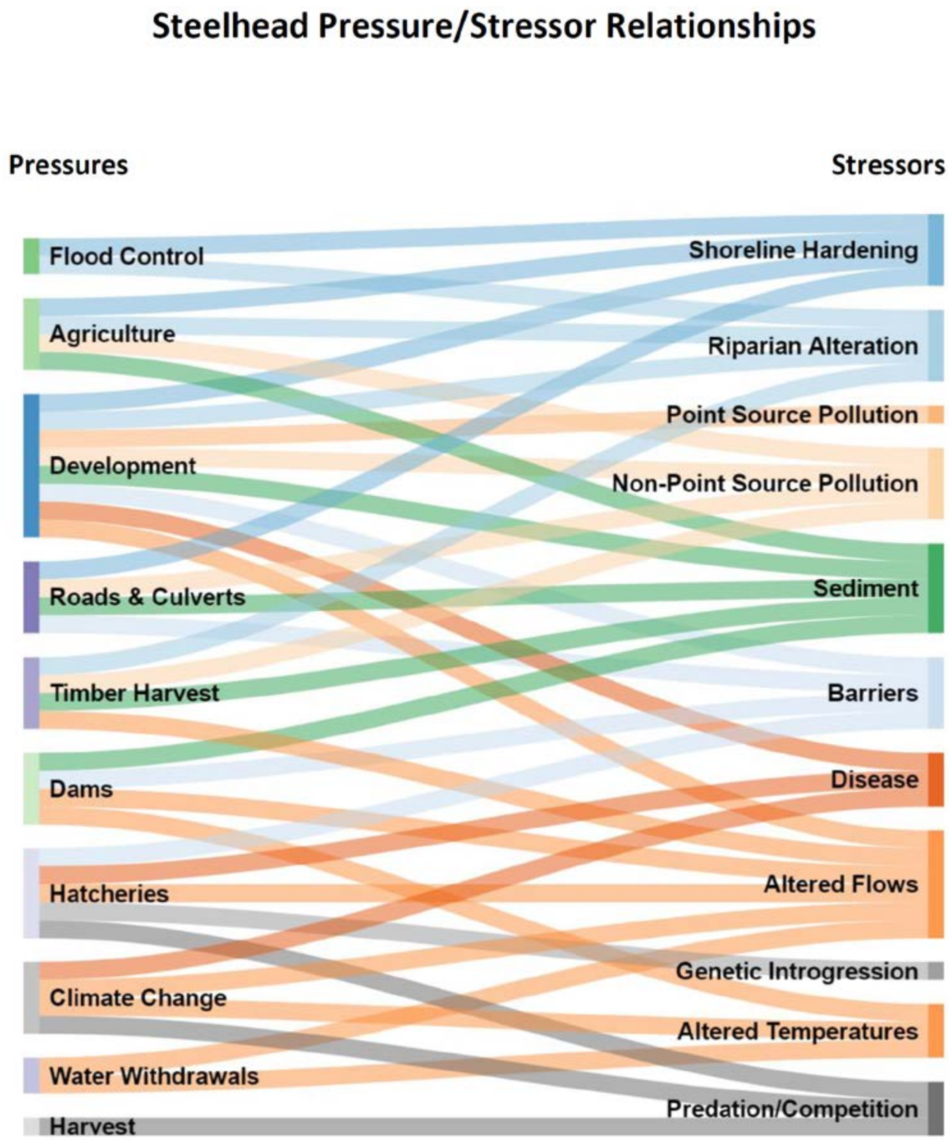

Figure 3. The complex relationship among pressures and stressors affecting steelhead abundance and productivity in Puget Sound ecosystems.

The sections below describe the adaptive management approach to Puget Sound recovery (Section 3.1), the various pressures on Puget Sound steelhead, and the strategies and actions to reduce, alleviate, or mitigate them (Sections 3.2–3.10). Additional sections in this chapter describe strategies to address the current and future threat of climate change (Section 3.11), and implement the necessary monitoring and research strategies and actions for adaptive management (Section 3.12), all of which crosscut multiple pressures and stressors. The strategies and actions are further described in Appendix 4.

3.1 Recovery Strategy and Adaptive Management Framework

Our recovery strategy aims to improve the viability of natural-origin populations of Puget Sound steelhead so the species is self-sustaining in the natural environment and the populations are sufficiently abundant, productive, and diverse so that the species no longer needs ESA protection.

In this Plan we describe strategies and actions that span DPS to DIP scales. Many of the strategies and actions identified in the Plan are common among multiple watersheds in the DPS. To effectively recover Puget Sound steelhead, recovery strategies must span multiple spatial scales (DPS to DIP), accommodate regional and watershed protection and restoration activities, include voluntary and regulatory elements, and directly address the listing factors.

A fundamental aspect of the recovery strategy for Puget Sound steelhead is to incorporate local, watershed-based strategies and actions (primarily DIP-level) into the Plan that address individual steelhead populations. Ultimately, these future watershed plans and localized strategies will form a critical piece of our recovery strategy — particularly since the overarching approach for recovery of Puget Sound steelhead focuses primarily on protecting and restoring ecosystem functions and freshwater habitats. A key strength of this effort is that each future watershed chapter will be tailored to the particular conditions and needs of that basin, while appropriately scaled to adapt to changing conditions or knowledge. Another key strength of this approach is that the individual watershed plans will create a composite result that meets the criteria for DPS recovery provided by the Puget Sound Steelhead Technical Recovery Team. The individual implementation strategies will remain dynamic; growing and changing over time as DPS, MPG, and watershed-level approaches to recovery evolve.

The strategies and actions described in Sections 3.2−3.11 address the following primary pressures contributing to the decline and listing of Puget Sound steelhead, as described in Section 1.2.3. Section 3.12 provides strategies and actions to focus and integrate research, monitoring, and evaluation activities to improve our understanding of the factors that affect steelhead viability and the success of our efforts to address them.

- Fish passage barriers at road crossings
- Dams, including fish passage and flood control
- Floodplain impairments, including agriculture
- Residential, commercial, industrial development (including impervious runoff)
- Timber harvest management
- Water withdrawals and altered flows
- Ecological and genetic interactions between hatchery and natural origin fish
- Harvest pressures (including selective harvest) on natural origin fish
- Juvenile mortality in estuary and marine waters of the Puget Sound
- Climate change

We believe that the strategies and actions identified in this chapter and Appendix 4, if successfully implemented, will lead to the recovery of Puget Sound steelhead. Importantly, our approach to recovery is multifaceted. We need to conduct monitoring and research to gain critical information to assess and model life cycles and pressures that limit recovery, identify the actions most likely to improve steelhead population status, measure the effectiveness of those actions, and track progress towards recovery. We also need to identify additional activities and implementation strategies within each MPG to adaptively manage DIP-specific pressures in individual watersheds. To that end, watershed-scale monitoring of natural-origin populations are necessary, and in a subset of watersheds, combined with habitat monitoring to validate recovery assumptions and progress.

3.1.1 Adaptive Management Process Framework to Guide Recovery Efforts

Our approach is centered on the adaptive nature of the recovery plan. We recognize the importance of learning as we go, and adjusting our efforts accordingly. Thus, the recovery plan is dependent on implementation of an adaptive management process that targets actions based on best available science, monitors to improve the science, and updates actions based on new knowledge. We need to:

- continue to identify critical uncertainties and address them through monitoring and evaluation;
- develop and integrate life-cycle modeling to weigh the effects of different factors, individually and combined, and among watersheds and life history strategies;
- monitor and evaluate the site-specific actions over time to determine progress and effectiveness in addressing the viability criteria; and
- identify the next round of future actions, implement them, and then monitor their effects and influence on our progress toward recovery.

Figure 4 shows the different steps in the adaptive management process framework.

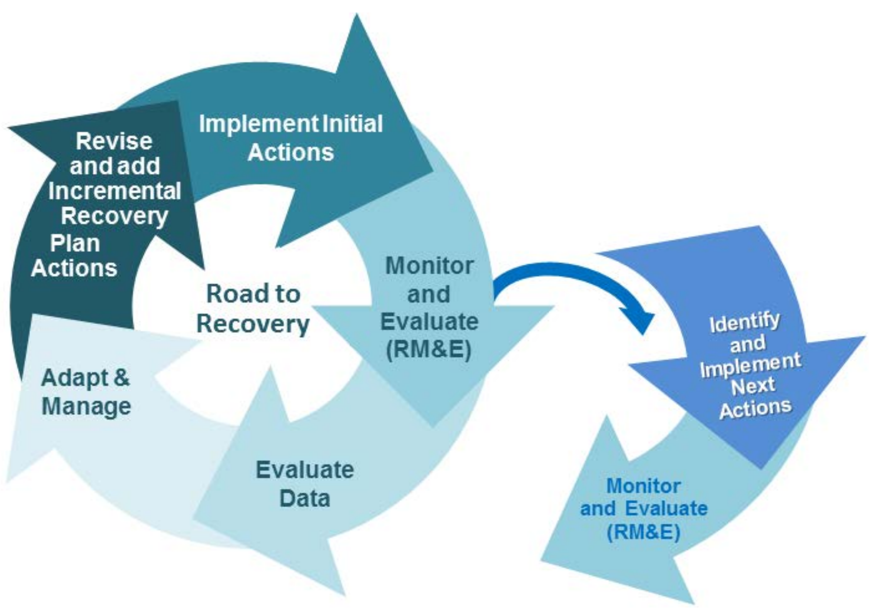

Figure 4. Adaptive management process framework.

Several key questions will guide the adaptive management process:

- Are efforts working according to expectations?
- For research, monitoring and evaluation (RM&E) implementation:
  - Are the actions being implemented?
  - Are our background assumptions still valid (e.g., climate)?
  - Are the actions having the expected effects (changes in habitat, response by fish populations)?
- What is the suite of potential future actions?
- What questions need to be answered to implement additional actions?

The adaptive management framework will provide structure for decision making so we can alter our course strategically as we gain new information.

1. Determine species current status (Chapter 1).
2. Establish recovery goals (Chapter 2) and viability and listing factor criteria for delisting (Chapter 4).
3. Assess the pressures and limiting factors that contribute to the gaps between current status and viability criteria (Chapter 3).
4. Identify and implement recovery strategies and actions that target the pressures and stressors (Chapter 3).
5. Identify and implement research, monitoring, and evaluation actions to evaluate the status of the species, the status and trends of pressures, and the effectiveness of ongoing and potential actions (Chapter 3).
6. Regularly review implementation progress, species response, monitoring and modeling results, and new available information (Chapter 4).
7. Adjust actions through an implementation structure that recognizes the interests of different stakeholders and the best opportunities to improve viability (Chapter 3).
8. Repeat the adaptive management cycle. Adaptive management should be a continuous loop of action including implementation, monitoring, and evaluation, assessment of new information, and updated actions.

3.1.2 Framework to Guide Recovery Plan Implementation

The recovery of Puget Sound steelhead will ultimately depend on the commitment and dedicated actions of the many entities and individuals who share responsibility for the species' future. During implementation of this recovery plan, NMFS will rely, to a great extent, on the continued implementation of ongoing programs, management actions and regulations, and on the implementation of the many new actions proposed in this plan to address threats to steelhead viability across the Puget Sound region. The various fish and habitat managers and local interest groups will need to work together through close coordination to ensure that our collective efforts can bring the species to a point where we are confident that it can be self-sustaining in the natural environment for the long term.

In general, NMFS' vision for recovery plan implementation is that recovery plan actions are carried out in a cooperative and collaborative manner so that recovery and delisting occurs. NMFS' strategic goals to achieve this vision are as follows:

- Sustain local and regional support and momentum for recovery plan implementation.
- Implement recovery plan actions within the time periods identified in the Plan.
- Encourage others to use their authorities to implement recovery plan actions.
- Ensure that the implemented actions are contributing to recovery.
- Provide accurate assessments of species status and trends, limiting factors, and threats.

NMFS' strategic approach to achieving these goals is as follows:

1. Support existing management forums and local efforts, and provide needed coordination among those existing efforts, to encourage recovery plan implementation.
2. Use recovery plans to guide regulatory decision-making.
3. Provide leadership in regional forums to develop RM&E processes that track recovery actions effectiveness and status and trends at the population and ESU/DPS levels.
4. Provide periodic reports on species status and trends, limiting factors, threats, and plan implementation status.
5. To the extent practicable, staff and support identified implementation groups for Puget Sound steelhead recovery.

During recovery plan implementation, NMFS will work with partners to integrate Plan strategies and actions into existing recovery forums, such as the Puget Sound Salmon Recovery Council (PSSRC) and the Washington State Salmon Recovery Funding Board (SRFB). Integrating Plan implementation includes facilitating the sharing of RM&E information and coordinating decisions regarding the prioritization and implementation of recovery actions. The components of this implementation framework, once integrated, should reinforce the need for (1) a science team to deliver rigorous, scientific reviews and ensure that the best available science informs implementation and is applied in all relevant research and monitoring activities; and (2) a PSSRC policy group made up of representatives from the tribes, states and federal agencies, local watershed teams, and other implementing entities to provide input and coordination on efforts to advance Puget Sound steelhead recovery and maintain strong communication among recovery entities.

3.2 Pressure: Fish Passage Barriers at Road Crossings

Fish passage barriers at road crossings are prevalent in Puget Sound streams. The Washington Department of Fish and Wildlife estimates that as many as 8,000 culverts block access to steelhead habitats in Puget Sound (WDFW 2009; GAO 2001; WDFW 2018). Impassable culverts reduce habitat carrying capacity, limiting abundance and spatial structure. Wofford et al. (2005) found that blocking culverts have caused genetic variation among isolated fish populations. Blocking culverts also reduce access to juvenile steelhead refugia habitat in tributaries during floods. Because steelhead occupy both higher elevation, smaller tributaries to major river systems, as well as independent tributary systems that flow directly into Puget Sound, fish passage barriers are a more prominent concern for this species than for listed Puget Sound Chinook salmon.

Culverts can form fish passage barriers in a number of ways. Roads and culverts are a fixed feature in a dynamic stream environment where shifting channels move both vertically and laterally. Culverts should be designed and installed to withstand these movements as well as flood pulses, sediment movement, and drifting large wood. Culverts that meet these criteria are most commonly among “stream simulation” designs. Culverts designed without these criteria often form barriers through time (Price et al. 2010). Barriers to steelhead occur when culverts becomes perched above the substrate, are designed or installed too steeply, or when they are undersized relative to the channel resulting in swimming velocity barriers.

A number of existing programs in Washington have improved fish passage over the last 20 years, but there is still a large number of barriers remaining to be repaired. Under the Forests and Fish Agreement (1999), state and private industrial forest landowners committed to repairing fish passage barriers on their roads under the road maintenance and abandonment program’s – Road Maintenance and Abandonment Plan (RMAP) process. Twenty years later, nearly all of those barriers (7,300 state-wide) have been fixed. Unfortunately, successful programs in non-forest landscapes are still developing or are under-funded. Among the programs showing the most promise for successfully removing barriers to steelhead are the Fish Barrier Removal Board (FBRB) and the Family Forests and Fish Passage Program (FFFPP). Programs within local governments (cities and counties) are among the most in need of development and progress.

The U.S. Supreme Court has recently affirmed the rights of Western Washington Treaty Tribes to have unobstructed salmon and steelhead passage at Washington State road crossings in Puget Sound and coastal streams (U.S. Supreme Court, 584 U.S. No. 17-269). The case pitted the tribes’ rights to harvestable fish against fish-blocking culverts on state-owned roadways. Although Washington State has been correcting fish passage barriers for more than 20 years, approximately 420 salmon/steelhead barriers remain to be repaired on state-owned roads at an estimated cost of $2.4 Billion over the next 12 years (WSDOT 2018). Both voluntary and regulatory tools are needed to recover Puget Sound steelhead.

Strategies and Actions to Improve Fish Passage

Strategy 1. Maintain and increase support for the Fish Barrier Removal Board and related programs.

- **Action 1.a.** Seek continued funding for the Fish Barrier Removal Board.
- **Action 1.b.** Complete RMAP program and increase funding for the FFFPP.
- **Action 1.c.** Support Snohomish County’s barrier repair pilot program and expand to other areas.
- **Action 1.d.** Develop and implement a robust RMAP monitoring/adaptive management program.
- **Action 1.e.** Ensure RMAP barriers are repaired in 6 years if they become renewed barriers.

Strategy 2. Highlight and remedy programmatic gaps in fish passage removal programs.

- **Action 2.a.** Ensure Lead Entities include fish passage projects in their priorities.

Action 2.b. Consult the railroad for barrier repair partnerships/opportunities.
Action 2.c. Provide training for contractors / engineers to prevent new barriers.
Action 2.d. Provide training for cities and counties to prevent new barriers.
Action 2.e. Leverage other programs to increase repairs (Floodplains by Design, Federal Emergency Management Agency [FEMA], Farm-Fish-Flood).
Action 2.f. Synchronize the FBRB and Federal Action Plan priorities.
Action 2.g. Encourage cities and counties to use taxing authority to repair barriers.
Action 2.h. Implement abundance monitoring in coordination with watershed barrier repairs.

Strategy 3. Provide funding and resources for fish barrier removal.
Action 3.a. Increase and diversify funding/resources for barrier removal.
Action 3.b. Maintain existing funding/resources.

Strategy 4. Increase the education, social science, and social marketing programs that support fish passage barrier removal.
Action 4.a. Create enthusiasm in landowners with barrier repair opportunities.
Action 4.b. Educate about the need for culvert repair to adapt/be resilient to climate change.
Action 4.c. Educate the general public on steelhead and road crossing barriers.
Action 4.d. Develop partnership opportunities with private corporations.

Strategy 5. Align fish passage correction programs to ensure consistency between federal, state, cities, counties, private entities.
Action 5.a. Share expertise, improvements in technology among local government agencies.
Action 5.b. Create and distribute a roster of experts.
Action 5.c. Develop a mechanism to share barrier correction data among agencies.

Strategy 6. Prohibit new fish passage barriers.
Action 6.a. Enforce and support regulation to prevent new fish passage barriers.
Action 6.b. Evaluate effectiveness of newly installed culverts.
Action 6.c. Improve federal permit process to expedite stream simulation designs in repairs.

Strategy 7. Increase monitoring, data collection, information sharing, and reporting of fish passage correction progress.
Action 7.a. Integrate steelhead life cycle data with the FBRB's work.
Action 7.b. Align mapped DIPs to HUC-10s.
Action 7.c. When inventorying culverts, focus on already prioritized fish passage recovery areas identified by the Lead Entities and the FBRB.
Action 7.d. Build for future climate change impacts (storm events, higher/lower flows, etc.)
Action 7.e. Examine current climate change tools in the design of culverts.
Action 7.f. Lead Entities and governments annually report corrected barriers to WDFW.
Action 7.g. Lead Entities and local governments annually plan DIP-level culvert repair priorities.
Action 7.h. Align the Habitat Work Schedule (HWS) with the WDFW fish passage database.
Action 7.i. Align permitting databases (e.g., Hydraulic Project Approval (HPA) database) with Fish Passage and Diversion Screening Inventory (FPDSI).

Strategy 8. Incorporate the benefits of beaver in barrier removal programs.
Action 8.a. Incorporate beaver needs into barrier removal programs and guidelines.

3.3 Pressure: Dams, including Fish Passage and Flood Control

Dams are found throughout the Puget Sound, and include hydroelectric generation facilities, flood control projects, large municipal water supply and diversion projects and smaller water storage reservoirs. Figure 5 shows the major dams that block steelhead access or modify their habitat in Puget Sound. Figure 6 shows the smaller dams that affect steelhead distribution.

Dams and their associated reservoirs can have a wide range of complex impacts on steelhead and their habitats in the Puget Sound. The key impacts to steelhead associated with dams include blocked or impaired upstream and downstream migration, loss of historic habitat in areas inundated by reservoirs, alterations to hydrology and water temperature regimes, alterations to sediment recruitment and transport, impaired large wood recruitment and altered woody debris transport, and alterations to nutrient and organic carbon inputs and cycling to downstream riverine ecosystems. The alterations in these natural ecosystem processes can extend substantial distances downstream of dams, and thus impact steelhead and their habitat over large areas in the Puget Sound.

Several dams in the Puget Sound have blocked the upstream passage of adults into historical steelhead spawning and juvenile rearing areas. These dams can also impair the downstream passage of juveniles of anadromous or resident *O. mykiss* that are present in the watershed upstream of the dam. The dams reduce the natural production of steelhead by reducing available spawning and rearing habitat. They can also impair life-history and genetic diversity by restricting spawning and rearing to the lowland habitat areas within a river basin. Key strategies for restoring access to watershed areas above dams that historically supported steelhead populations include dam removal, and construction and improvement of fish passage facilities at dams. The removal of the two Elwha River dams provides an excellent example of a dam removal project that has restored steelhead migration into a large headwaters basin that historically supported a distinct steelhead population. The removal of these dams also restored the natural hydrological and thermal regimes, sediment and wood transport, and aquatic and riparian ecosystem functions to the river. Fish passage facilities can also be constructed to restore or improve the upstream migration of adults and downstream migration of juveniles at existing dams. NMFS can prescribe mandatory fish passage conditions for steelhead and salmon for inclusion in the license issued by the Federal Energy Regulatory Commission (FERC) for hydroelectric dams. For existing dams in the Puget Sound, the opportunity for prescribing fish passage typically occurs during the relicensing process for existing hydroelectric dams.

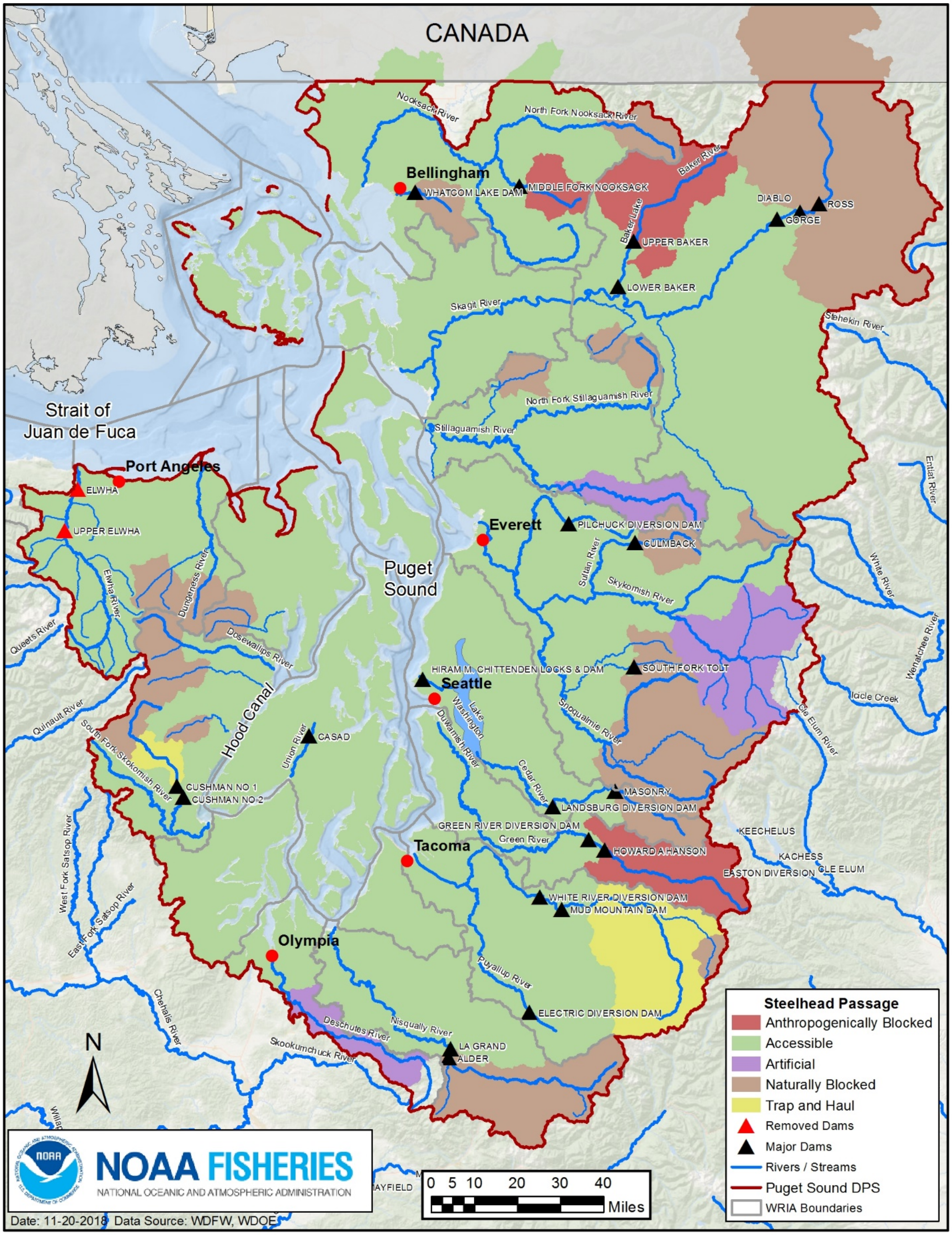

Figure 5. Major dams blocking steelhead or modifying their habitat in Puget Sound.

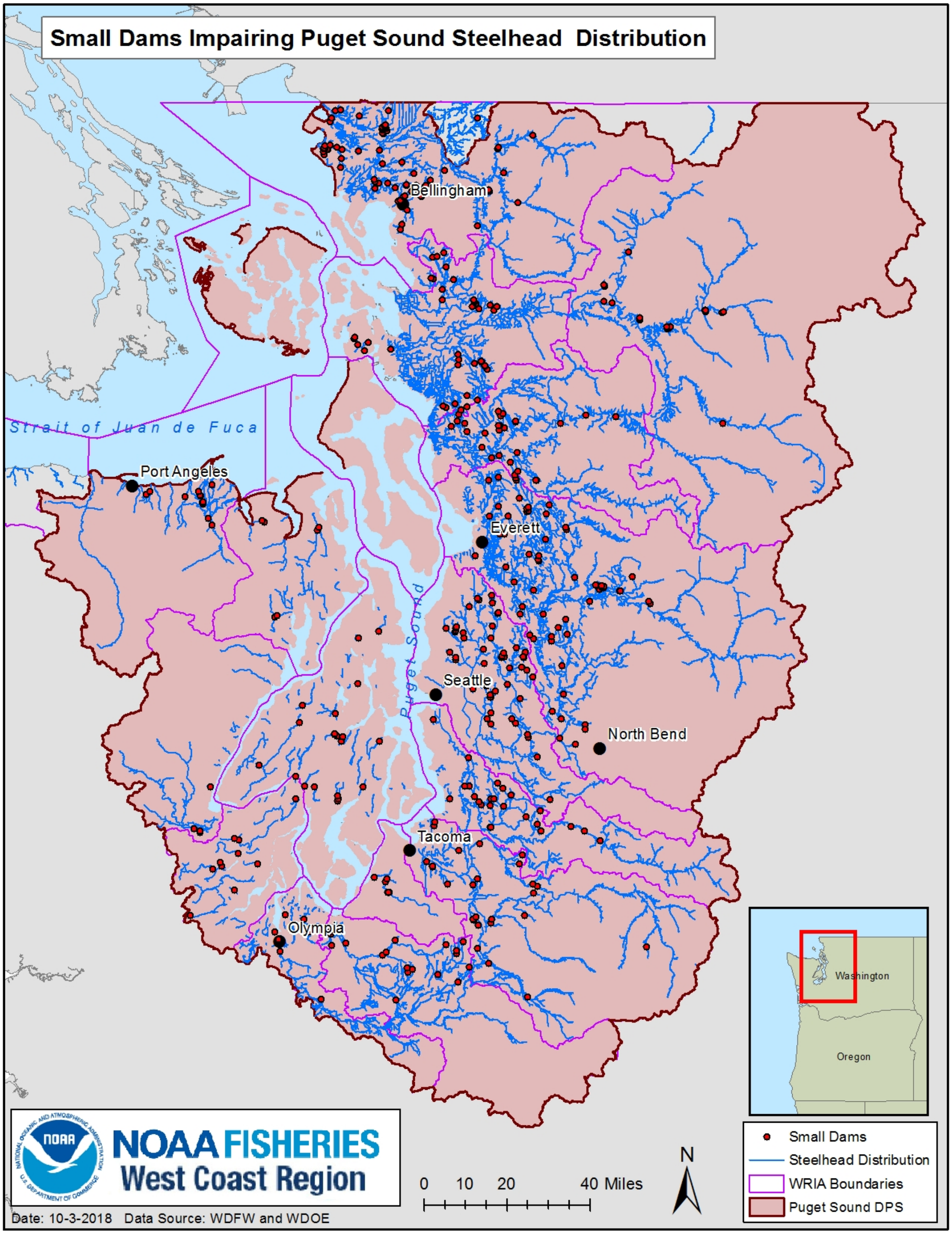

Figure 6. Small dams in the Puget Sound DPS that impair steelhead distribution**.**

Table 2 identifies the major dams in the Puget Sound steelhead DPS and describes their location, purpose, and status. The table also identifies whether a dam affects summer-run or winter-run steelhead, whether it allows steelhead passage, and whether it meets NMFS' fish passage standards.

Table 2. Major dams in the Puget Sound steelhead DPS.

Dam	River	Dam purpose	Status	DIP affected (Summer-run; Winter-run)	Steelhead Passage[2]	Meeting NMFS fish passage standards (Yes/No)
Elwha Dam (1910)	Elwha	Hydroelectric /water supply	Removed (2012)	Winter Summer	Not blocking	Yes
Glines Canyon Dam (1926)	Elwha	Hydroelectric /water supply	Removed (2014)	Winter Summer	Not blocking	Yes
LaGrande (Alder) Dam (1945)	Nisqually	Hydroelectric	Presumed Historical natural barrier	N/A	Not blocking	N/A
Pilchuck Dam	Pilchuck	water supply[4]	fishway	Winter	Partial blockage	No
Mud Mountain (1948) and Buckley diversion dam (1911)	White	Flood control Recreation/ Hydroelectric	Trap and haul	Winter	Blocking	No, but fish passage being improved
Electron Dam (1904)	Puyallup	Hydroelectric	Fishway	Winter	Partial blockage	No
Howard Hansen Dam (1961)	Green	Flood control	Trap and haul	Winter	Blocking	No
Cushman 1 (1926) and Cushman 2 Dams (1930)	Skokomish	Hydroelectric	Trap and haul	Winter	Blocking	No, but early fish passage is being improved
CASAD (1957)	Union	water supply	Historical natural barrier	Winter	Not blocking	N/A
MF Nooksack Dam (1962)	Nooksack	water supply	Barrier	Winter	Blocking	No, but Dam removal planned
Ballard locks (HCL) (1916)	Cedar/ N. Lk. Wash.	Transportation	Current partial barrier	Winter	Blocking	No
Culmback/Jackson Dam (1965)	Sultan River	Hydroelectric / water supply	Volitional passage created (2017)	Winter	Not blocking	Yes
Lower Baker Dam (1925)	Skagit	Hydroelectric	Trap and haul	Summer Winter	Blocking	No
Upper Baker Dam (1959)	Skagit	Hydroelectric	Trap and haul	Summer Winter	Blocking	No
Gorge Dam (1961)	Skagit	Hydroelectric	Historical natural barrier	Summer Winter	N/A	N/A
Diablo Dam (1930)	Skagit	Hydroelectric	Historical natural barrier	Summer Winter	N/A	N/A
Ross Dam (1949)	Skagit	Hydroelectric	Historical natural barrier	Summer Winter	N/A	N/A
Whatcom Lake Dam	Nooksack	water supply	Historical natural barrier	Winter	N/A	N/A
Landsburg diversion	Cedar	water supply	Fishway	Winter	Passable	Yes
Green R diversion	Green	Water supply	Trap and haul	Winter	Blocking	No
Tolt Dam (1964)	SF Tolt	Water supply	Above natural barrier	Summer	N/A	N/A
Masony Dam (1915)	Cedar River	Water supply / Hydroelectric	Historical natural barrier	Winter	Not blocking	N/A

Dams can significantly alter the hydrology of a stream or river downstream of the project, especially when large volumes of water are stored in the reservoir for hydroelectric generation and water supply purposes. The altered flows released by dams can impact all freshwater life stages of steelhead, including upstream and downstream migration, spawning, incubation, and juvenile rearing.

Most hydroelectric and water storage dams in the Puget Sound store water during high flow periods of the year (winter storm flow and spring snowmelt periods), and release this water during seasonal low flow periods (late summer and fall; winter snow accumulation). Without flow management measures to protect fish, the alterations in seasonal runoff can result in impaired access by adult steelhead to spawning areas, reduced spawning success, and increased rates of redd dewatering(Gendaszek et al. 2017). Seasonal alterations in flow also impact the rearing habitat of juvenile steelhead downstream of a dam, and can provide too much or too little flow depending upon channel characteristics and the habitat requirements of the fish (Nagrodski et al. 2012). Hydroelectric dams can also alter daily flow patterns in downstream streams and rivers through peaking and load-following generating practices, which involve the release of larger volumes of water during periods of high electricity demand. The alteration of daily flow patterns can dewater steelhead redds during the late spring and summer incubation periods, and dewater juvenile steelhead which become stranded along the banks of the river during periods of down-ramping (i.e., water releases from dams are reduced due to lowered electricity demand). The impacts of hydrological alterations to steelhead below dams can be substantially reduced through instream flow prescriptions and fish flow protection agreements with the utilities that are produced in consultation with NMFS, WDFW, the Washington Department of Ecology (WDOE or Ecology), tribes, and non-governmental organizations. Dams can also be operated to reduce impacts to steelhead from natural flood events, including reducing peak flows that can scour spawning redds and injure and kill juvenile fish. The lead state agency for setting instream flow regimes for fish downstream of dams is typically WDOE under the authority of state water rights regulations and instream flow rules.[7] Instream flows set by rule are intended to protect beneficial uses, including fish and wildlife. WDOE can also prescribe instream flow requirements below dams to protect water quality, fish habitat conditions, and ecological processes important for steelhead growth and survival under the authority of the Clean Water Act.

Dams can impact the quantity and quality of habitat for steelhead in the receiving stream or river by cutting off the natural supply of sediment (especially gravels required for spawning) from the upper watershed. Dams also cut off the natural supply of large wood from the upper watershed, which can reduce the quality of holding, spawning, and juvenile rearing habitat. Alterations in peak flows can also impact the transport of sediments and large wood in the channel downstream, subsequently altering the geomorphology of river (and thus fish habitat conditions) below the dam. In some cases, the capture of sediments from the upper watershed by a dam results in gravel "starvation" to a river, which can reduce available spawning habitat and juvenile foraging habitat for steelhead. Mitigation measures, including gravel seeding, can be prescribed during the relicensing process of hydroelectric dams to reduce the impacts to steelhead caused by sediment starvation. In other cases, fine sediment can accumulate in the river channel downstream of a dam resulting in reduced egg survival in redds, and degraded habitat for

[7] RCW 43.21A.064.

juvenile rearing. In these cases, flushing flows can be prescribed as part of the instream flow regime developed during the FERC licensing and relicensing process for a hydroelectric dam. Flows regimes and downstream habitat improvements can also be prescribed as a reasonable and prudent measure by NMFS as part of the ESA Section 7 consultation process for federal dams that don't produce electricity. Habitat mitigation measures including improvements to instream habitats (e.g., large wood habitat projects) can also be used to reduce the impacts of dams to steelhead.

Dams with large storage reservoirs can substantially alter the natural temperature regime of the river or stream downstream of the dam. The resulting shifts in temperature can alter the migration and spawning timing of adult steelhead, the outmigration timing of smolts, alter the incubation timing and survival rates of eggs and embryos, and alter the growth and survival rates of rearing juveniles. Dams can release water that is too warm, too cold, or nearly optimal for incubation and juvenile rearing depending upon where the water is withdrawn from the reservoir. Withdrawal of surface waters typically result in releases of water that are warmer than natural, while the withdrawal of deep waters results in the release of water that is colder than natural. Temperature regimes below dams can be improved for steelhead by modifying dam operations and instream flow releases. These actions can be prescribed by WDOE under the authority of the Section 401 Certification process required under the Clean Water Act that occurs as part of the FERC licensing process, during 401 certifications of water storage reservoirs, and under WDOE's Total Maximum Daily Load (TMDL) process for water quality impaired waters. WDOE also monitors the safety of smaller dams that are not tracked by FERC and other entities. Although these individual dams may not block large amounts of habitat, they cumulatively limit the abundance, production, and spatial structure of Puget Sound steelhead (see Figures 5 and 6).

Strategies and Actions to Address Effects of Dams

Strategy 1. Identify opportunities and priorities for dam removal in watersheds where steelhead migration has been blocked.

- **Action 1.a.** Educate and assist cities / counties on non-FERC / non-federal dams.
- **Action 1.b.** Follow and participate in work of the ongoing dam removal prioritization team.

Strategy 2. Provide funding and resources for dam removal.

- **Action 2.a.** Seek federal authorization and funding for dams high priority dam removal.
- **Action 2.b.** Seek funding for state and local governments for the removal of local and private dams.
- **Action 2.c.** Support federal and state salmon restoration funds to remove high priority dams.

Strategy 3. Remove high priority dams that block or impair steelhead migration into historical spawning and rearing areas.

- **Action 3.a.** Remove Middle Fork Nooksack Diversion Dam.
- **Action 3.b.** Remove the Pilchuck Diversion Dam.

Strategy 4. Construct or improve fish passage facilities at dams, locks, and water diversions where steelhead migration is blocked or impaired. Reduce passage injuries and mortalities at these facilities.

- **Action 4.a.** Require fish passage at FERC forums for licensing and relicensing of dams.
- **Action 4.b.** Use regulatory tools to remove or provide fish passage at non-FERC dams.

Action 4.c. Improve Ballard Locks and Dam for upstream and downstream passage.
Action 4.d. Provide effective fish passage facility at Howard Hanson Dam.
Action 4.e. Provide effective passage at Buckley Diversion Dam and Mud Mountain Dam.
Action 4.f. Monitor effectiveness of steelhead passage above Electron Dam.
Action 4.g. Pass steelhead above Baker Dam. Improve and monitor effectiveness of steelhead passage (up and downstream) at Baker Dam and improve effectiveness through time.

Strategy 5. Increase education, social science, and social marketing.
Action 5.a. Educate and engage in FERC relicensing processes.
Action 5.b. Educate and engage in NEPA review process for dams and diversion structures.
Action 5.c. Educate the public on the effects of dams on steelhead that include all consequences.

Strategy 6. Dis-incentivize new dams, locks, and water diversion structures.
Action 6.a. Enforce regulations to prevent new steelhead passage barriers, including dams.
Action 6.b. Use Federal Power Act to require fish passage at FERC dam relicensing.
Action 6.c. Use the Wild and Scenic Rivers Act and Wilderness Act to prevent new dams.

Strategy 7. Improve instream flows downstream of hydroelectric dams and water storage reservoirs.
Action 7.a. Revise instream flow requirements at dams to meet steelhead recovery goals.
Action 7.b. Increase steelhead life stage survival through improved dam flow operations and maintenance (O&M).
Action 7.c. Develop and use flow ramping criteria to increase life stage productivity at dams.

Strategy 8. Using mitigation and restoration, improve habitat conditions downstream of hydroelectric dams and water storage reservoirs.
Action 8.a. Synchronize habitat restoration, life stage needs, and improved dam flow O&M.
Action 8.b. Mitigate and restore geomorphological conditions downstream of dams.
Action 8.c. Reintroduce gravels and large wood where starved due to dam O&M.
Action 8.d. Restore large wood jams downstream of dams.

Strategy 9. Improve temperature and water quality conditions downstream of hydroelectric dams and water storage reservoirs.
Action 9.a. Ensure dams O&M meets state water quality standards for steelhead recovery, including temperature, turbidity, and dissolved gases.

3.4 Pressure: Floodplain Impairments, including Agriculture

Diverse stream features and associated habitats are important for a variety of steelhead life-history stages. Dikes and levees adjacent to rivers and streams have isolated channels to single threads which are largely absent of habitat features. Floodplains commonly support rich nutrients built up over millennia as floods inundated adjacent river terraces. As early farmers settled Puget Sound and began farming the rich soils, levees were constructed to protect their crops and farm animals from the very floods that deliver nutrients. Where levees were constructed to protect farms, river velocities accelerated and river height increased, which forced farmers on the opposing side and downstream of the levee to also construct levees. As Puget Sound became increasingly populated, farms were converted to sprawling urban and suburban communities with increasing need for public safety and associated infrastructure. As a result, flood control dams and levees have become more prominent and damaging to steelhead populations.

Approximately 254 miles of Puget Sound's 17 major streams and rivers are narrowed and armored with dikes and levees. Figure 7 shows the dikes and levees in Puget Sound. As one consequence of this construction, Beamer et al. (2002) estimated that Skagit River delta habitats, including channels, sloughs, and intertidal habitats, had decreased by 72 percent from historical conditions. Dikes and levees greatly reduce or eliminate the opportunity for spawning or rearing in those reaches and hasten the entry of juvenile steelhead to marine waters.

Figure 7. Dike and levees in Puget Sound rivers and streams.

Agriculture is commonly an exempted land use activity in the implementation of the Shoreline Management Act (SMA [1971]) and Growth Management Act (GMA [1990]). As a result, riparian habitats have not received adequate protection to support steelhead habitats in floodplains as farmers maintain cleared riparian areas to support agriculture activities. Likewise, where agriculture yields to development pressure, opportunities to restore habitat for salmon and steelhead are too often lost to unyielding dikes and levees. Healthy riparian habitats are necessary to maintain suitable stream temperature, provide a long-term supply of large wood to form complex habitats and diverse channel structure, and support water supply and water quality.

Strategies and Actions to Improve Floodplain Connectivity and Condition

Strategy 1. Protect intact floodplains using effective land use regulations and enforcement.

Action 1.a. Integrate NMFS riparian buffer tables into land use planning and regulations.

Action 1.b. Increase coordination between local governments and recovery groups to protect habitat.

Action 1.c. Fund and assess the effectiveness of existing land use regulations (GMA/SMA).

Action 1.d. Incentivize agriculture programs to retain compatible steelhead habitat.

Action 1.e. Prioritize stream recharge areas to restore low flows and moderate high flows.

Action 1.f. Increase the public education and awareness of land use regulations for steelhead.

Action 1.g. Fund and enforce floodplain, riparian, and instream habitat regulations.

Action 1.h. Limit the exemptions and variances to anadromous habitat Critical Area Ordinances (CAOs) and SMA.

Action 1.i. Develop and implement standardized mitigation where floodplain development is unavoidable to create a net habitat benefit for steelhead.

Action 1.j. Use land swaps, transferable development rights, mitigation banking programs, and in-lieu fee mitigation to increase habitat or mitigate impacts.

Action 1.k. Require a qualified geotechnical professional to assess safety needs to avoid land-use encroachments before minimizing and mitigating impacts.

Action 1.l. Coordinate with Regional Transportation Councils and agencies to incorporate steelhead and salmon protection and recovery into long-range planning efforts.

Strategy 2. Identify and protect floodplains and freshwater wetlands for steelhead through funding and implementing farm-fish-flood integrated planning programs at the local level.

Action 2.a. Increase funding and use of Floodplains by Design to protect and restore floodplains.

Action 2.b. Support engagement in locally developed plans such as the Snoqualmie Farm, Fish, and Flood, Snohomish County Sustainable Lands Strategy, Puyallup Floodplains for the Future Project.

Action 2.c. Use High Resolution Change Detection to determine where land change is happening, the type of conversion, and identify hotspots where change is rapid.

Action 2.d. Use NMFS riparian buffer tables to standardize protocols and priorities for permanent riparian buffer easements and fund these priorities.

Action 2.e. Develop a tax benefit program for landowners willing to retain adequate existing riparian buffers (e.g., Public Benefit Rating System).

Action 2.f. In rural areas, use conservation easements, current use taxation (e.g., Public Benefit Rating System and other programs.

Action 2.g. Increase technical assistance for small forest landowners and develop farm plans and assess benefits afforded to steelhead.

Action 2.h. Develop funding mechanisms to pay farmers to "grow salmon" on their high priority ownerships.

Strategy 3. Reduce levee impacts through setbacks and improved vegetation management.

Action 3.a Integrate floodplain planning guidance on the National Flood Insurance Program, Clean Water Act (404), levee standards, SMA, and GMA.

Action 3.b. Analyze floodplain data for projected population growth, flood risk, and hydrological and geomorphological benefits to steelhead.

Action 3.c. Update climate change projections to strengthen knowledge of high-risk flooding.

Action 3.d. Educate policymakers on flood and flood risk tolerance projections.

Action 3.e. Develop and showcase examples of mutual benefit projects that help alleviate flooding and benefit steelhead.

Action 3.f. Develop and implement regional variance models to existing U.S. Army Corps of Engineers (Corps') vegetation requirements on levees.

Action 3.g. Incorporate Reasonable and Prudent measures from the FEMA Biological Opinion into local government planning and Critical Area Ordinances.

Action 3.h. Prioritize and fund opportunities to set back levees and increase floodplain access.

Strategy 4. Reduce bank armoring and other habitat stressors in steelhead river systems.

Action 4.a. Increase the use of "demonstration of need" for new hard armor permits.

Action 4.b. Incentivize soft bank protection permitting where needed where wood is mostly used.

Action 4.c. Fully mitigate the installation of unavoidable bank armoring in steelhead streams to off-set the loss of steelhead habitat by removing at least an equivalent amount of armoring elsewhere in the basin.

Action 4.d. Develop civil penalties and enforce un-permitted bank armoring and the removal of large wood from streams and riparian areas.

Action 4.e. Incentivize and promote the removal of invasive vegetation and promote the plantings of native and beneficial species.

Action 4.f. Assist property owners (e.g., templates for riparian planting plan, assistance with designing habitat restoration, identifying potential grant funding.

Action 4.g. Implement actions to remove hard bank protection from streams and replace with soft approaches where necessary or opportunistic.

Action 4.h. Implement site-specific actions, such as removing bulkheads/shoreline hardening at key forage fish sites, adding wrack to beaches, protecting and restoring submerged vegetation including eelgrass and kelp, and removing pilings. Explore beach nourishment options where infrastructure disconnects drift cells.

Strategy 5. Educate the community to reduce bank armoring and other habitat stressors in steelhead river systems.

Action 5.a. Educate and engage the public in local government planning, development and public works processes.

Action 5.b. Educate and engage the public in State Environmental Policy Act (SEPA) review process for bank armoring.

Action 5.c. Educate the public on the effects of riprap on steelhead that include all consequences.

3.5 Pressure: Residential, Commercial, Industrial Development

Residential, commercial, and industrial development have dramatically altered stream ecosystems, reducing steelhead habitat and population abundance. In addition to fostering other pressures, such as increasing fish passage barriers at road crossings and increasing the armoring of stream banks with dikes and levees, urban development has reduced groundwater levels and instream flows (especially during summer). The reduction in summer flows reduces available habitat directly for juvenile steelhead, but it also indirectly elevates stream temperatures which leads to increased susceptibility of steelhead to disease and predation. Urbanization also increases stormwater run-off during fall and winter months (Booth 1991), which can scour steelhead redds and pollute water quality.

The Puget Sound basin has experienced rapid human population growth. In 1985, approximately 3 million people lived in the basin; today, population growth has increased to 4.9 million people.

As the number of people on the landscape has increased, so too have their demands on natural resources, including space for residential, commercial, and industrial development. Figure 8 shows the different land uses that occur in the Puget Sound steelhead DPS.

Land use management in Puget Sound is regulated through a complex system of federal, state and local governments, each with unique responsibilities and jurisdictions. While NMFS has responsibility for administration of the ESA, for example, our authority to regulate habitat activities that affect ESA-listed species is limited to activities that are funded, authorized, or carried out by other federal agencies. Typically, we do not have a regulatory role in activities that occur on state or local lands. Similarly, state and local natural resource management agencies have defined management responsibilities. Successful habitat management for Puget Sound steelhead will require effective collaboration across all levels of government.

In 2017, Puget Sound federal natural resource management agencies signed a Memorandum of Understanding creating the Puget Sound Federal Task Force (Task Force) and clarifying agency commitments to align their programs, activities and funding priorities to expedite recovery of the Puget Sound Ecosystem, including ESA listed salmon and steelhead. The Task Force released an Interim Puget Sound Federal Action Plan that lays out a shared vision and priority actions for Puget Sound Recovery. NMFS co-chairs the Regional Leadership and Implementation teams for the Task Force and is actively engaged with other federal agencies on common science, management and funding activities.
https://www.westcoast.fisheries.noaa.gov/habitat/conservation/puget_sound_federal_task_force.html.

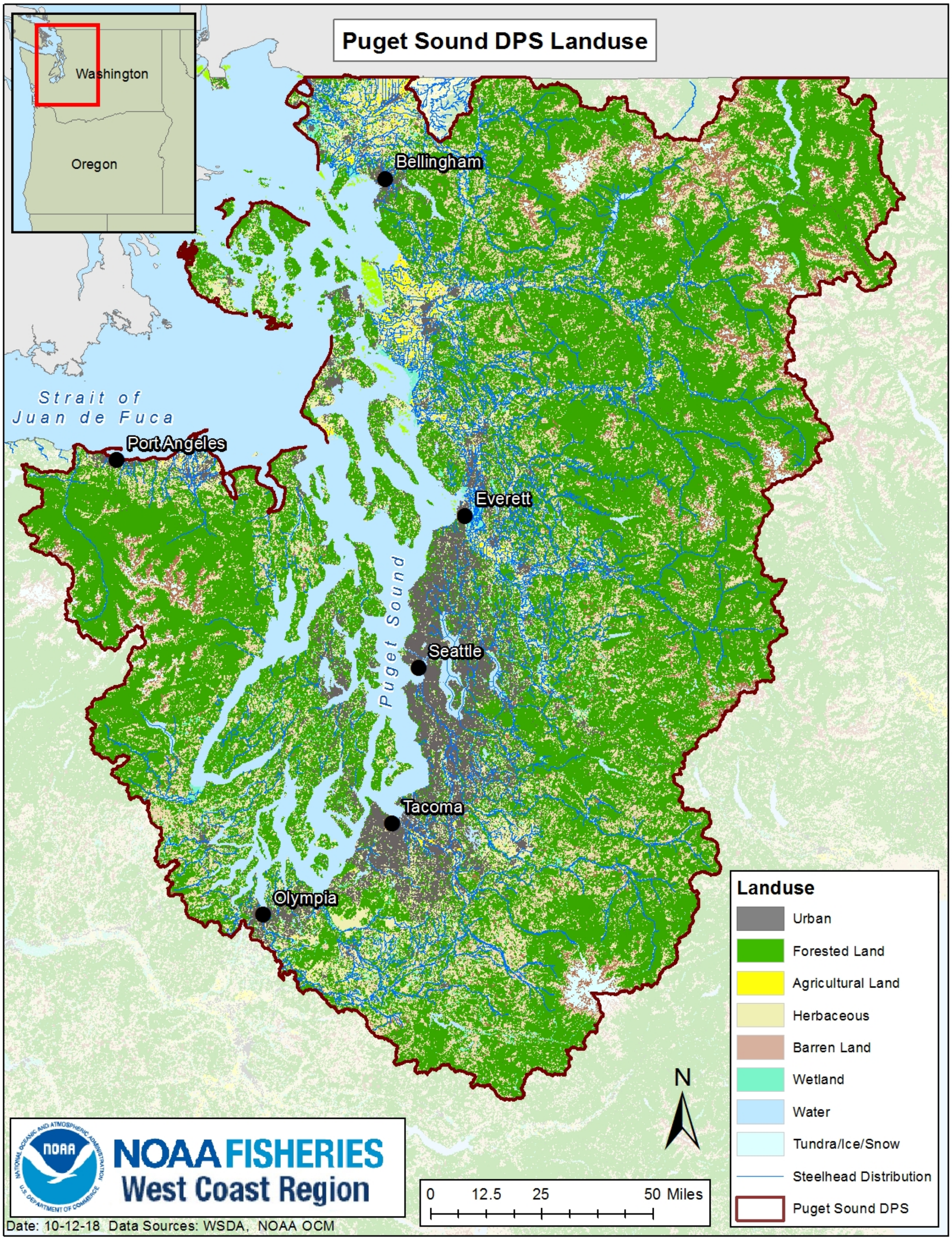

Figure 8. Different land uses in the Puget Sound steelhead DPS.

In 1990, the Washington legislature passed the Washington State Growth Management Act (GMA), which is a state law that requires state and local governments to manage human population growth by identifying and protecting critical areas and natural resource lands, including habitat for anadromous fishes such as steelhead. To adequately protect critical habitat, the GMA requires counties and some cities to designate urban growth areas, prepare comprehensive plans, and implement the plans through capital investments and development regulations. Impairments to steelhead habitat occur when these rules are not fully implemented or where exemptions and variances are allowed. Steelhead habitat is similarly degraded when transportation planning fails to account for adequate fish passage and effective stormwater control for water quantity and quality factors.

Strategies and Actions to Address Effects of Residential, Commercial, Industrial Development

Strategy 1. Reduce impediments to infill and redevelopment in Urban Growth Areas (UGAs).

Action 1.a. Increase incentives for developers during redevelopment of infilled property to upgrade stormwater systems or substantially increase shoreline riparian function through planting or removal of armoring.

Action 1.b. Increase resources for Washington Department of Ecology voluntary cleanup program.

Strategy 2. Improve local implementation and enforcement of Growth Management Act existing regulations that protect streams and wetlands from residential/ commercial/ industrial development.

Action 2.a. Minimize increases of current Urban Growth Areas.

Action 2.b. Encourage cluster developments in rural areas in areas.

Action 2.c Improve compliance with CAO protections for aquatic buffers and wetlands.

Action 2.d. Require a qualified geotechnical professional to avoid land-use on steep stream slopes.

Action 2.e. Align UGAs with steelhead habitat data to prioritize protection applications.

Action 2.f. Assess accuracy of historic buildout scenarios (Alternative Futures) to determine where habitat protection efforts are most crucial.

Action 2.g. Advance other, systemic ways of improving local implementation of GMA such as restoring state funding that supports county-level GMA planning.

Action 2.h. Use High Resolution Change Detection to determine where land change is happening, the type of conversion, and identify hotspots where change is rapid.

Action 2.i. Assess the degree to which exemptions and variances are occurring and the resulting extent of degradation to riparian and wetland habitats.

Strategy 3. Incentivize protection of priority habitat areas beyond those covered via regulations.

Action 3.a. Assist small forest and rural landowners in land-use and conservation plans.

Action 3.b. Assist property owners in steelhead restoration (e.g., templates for riparian planting plan, assistance with designing habitat restoration, and grant funding.

Action 3.c. Implement transferable development rights, environmental mitigation banking/reserve programs, and in-lieu fee mitigation for steelhead restoration.

Action 3.d. Develop a tax benefit program for landowners willing to retain adequate existing riparian buffers (e.g., Public Benefit Rating System) and share information with local governments Puget Sound-wide to maximize this program.

Action 3.e. Align steelhead priorities with open space priorities mapped and highlighted as "conservation needs" in the Puget Sound Regional Council's Regional Open Space Conservation Plan.

Strategy 4. Ensure and improve effectiveness of mitigation to offset impacts of development.

Action 4.a. Support on-site, in-kind mitigation when it is ecologically feasible and likely to succeed long-term.

Action 4.b. Consider off-site mitigation options, such as a mitigation bank or in-lieu fee mitigation, for restoring ecological function of habitat that supports steelhead.

Strategy 5. Improve federal and state highway maintenance and management to reduce impacts to steelhead.

Action 5.a. Treat or mitigate runoff from major bridges.

Action 5.b. Implement solutions once identified to steelhead mortality at Hood Canal Bridge and other locations where steelhead may be concentrated.

Action 5.c. Coordinate with Regional Transportation Councils and agencies to incorporate steelhead and salmon protection and recovery into long-range planning efforts.

Action 5.d. Determine feasibility of I- 5 and Hwy 101 improvements such as bridges at confined estuaries.

Action 5.e. Reduce crossings of steelhead tributaries and improve passage at existing crossings.

Action 5.f. Follow best management practices for road maintenance and management (e.g. Aquatic Habitat Guidelines by state and federal agencies.

Strategy 6. Improve county and city road maintenance and new road development.

Action 6.a. Counties to develop a long-term plan to accelerate fish passage barrier removal or improvements on county roads.

Action 6.b. Align County and City Public Works Capital Improvement Program priorities with steelhead recovery activities.

Action 6.c. Track highway expansions and new roads in steelhead habitat. Consultation should pay particular attention to steelhead cumulative impacts.

Action 6.d. Determine feasibility of I- 5 and Hwy 101 improvements such as bridges at confined estuaries.

Action 6.e. Reduce crossings of major steelhead tributaries and improve passage at existing crossings.

Action 6.f. Follow best management practices for road maintenance and management (e.g. Aquatic Habitat Guidelines by state and federal agencies.)

Strategy 7. Align infrastructure improvements with steelhead recovery at the federal, state and local level.

Action 7.a. Restore Public Works Trust Fund and include salmon habitat benefits when reforming the program.

Action 7.b. Use pollution load heat maps to identify areas with the greatest opportunity to address water quality.

Strategy 8. Consider climate change impacts in planning and permitting.

Action 8.a. Develop and implement plans to address an increased number of emergency permits for shoreline and property protection will be likely due to sea level rise, saltwater intrusion, storm surge, and high flows becoming more common.

Action 8.b. Develop climate change considerations in comprehensive planning by local governments to acquire at-risk parcels where they may benefit steelhead.

3.6 Pressure: Timber Management

Riparian forests in Puget Sound are largely isolated to headwater reaches of Puget Sound watersheds and are subject to short rotation periods. Timber management practices can affect steelhead habitat by limiting the recruitment of instream features (especially large wood), reducing shade by harvesting riparian trees (which moderates stream temperature), and by road construction (which increases fish passage barriers and delivers fine sediment). Deforestation has been associated with lower water tables and reduced stream flows. Without adequate riparian shade, stream temperatures in Puget Sound streams increase during summer months. As described in Section 3.2, Fish Passage Barriers at Road Crossings, fish blocking culverts still are pervasive on the landscape, although barriers have dramatically declined on forested landscapes due to the implementation of the state's Road Maintenance and Abandonment program. Roads also deliver fine sediment to streams, which is a source of redd and emergent fry mortality. Timber management has improved over the last several decades, but the adequacy of current riparian "buffers" (no-harvest zones) are in question and the adequacy of road management practices requires improved monitoring and potential adaptive management.

State and private forest management activities are largely governed by state regulations and federal Habitat Conservation Plans (HCPs). For the most part, these rules and plans are supportive of steelhead habitat and recovery. Especially on private forest lands, monitoring and adaptive management remain the main concern to adequately understand if those protection standards are being implemented and are successful. On federal lands, adequate funding to support restoration activities is needed, including for the repair of fish barriers and installation of instream restoration applications.

Strategies and Actions to Address Effects of Timber Management

Strategy 1. Develop and perform an independent and comprehensive review of forest practices rule compliance and effectiveness.

Action 1.a. Develop and implement an independent compliance monitoring review of the Forests and Fish rules for riparian buffers, sediment management, stream typing, and fish passage.

Action 1.b. Develop and implement effectiveness studies where compliance is understood to fully implement the adaptive management program.

Action 1.c. Implement strategic outcomes of the Subcommittee on Adaptive Management Program Improvements.

Strategy 2. Collaborate on water temperature monitoring and modeling.

Action 2.a. Improve understanding of water temperature dynamics in forest headwater riverscapes by identifying novel water monitoring and modeling efforts.

Action 2.b. Coordinate, integrate and expand existing water temperature monitoring efforts.

Action 2.c. Coordinate with Ecology to test assumptions about adequacy of forest practice rules to meet Clean Water Act criteria, specifically for temperature.

Strategy 3. Prioritize forest riparian restoration with Clean Water Act 303d listings.

Action 3.a. Identify and compare 303d listings with steelhead streams and the Type N streams above them, and make these data available.

Action 3.b. Using vegetation Change Detection tools* prioritize revegetation efforts using existing temperature models.

Action 3.c. Identify a list of the most impaired streams in each DIP and seek restoration agreements with landowners.

Strategy 4. Explore potential funding and financial incentives for discussions with timber companies.

Action 4.a. Collaborate with timber companies to explore longer rotation harvest practices to benefit steelhead while maintaining the timber company's bottom line.

Action 4.b. Explore successes and failures of Pacific Northwest Community Forest ventures and their ability to maintain or increase functional stream habitats.

Action 4.c. Develop, fund, and implement volunteer incentives related to harvest rotation cycles where benefits to steelhead may be realized more effectively and quickly.

Strategy 5. Improve accuracy of water type classifications to ensure steelhead habitats (per WAC 222-16-010).

Action 5.a. Develop methodologies for accurately delineating steelhead habitat that is less harmful to steelhead than electrofishing.

Action 5.b. Use LiDAR to improve watercourse delineation to improve habitat breaks.

Action 5.c. Require training and certification of water type surveyors and reviewers, especially where electrofishing is used.

Action 5.d. Require water type modification process for all ground-truthed mapping confirmations or modifications.

Action 5.e. Improve water type modification process to increase agency review and participation.

Strategy 6. Improve fish passage at artificial barriers (note: there is some duplication in this strategy with the culverts strategy).

Action 6.a. Assist landowners to ensure that Road Maintenance and Abandonment Plans (RMAPs) are completed to meet the 2021 time extension deadline.

Action 6.b. Repair remaining barriers that may have remained uncorrected due to incorrect determinations of steelhead habitat.

Action 6.c. Sampling compliance and repair programs to ensure that new roads do not feature new barriers or that non-barriers do not become barriers.

Action 6.d. Increase funding to support the Family Forest Fish Passage Program (FFFPP).

Strategy 7. Implement best science practices on other private forest protection needs.

Action 7.a. Review forest practice regulations for “20-acre exempt” protections (WAC 222-30-023) for steelhead. Develop recommendations for Forest Practices Board.

Action 7.b. Ensure that Washington State Department of Natural Resources (DNR) is using best available science on steelhead, steelhead habitats and possible threats when processing and approving Class IV special actions permits.

Action 7.c. Provide relevant jurisdictions with best available science for managing Class IV general permits.

Action 7.d. Identify all relevant entities and ensure compliance with conservation measures in HCPs throughout Puget Sound, and ensure they are adequately funded.

Strategy 8. Manage the Northwest Forest Plan (U.S. Forest Service [USFS] for federally managed forestlands).

Action 8.a. Fund ongoing USFS forest management planning and activities to manage forests for hydrologic and habitat forming benefits to steelhead.

Action 8.b. Increase funding for acquisitions within the USFS district boundaries to secure inholdings and ecologically sensitive areas.

3.7 Pressure: Water Withdrawals and Altered Flows

Steelhead require adequate stream flow to meet their life-history requirements. The high demand for water through residential, commercial, industrial and agricultural industries, and climate change effects, have decreased stream flows through time. Water withdrawals and flow modifications occur through several activities. Water withdrawals can occur through the exercise of a municipal, agricultural, industrial, commercial, and residential water right, either by diverting stream flows directly to drinking water facilities or by pumping groundwater which can have hydrologic connectivity to streams. Because some Puget Sound streams experience seasonal periods of extremely low flow due to water withdrawals for human consumption (domestic and municipal water use), summer rearing habitat has become limited in some streams. Altered flows also occur when stream flows are held back or accelerated artificially (usually with a dam) or are diverted and returned to the river at a downstream location.

Water withdrawals from streams require a water right issued by the Washington Department of Ecology. Groundwater withdrawals (wells) are exempted from water right requirements when use is less than 5,000 gallons per day. When many exempted wells occur within a hydrologically connected aquifer, stream flows are often diminished. A new state law (ESSB 6091) was recently passed to minimize and mitigate for the situation where wells reduced stream flows. However, it remains unclear how stream restoration mitigation that does not involve stream flow could be effective in mitigating for lost flow in those streams where flow limits steelhead production and abundance.

Strategies and Actions to Improve Instream Flows during Critical Periods

Strategy 1. Identify, protect, and preserve instream flows for steelhead.

- **Action 1.a.** Determine instream flows required for steelhead recovery in Puget Sound streams and rivers.
- **Action 1.b.** Ecology annually publish actual instream flows relative to recommended flows for steelhead.
- **Action 1.c.** Develop tools to locate areas where water diversions and withdrawals are impairing steelhead and catalog them, such as Instream Atlas for Puget Sound Steelhead.
- **Action 1.d.** Establish or revise Instream Flow rules in Puget Sound Water Resource Inventory Areas (WRIAs) to better protect steelhead.
- **Action 1.e.** Identify and protect instream flows required to meet state water quality standards established under authority of Clean Water Act.
- **Action 1.f.** Address instream flows requirements for steelhead under Watershed Planning and Management process established under (RCW 90.82).
- **Action 1.g.** Improve habitat-flow models (e.g., 2D flow modeling, bioenergetic models) for determining instream flows for steelhead.

Strategy 2. Maintain, restore, or improve instream flow by protecting tribal, state, and federal water rights by enforcing regulations and improving transparency, efficiency, and accountability.

- **Action 2.a.** Implement and enforce instream flows for steelhead once established.
- **Action 2.b.** Eliminate illegal surface water diversions by enforcing regulations.
- **Action 2.c.** Extinguish water rights if they are not used in 5 years.
- **Action 2.d.** Protect existing wetlands in aquifer recharge areas.
- **Action 2.e.** Set a limit (number of gallons per day) for domestic water use and stock watering use in over allocated basins.
- **Action 2.f.** Enforce or implement monitoring requirements for surface and groundwater diversions.
- **Action 2.**g. Evaluate the effects of the Hirst decision and the Washington State remedy (ESSB 6091).

Strategy 3. Develop and implement incentive programs to protect and restore instream flows for steelhead.

Action 3.a. Develop collaborative funding mechanisms to support willing irrigation districts and landowners in applying more efficient irrigation systems.

Action 3.b. Support and encourage irrigation districts to upgrade their efficiency and bank the saved rights into the Trust for Water Rights Program.

Action 3.c. Apply new funding under streamflow restoration law (ESSB 6091) toward restoring instream flows for steelhead, including acquiring senior water rights.

Strategy 4. Protect uplands to improve hydrological characteristics of watersheds; protect groundwater recharge areas to improve infiltration of precipitation and runoff into aquifers.

Action 4.a. Where Critical Area Ordinances (CAOs) have not adequately protected recharge areas, acquire transfer of development rights of key hydrologic importance.

Action 4.b. Determine the adequacy of timber harvest methods and their protection of natural hydrologic regimes.

Action 4.c. Add steelhead-specific recovery goals in the checklist of CAOs to include the protection of hyporheic areas from development pressures.

Action 4.d. Develop best management practices for stormwater management and enforce these actions in development strategies, especially to reduce peak flows and enhance base flows.

Action 4.e. Retrofit stormwater ditch runoff and other opportunities to reduce storm runoff impacts.

Action 4.f. Implement Low Impact Development for future development, and inside cities and UGAs to protect flows.

Action 4.g. Protect natural hydrologic processes and/or acquire land in floodplains for future levee setbacks.

Action 4.h. Protect forestlands and agriculture lands from conversion (minimize sale of agricultural land and tree farms to residential developers.

Action 4.i. Evaluate DNR Public Trust lands for hydrologic contributions for steelhead.

Action 4.j. Reintroduce beavers into areas where historic wetlands have been lost or diminished in function.

Strategy 5. Improve instream flow protections and water rights for fish on federal lands.

Action 5.a. Ensure steelhead and instream flow experts are part of evaluating project alternatives in SEPA/NEPA processes.

Action 5.b. Participate in EIS review of major water resources developments, including storage reservoirs and water diversions, on federal lands.

Action 5.c. Exercise Federal Reserve Water Rights on federal lands and Native American reservations for protecting and restoring instream flows.

Action 5.d. Establish instream flows to protect critical habitat for steelhead on federal lands.

Strategy 6. Through the Habitat Conservation Plan (HCP) process, provide long-term protections and conservation measures for steelhead instream flows.

Action 6.a. Ensure that instream flows for steelhead are considered in the development, review, and implementation of new HCPs.

Action 6.b. Review and engage in adaptive management plans for existing HCPs, particularly if any instream flow committees.

Strategy 7. Restore instream flows for steelhead in over-allocated watersheds.

Action 7.a. Acquire water rights in basins where instream flows are insufficient for steelhead.

Action 7.b. Facilitate water right transfers that result in increased channel flow.

Action 7.c. Encourage local governments and water districts to develop and implement water reuse and recovery strategies.

Action 7.d. Reclaim water at wastewater facilities to replace water diversions for golf courses, irrigation, and other appropriate uses.

Action 7.e. Reuse irrigation water, and use agricultural drainage water, to improve instream flows.

Action 7.f. Allocate or purchase reservoir storage to meet instream flow requirements for steelhead.

Action 7.g. Develop and market conservation programs that reduce water demand.

Strategy 8. Identify, develop, and fund habitat restoration projects that result in improved streams.

Action 8.a. Develop and fund habitat restoration projects that result in improved instream flows to streams and rivers.

Action 8.b. Increase access to beaver management resources, including beaver relocation programs, and hunting and fatal trapping prohibitions.

Action 8.c. Streamline Hydraulic Project Approval permits for pond levelers and beaver deceivers.

3.8 Pressure: Hatcheries ─ Ecological and Genetic Interactions between Hatchery and Natural-Origin Fish

Hatchery production of steelhead can be an effective tool to increase fish abundance for conservation and harvest. However, use of hatcheries also poses demographic, genetic, and ecological risks to natural steelhead. Hatcheries intended to aid steelhead conservation strategies are successful when they provide benefits that outweigh risks to recovery.

Successful hatcheries have three common characteristics that form the basis for the steelhead hatchery strategies and actions outlined below:

1. They are intentional. Successful program will have clearly stated descriptions of the hatchery’s purpose (conservation or harvest); the intended relationship with natural production (integrated or segregated); the population viability objectives (abundance, productivity, diversity, and spatial structure) they are intended to promote; and the tradeoffs associated with these objectives given the stage of recovery of the ecosystem.
2. They are accountable. They use the best available scientific information to minimize genetic and ecological stressors and demographic risks on potentially affected populations while maximizing benefits.
3. They adapt to new information and challenges.

Risks and benefits of hatchery steelhead production are best evaluated in the context of the purpose of the program. A common purpose related to steelhead recovery is conservation. The primary goal of steelhead conservation in Puget Sound is sustainable natural production of locally adapted fish throughout the accessible watersheds in the DPS (Hard et al 2015). Thus, to effectively achieve its goals, a conservation hatchery program must increase the abundance, productivity, spatial structure, and/or diversity of a natural-origin steelhead population. In an applied context, a conservation hatchery goal might be reintroducing fish to unoccupied habitat (Anderson et al. 2014), preventing the extinction of a unique genetic lineage until habitat restoration can support a self-sustaining natural population (Peters et al. 2014), providing a demographic abundance boost to cross a demographic threshold needed for population growth (Berejikian et al. 2008; Venditti et al. 2015; Berejikian and Van Doornik 2018), or amplifying a unique or underrepresented life-history trait. Where necessary to preserve or recover the DIP, these conservation programs would utilize local founding stocks, where available, and be operated in an integrated fashion, because these stocks are likely to be more effective in supplementing natural reproduction than non-local stocks that are genetically distinct from local populations, and integration should limit divergence from the natural genetic profile. In contrast, some hatchery programs have a different goal: to provide harvest opportunities. These harvest programs may be either integrated or segregated. Traditionally, steelhead hatchery programs in Puget Sound have segregated operations using hatchery stocks (Chambers Creek winters and Skamania summers) which have been selectively bred to have low levels of interbreeding with the natural populations with the added goal of not appreciably reducing the likelihood of survival and recovery of ESA-listed Puget Sound steelhead.

Interactions of hatchery and natural-origin steelhead pose different risks to abundance, productivity, genetic diversity and fitness of fish spawning in the natural environment depending on how hatcheries are operated. A growing body of scientific literature stemming from improved tools to assess parentage and other close genetic relationships on relative reproductive success (RRS) of hatchery and natural-origin salmonids suggests that strong and rapid declines in fitness of natural produced fish due to interactions with hatchery produced fish are possible (Araki et al. 2008; Christie et al. 2014). These studies have focused primarily on steelhead (*O. mykiss*), Chinook salmon (*O. tshawytscha*), Coho salmon (*O. kisutch*), and Atlantic salmon (*Salmo salar*). Limited but growing evidence suggests that steelhead may be more susceptible to genetic risk (i.e., domestication) posed by hatchery propagation than other species (Ford et al. 2016). Further, because selective regimes and mortality differ dramatically between natural and cultured populations, some genetic change cannot be avoided (Waples 1999). These changes are difficult to predict quantitatively because there may be considerable variation in RRS among species, populations, and habitats, as well as temporal variability owing to environmental change. Where uncertainty makes precise predictions difficult, precautionary strategies are appropriate for reducing unexpected risks and impacts.

Some of the genetic risk associated with hatchery programs can be reduced by choosing an appropriate broodstock strategy. As described above, two different choices are integrated and segregated broodstock management (Ford 2002; Currens and Busack 2004; Mobrand et al. 2005). The integrated strategy incorporates natural-origin steelhead into hatchery brood stock and allows some hatchery-origin steelhead to spawn and undergo selection in the wild with the intent of promoting greater local adaptation to the natural environment. The intent of integrated hatcheries is for hatchery broodstock and hatchery-origin fish produced by the hatchery to be as biologically similar to the native population as possible (e.g., Baskett and Waples 2013). Consequently, conservation hatcheries employ integrated broodstock management. By contrast, ideally, the segregated hatchery strategy is designed to minimize genetic interaction between hatchery-origin and natural-origin fish. In segregated hatcheries, mostly hatchery-origin fish are spawned in the hatchery, and hatchery and harvest management aims to minimize the number of hatchery-origin fish that spawn in the natural environment. Harvest-oriented hatchery programs commonly employ segregated broodstock management.

Examples of the segregated strategy are the programs that have used early winter-run steelhead (Chambers Creek stock) and Skamania Hatchery summer-run steelhead to provide harvest opportunities. In Puget Sound, early returning winter-run hatchery steelhead broodstocks are derived from a Chambers Creek population from southern Puget Sound, which was developed in the mid-20th century and has been highly domesticated for many generations to produce fast-growing, yearling smolts (Crawford 1979). Likewise, "Skamania" summer-run hatchery steelhead currently produced in Puget Sound are derived from the Washougal and Klickitat Rivers in the Columbia River basin, an out-of-DPS population (Crawford 1979). The Chambers Creek early returning winter-run steelhead were specifically excluded from the Puget Sound steelhead DPS because the long-term genetic effects of artificial selection and domestication have led to considerable divergence in life history (Myers et al. 2015). Similarly, Skamania summer-run hatchery steelhead were excluded from the DPS at listing because they did not originate from Puget Sound. These hatchery stocks generally show variable but low levels of gene flow resulting in high levels of segregation from natural populations, except where Skamania-origin steelhead have established natural populations from introduction above waterfalls in the Tolt River or colonization of available habitat in the North Fork Skykomish River. Because naturally produced, indigenous stocks of fish are the definitive unit in measuring population viability of the DPS, neither Chambers Creek early winter-run nor Skamania River summer-run hatchery programs can directly contribute to conservation and recovery of Puget Sound steelhead.

Appropriate sizing, rearing, and release of hatchery steelhead also reduces risk. Ecological interactions with natural-origin steelhead that reduce abundance or productivity because of the abundance, fish size, and release strategies of hatchery fish are a risk common to both segregated and integrated hatchery programs (see Kostow 2009). Once released from the hatchery, for example, juvenile steelhead might compete with natural-origin steelhead if they consume resources such as food and rearing territories, thereby reducing the resources available to natural-origin fish. Hatchery produced steelhead might prey on natural-origin steelhead, or other ESA-listed salmonids such as Chinook salmon, although recent studies have not revealed a strong predation risk (e.g., Sharpe et al. 2008). The time frame of competition and predation could be extended, and the effects magnified, if hatchery juveniles do not migrate rapidly downstream but rather rear in freshwater, extending the period they could interact with natural-origin fish. Finally, hatcheries may release large pulses of juveniles that can potentially attract avian, mammalian, and piscine predators that have learned to anticipate the releases.

Hatchery actions typically involve trade-offs between different population viability characteristics that change as the ecosystem changes or is restored. Acceptable trade-offs may also depend on the biological importance of the population in the recovery of the DPS. For example, for populations facing imminent threat of extinction, using hatcheries to maintain and increase abundance may come at the cost of reducing genetic diversity and short-term fitness. However, in watersheds where populations are more stable, the objective of integrated programs to release hatchery fish that are as ecologically and genetically similar as possible to natural-origin fish to promote better survival may also increase the potential for ecological interactions.

Table 3 describes the current hatchery programs where steelhead are produced in Puget Sound. For each program, it identifies the watershed it is located in, the hatchery program name and date for its Hatchery Genetic Management Plan (HGMP), steelhead population origin, species run or race, program purpose, hatchery operator, the HGMP release number, and the primary hatchery facility.

Table 3. Hatchery programs producing steelhead in Puget Sound. Programs shown in BOLD type are listed or proposed for listing as part of the DPS.

Steelhead major population group	Watershed	Hatchery program name, HGMP date (in parentheses), and listing status [listed or proposed for listing as part of the DPS shown in bold]	Steelhead population origin	Species run or race	Hatchery program type	Hatchery program purpose	Hatchery operator	HGMP release number	Primary facility
Northern Cascades	Nooksack	Kendall Creek Hatchery (July 2014)	Chambers Creek	Winter	Segregated	Harvest	WDFW	150,000	Kendall Creek Hatchery
Northern Cascades	Stillaguamish	Whitehorse Pond Program (draft 2014)	Skamania Hatchery	Summer	Segregated	Harvest	WDFW	70,000	Whitehorse Pond
Northern Cascades	Stillaguamish	Whitehorse Pond Program (July 2014)	Chambers Creek	Winter	Segregated	Harvest	WDFW	130,000	Whitehorse Pond
North Cascades	Snohomish/ Skykomish	Reiter Pond Program (draft 2013)	Skamania Hatchery	Summer	Segregated	Harvest	WDFW	130,000	Reiter Ponds
Northern Cascades	Snohomish/ Skykomish	Skykomish River Program (February 2016)	Chambers Creek	Winter	Segregated	Harvest	WDFW	140,000 27,600	Reiter Ponds Wallace Hatchery
Northern Cascades	Snohomish/ Snoqualmie	Tokul Creek Program (July 2014)	Chambers Creek	Winter	Segregated	Harvest	WDFW	74,000	Tokul Creek Hatchery
Northern Cascades	Green	Soos Creek Program (October 2015)	Skamania Hatchery	Summer	Segregated	Harvest	WDFW	50,000 50,000	Soos Creek Hatchery Icy Creek Pond
Northern Cascades	Green	Green River Program (October 2017)	Green River	Winter	Integrated recovery	Conservation	WDFW	23,000 15,000 17,000	Soos & Icy Creek Pond Soos & Flaming Geyser (Pond) Soos & Palmer Pond
Central and South Puget Sound	Green	Fish Restoration Facility (FRF) (July 2014)	Green River	Winter	Integrated Recovery	Conservation/ Harvest Augmentation	Muckleshoot Indian Tribe	350,000	FRF
Central and South Puget Sound	White	White River Program (June 2018)	White River	Winter	Integrated recovery	Conservation	Puyallup Tribe of Indians	60,000	Diru Creek Hatchery and upper river acclimation sites
Hood Canal and Strait of Juan de Fuca	Skokomish, Dewatto, Duckabush	Hood Canal Supplementation Project (April 2014)	Skokomish River & Hood Canal tributaries	Winter	Integrated recovery	Conservation	Long Live the Kings	42,000	McKernan Hatchery & Lilliwaup
Hood Canal and Strait of Juan de Fuca	North Fork Skokomish River	North Fork Skokomish River Program (draft April 2016)	Skokomish River	Winter	Integrated recovery	Conservation	Tacoma Power	15,000 (225 adults)	NF Skokomish Salmon Hatchery
Hood Canal and Strait of Juan de Fuca	Dungeness	Dungeness Program (July 2014)	Chambers Creek	Winter	Segregated	Harvest	WDFW	10,000	Dungeness Hatchery
Hood Canal and Strait of Juan de Fuca	Elwha	Lower Elwha Fish Hatchery (August 2012)	Elwha River	Winter	Integrated recovery	Conservation	Lower Elwha Klallam Tribe	175,000	Lower Elwha Hatchery

Strategies and Actions to Reduce Negative Effects and Improve the Conservation Benefits of Hatchery Programs

To ensure that benefits of hatchery programs outweigh potential risks and at least do not impede recovery, hatchery steelhead programs in Puget Sound should follow these basic strategies:

Strategy 1. Be Intentional in the purpose of the hatchery program.

Action 1.a. Ensure that each hatchery program has a clearly identified purpose and actions for the program are consistent with that purpose.

Action 1.b. Ensure that each hatchery program has clearly stated population viability objectives for abundance, productivity, diversity, and spatial structure and the objectives are consistent with the role of the population in recovery of the DPS.

Action 1.c. Where harvest is the purpose, harvest objectives reflect the contribution to specific fisheries and expected impacts on abundance, productivity, spatial structure and diversity of the natural population.

Action 1.d. Ensure that each hatchery population has implemented a broodstock strategy that minimizes risk to natural-origin populations.

- For all programs, selection of the appropriate broodstock source, for both the program objective and for the management of the associated risks, is paramount. Broodstock sources that cannot achieve the program objective for both benefits and risks should be phased out of use.
- For integrated strategies, the primary purpose is to reestablish or rebuild indigenous populations, although use of an integrated strategy for harvest may be possible when a segregated strategy is not workable and risks of the integrated strategy are understood and can be controlled.
- For integrated strategies, broodstock should be limited to local, indigenous populations.
- For segregated strategies, monitor gene flow and potential ecological interactions to ensure they do not constrain conservation objectives for the natural population.

Action 1.e. Ensure all hatchery programs have self-sustaining broodstocks and minimize impacts on natural-source populations while maximizing survival of hatchery fish consistent with conservation goals. To this end, natural-origin steelhead should be purposefully taken for broodstock only when

- the donor population is currently at or above the viable threshold and the collection would not impair its viability; or
- if the donor population is not currently viable but the sole objective of the current collection program is to enhance the viability or survival of the listed DPS; or
- if the donor population is shown with a high degree of confidence to be above critical threshold although not yet functioning at viable levels, and the collection will not appreciably slow the attainment of viable status for that population.

Action 1.f. Ensure that trade-offs among benefits and risks are appropriate for the population's stage of ecosystem recovery as ecosystem conditions change based on understanding of how the ecosystem is functioning from

- Monitoring habitat, including the quality and quantity of spawning areas, rearing areas, migratory corridors, and changing selection pressures on natural-origin populations, including other species;
- Monitoring population status and response to hatchery actions, such as gene flow, proportions of hatchery fish spawning in the natural environment, RRS, and phenotypic and life characteristics (size, age structure, fecundity, breeding sex ratios, phenology, and iteroparity); or
- Developing metrics, models, and thresholds for assessing trade-offs and transitioning between recovery stages.

Strategy 2. Be Accountable for reducing risk of hatchery programs on natural-origin steelhead.

Action 2.a. Ensure that management actions for integrated programs reduce the loss of natural-origin characteristics in hatchery-origin fish that can arise from broodstock collection, rearing, and release by

- Scaling hatchery programs based on habitat carrying capacities to keep the relative size of natural production as high as feasible to promote adaption to the natural environment and increase abundance and productivity without degrading genetic diversity; and

- Reducing impacts of returning adult hatchery-origin fish on natural-origin fish by controlling the proportions of hatchery fish spawning in the natural environment consistent with the natural population's biological significance and stage of recovery.

Action 2.b. Ensure that hatchery facilities are constructed and operated to use appropriate ecological, genetic, and demographic risk containment measures for handling adults, withdrawal of water for hatchery use, discharging effluents, and promoting floodplain function.

Action 2.c. Ensure that each hatchery program implements fish culture practices that avoid disease and parasite risks, including low rearing densities, adequate water supply, and appropriate food and feeding management.

Action 2.d. Ensure that fish cultural practices at each hatchery implement rearing strategies to induce smoltification and reduce residualism and precocial male maturation. These should consider

- Growth regimes that consider growth opportunity (temperature units from emergence to the spring smolt window) based on spawn timing and water temperatures; and
- Releasing smolts at age-1 for earlier spawning and warmer rearing temperatures, and age-2 smolts for later spawning and colder rearing temperatures, or a combined approach. Manipulating incubation temperatures and size sorting may be useful tools in this approach.

Action 2.e. Ensure that release strategies, such as volitional release, minimize ecological interactions and promote survival while achieving other objectives.

Strategy 3. Adapt to new information and challenges in the operation and management of hatcheries.

Action 3.a. Ensure that every hatchery program has a process for regularly reviewing its objectives and performance as new information becomes available

Action 3.b. Ensure that monitoring and evaluation processes are in place to assess the status of the population, the health of the watershed, and hatchery effectiveness.

Action 3.c. Ensure that the State, Tribes, and federal agencies prioritize research to improve understanding of factors affecting fitness and ecological interactions to promote solutions to potential problems.

Action 3.d. Ensure that hatchery programs adapt to the impacts of climate change by monitoring and managing stage-specific survival, growth, and reproduction.

Action 3.e. Discontinue or modify programs if risks outweigh benefits.

Additional details and explanations on these strategies may be found in Appendix 4 of this Plan.

3.9 Pressure: Harvest Pressures (including Selective Harvest) on Natural-Origin Fish

Ensuring fisheries are consistent with the survival and recovery of Puget Sound steelhead requires addressing direct and indirect fishery effects on the diversity, spatial structure, abundance, and productivity of steelhead populations. Steelhead fishery management traditionally focused on controlling the harvest of returning adults to meet spawner abundance objectives. While this remains essential, managers now recognize that fishery mortality during other life stages can affect population viability, and that fishery effects on other VSP parameters must also be carefully assessed and addressed. Selective harvest, for example, has been shown to reduce age at maturation in anadromous salmonids, with concomitant effects on size at age, fecundity, and potentially timing of adult return. For iteroparous steelhead, harvest levels that are too high may also reduce population productivity by constraining the proportion of repeat spawners. Sustainable harvest of steelhead should be sufficiently low to allow adequate numbers of large, old adults to spawn; to be nonselective with respect to return timing; and to trend towards historical levels of repeat spawning. In particular, given the importance of life-history diversity to the viability of steelhead populations, it is important that fisheries (consistent with habitat protection strategies) are conducted in a manner that maintains local adaptation and does not limit a population's ability to respond to natural selection.

NMFS' proposal to list Puget Sound steelhead[8] concluded that "Although overutilization for recreational purposes was a factor that contributed to the present decline of Puget Sound steelhead populations, we do not believe that overutilization is a factor limiting the viability of the Puget Sound steelhead DPS into the foreseeable future." The associated status review expressed concern, however, that "High harvest rates before the mid-1990s may have removed a substantial proportion of natural-origin summer-run and early returning/spawning natural-origin winter-run fish from many of these systems" (Good et al. 2005). Fisheries during November, December, and January, although directed at early returning hatchery-origin steelhead, may have had the unintended consequence of reducing the diversity of steelhead populations by placing an unsustainable harvest rate on the early returning or early spawning natural-origin steelhead.

The PSSTRT identified two additional diversity characteristics, iteroparity (repeat spawners) and the abundance of sympatric resident fish, which can be important contributors to the viability of Puget Sound steelhead populations (Hard et al. 2015). Modeling of the influence of iteroparity on steelhead demography (Hard et al. 2015) and a recent analysis of reproductive success in Hood River (Oregon) steelhead (Christie et al. 2018 PNAS) indicate that the frequency of repeat spawning in steelhead can have a substantial effect on individual fitness and population productivity. While the frequency of repeat spawners is affected by many factors, fisheries directed at returning adult spring-run Chinook or sockeye salmon, or other fisheries conducted when kelts are present, can reduce the potential for repeat spawners by reducing the number of steelhead that successfully return to marine waters. While the incidental impact to kelts from these fisheries may be relatively low (3 – 5% in the Skagit), the contribution of kelts to the reproductive success of steelhead may be meaningful (Hard et al. 2015). Freshwater fisheries directed at trout can inadvertently affect the viability of steelhead populations by reducing the abundance of the resident life-history form of *O. mykiss* which, under some conditions, can be a valuable genetic and demographic component of the anadromous population.

Limit 4 of NMFS 4(d) rule recognizes the breadth of direct and indirect effects of fisheries and describes the fundamental considerations for assessing proposed fishery management plans for consistency with the survival and recovery of listed species. The limit is structured around the importance of maintaining the biological diversity provided by populations within the DPS, and addresses the significant risk that fisheries could pose when natural-origin populations are below a critical threshold. A population not achieving the critical threshold is at a high risk of extinction over a short time period.

Limit 4 of NMFS 4(d) rule establishes three tiers with associated fishery management actions:

[8] 71 Federal Register 15666, 03/26/2006. Listing Endangered and Threatened Species and Designating Critical Habitat: 12–Month Finding on Petition to List Puget Sound Steelhead as an Endangered or Threatened Species under the Endangered Species Act

1. Population below Critical Threshold. Fisheries impacting populations that are functioning at or below the critical threshold should be managed to avoid or have negligible impact to the genetic and demographic risks facing the population and must be designed to permit the population's achievement of viable function, unless the plan demonstrates that the likelihood of survival and recovery of the entire ESU in the natural environment would not be appreciably reduced by greater risks to that individual population.
2. Population between Critical and Viable Threshold. For a population shown with a high degree of confidence to be above a critical level but not yet at a viable level, fishery management must not appreciably slow the population's achievement of viable function.
3. Populations at or above Viable Threshold. Fisheries impacting populations at or above the viable level must be designed to maintain the population or management unit at or above that level.

Strategies and Actions to Reduce Harvest Pressures on Natural-Origin Fish

The framework described above for limit 4 of NMFS 4(d) rule is encapsulated in the harvest strategy for the recovery plan, which is "Manage steelhead fisheries to allow harvest without jeopardizing or appreciably slow(ing) the population's achievement of viable function."

Actions to implement this strategy include addressing the criteria of limit 4 or 6 of NMFS 4(d) rule (50 CFR § 223.203(b)(4) and § 223.203(b)(6)) and ensuring the development of integrated "All-H" management. Consistent with the discussion above, the actions also identify three specific considerations important for Puget Sound steelhead: contributing to an increase in repeat spawners, restoring the diversity of run- and spawn-timing, and providing sufficient protection for juvenile migrant and resident *O. mykiss*.

Strategy 1. Coordinate harvest among all co-managers to ensure that the collective impacts to each population are consistent with recovery goals, and associated management plans and biological opinions.

Action 1.a. Continue to conduct harvest management in a manner consistent with limits 4 and 6 of the 4(d) rule.

Action 1.b. Consistent with Section 2.3, integrate the best available science and policy regarding habitat and harvest management.

Action 1.c. Co-managers will work to identify and implement ways that harvest can help maintain or increase the abundance and survival of repeat spawners (kelts), including managing stream fishing during steelhead, Chinook, Coho, Pink, and sockeye salmon harvest.

Action 1.d. Consistent with habitat protection strategies, develop and manage harvest plans to ensure adequate escapement and abundance of breeding adults and execute plans and actions in such a way that key aspects of phenotypic and genetic diversity are maintained or enhanced in the population throughout a watershed (i.e., minimizing the selectivity of fisheries). Examples of key diversity elements include the extent of run and spawn timing; spatial distribution; variability in size, age, and sex ratio of spawners; and the abundance and condition of kelts.

Action 1.e. Consistent with DIP goals, manage recreational fisheries to avoid or minimize negative effects to juvenile steelhead and rainbow trout.

3.10 Pressure: Early Marine Mortality

This section addresses a key limiting factor for steelhead survival and provides related strategies necessary to recover the species. Puget Sound steelhead early marine mortality is generally defined as mortality that occurs as steelhead smolts (juveniles) enter the marine environment and die during a short outmigration window though the Sound before entering the Pacific Ocean. Steelhead spend a few days to a few weeks migrating through the Puget Sound, and the mortality rates during this short period of their life history is critically high. Puget Sound steelhead marine survival rates are lower than for populations from other nearby regions, including for coastal Washington and Columbia River populations.

The high mortality rates currently observed in steelhead smolts migrating through Puget Sound towards the ocean represent a major bottleneck to the productivity and abundance of steelhead on a regional basis. These high mortality rates are unsustainable over the long term, since they are seriously impairing the VSP components of steelhead (especially productivity), and thus the recovery of this species in the Puget Sound steelhead DPS.

The Salish Sea Marine Survival Project set out to answer where and why high mortality exists in Puget Sound. Specific funding was provided by Washington State to examine steelhead mortality during the smolt outmigration and develop management actions to address the early marine mortality of Puget Sound steelhead. This research is part of a larger effort looking at high early marine morality in Puget Sound, the Strait of Georgia, and the Strait of Juan de Fuca that also includes Coho and Chinook salmon out-migrants. This multi-year, cross-boundary research effort is ongoing as of the development of this recovery plan, with some clear results pointing toward management solutions to test. The list of possible management strategies and actions are summarized below.

Appendix 3 of this Plan discusses an adaptive management approach to increasing early marine survival. The appendix includes an overview of the research methods and findings, and justifications for the proposed strategies. It provides a summary of the evidence for each hypothesis for high early marine mortality, ranging from direct mortality from predation to fish condition. See Appendix 3 to understand how, why, and where these management strategies and actions should be implemented and tested. It is also important to note that, as of the drafting of the Plan, the Salish Sea Marine Survival Project and assessment of the Hood Canal Bridge were still underway; the recommendations here reflect specific actions based on those findings, as well as best available science.

This section summarizes elements of adaptive managing and monitoring because this work is still in progress. Elements are repeated in other sections of the Plan, such as nearshore habitat restoration, hatchery management, research, and monitoring. Including the research and monitoring elements in this part of the Plan is important for implementation of the Plan and integration of adaptive management at the regional and local level. The order below does not imply a sequence for implementation of actions to be taken. Several strategies need further research before being implemented while others are specific to certain DIPs or MPGs.

Strategies and Actions to Reduce Early Marine Mortality and Predation

Strategy 1. Continue predation research and monitoring, with a focus on areas of greatest steelhead early marine mortality.

Action 1.a. Monitor steelhead early marine mortality rates, predation (e.g. diets, behavior), and other response variables for reactions to environmental change and before and after testing management strategies to assess effectiveness. Monitor later marine mortality for the same steelhead populations to test whether early marine, predation-based mortality is additive vs compensatory.[9] Use information to help determine whether, when, what, and where management actions should be fully implemented.

Action 1.b. Monitor the abundance of harbor seals and their distribution during the juvenile steelhead outmigration period. Continue to assess the trajectory of harbor seal population abundance and consider impacts such as the increasing presence of transient killer whales as a potential natural moderator of harbor seal population size.

Action 1.c. Continue to improve assessments of harbor seal predation rates on juvenile steelhead. Conduct studies on specific steelhead DIPs to estimate the impact of harbor seal predation on steelhead smolts in estuaries and in specific segments in Puget Sound during the smolt migration window. Acoustic telemetry and harbor seal scat analyses should be conducted in carefully coordinated studies to estimate predation rates from populations with estimated smolt abundance(s).

Strategy 2. Assess and test the effectiveness of specific actions to alter harbor seal behavior at locations associated with high steelhead mortality. Thoroughly assess whether predator distribution will be adequately altered and evaluate unexpected consequences.

Action 2.a. Identify and remove artificial haul-out sites in key areas while animals are not present.

Action 2.b. Consistent with the Marine Mammal Protection Act (MMPA), test acoustic deterrents or hazing of animals in mortality hotspots during the short steelhead outmigration window

Strategy 3. Implement regional actions to allow for testing the effectiveness of site-specific marine mammal management in support of steelhead recovery.

Action 3.a. Continue monitoring to determine whether marine mammal populations of concern are at optimum sustainable population sizes.

Action 3.b. Consistent with MMPA, identify "problem areas or animals" and experiment with non-lethal action (see Strategy 2).

Action 3.c. If warranted, work with Washington's congressional delegation to change requirements in the MMPA to allow for proactive and flexible management actions by the state.

Action 3.d. Specify the regulatory options in the MMPA for controlling specific marine mammals.

Action 3.e Track progress in the Columbia River pinniped management program and learn from results.

Action 3.f. Determine the feasibility and effectiveness of actions that reduce predator numbers, including wildlife contraception, relocation, and culling.

Strategies and Actions Related to Factors that may Lead to, Exacerbate, or Ameliorate Predation-based Mortality in Puget Sound

It may be more feasible and effective to address factors that may exacerbate or ameliorate predation-based mortality in certain populations and MPGs, as summarized below and further described in Appendix 3. We need to determine which of these factors to address based upon the specific predator, location of high out-migrating juvenile steelhead mortality, and specific steelhead populations affected. Factors include but may not be limited to buffer prey, human infrastructure, disease, contaminants, hatchery fish distribution, and genetic fitness, as described in Appendix 3.

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[9] Additive predation decreases survival in a prey population. Compensatory predation does not affect overall survival of a prey population and merely replaces or compensates for existing sources of mortality.

Strategy 4. Support efforts to recover or enhance the abundance of forage fish as buffer prey.

Action 4.a. Advocate for, fund and track progress to develop and test herring management strategies, such as increasing egg survival rates, reducing noise at spawning sites at key times, identifying herring predation hotspots, and improving habitat quality (see 1998 WDFW Forage Fish Management Plan and the update by the Salish Sea Pacific Herring Assessment and Management Strategy Team).

Action 4.b. Evaluate the benefits to steelhead of reducing commercial harvest of herring in Puget Sound.

Action 4.c. Fund and expedite acquisition, restoration, and protection of high-priority nearshore habitat for forage fish population spawning and rearing sites in Puget Sound.

Action 4.d. Implement site-specific actions, such as removing bulkheads/shoreline hardening at key forage fish sites, adding wrack to beaches, protecting and restoring submerged vegetation including eelgrass and kelp, and removing pilings. Explore beach nourishment options where infrastructure disconnects drift cells.

Strategy 5. Support efforts to recover or enhance the abundance of other prey historically important to harbor seals and other predators of concern (e.g. hake, cod, rockfish).

Action 5.a. Implement NMFS' rockfish recovery plans for Puget Sound/Georgia Basin.

Action 5.b. For other species not covered by recovery plans, work with NMFS, WDFW, and advocacy groups to identify and protect key habitats and populations.

Strategy 6. Address high steelhead mortality at the Hood Canal Bridge through structural modifications or through management approaches to facilitate steelhead passage or alter predator behavior during the steelhead outmigration period.

Action 6.a. Fund and complete the Hood Canal Bridge Assessment to isolate how bridge is leading to high steelhead mortality.

Action 6.b. Develop, test, and implement specific actions based on the results of the assessment.

Action 6.c. Continue research to further assess the extent of impact by human infrastructure on Puget Sound steelhead mortality.

Strategy 7. Determine if hatchery fish act as a predator attractant or buffer prey, or both, in relation to steelhead early marine survival.

Action 7.a. Determine the effectiveness of distributing the marine-entry timing of hatchery Chinook salmon (and possibly other species, such as Coho salmon), particularly in areas where hatchery Chinook and Coho salmon are of a size that attracts predators, in places that overlap with high steelhead early marine mortality. Assess the hatchery management, harvest, and natural-origin fish recovery implications to Chinook and Coho salmon of any action considered.

Action 7.b. Test and, if successful, implement different release strategies that attempt to increase distribution of marine entry timing.

Action 7.c. Test and, if successful, implement other manipulations to hatchery fish (photoperiod, water temperatures, feeding) that improve ability to increase distribution of marine entry timing.

Action 7.d. Assess whether increasing the abundance of similar-sized natural-origin or hatchery out-migrating juvenile Chinook and Coho salmon buffers predation and lowers steelhead smolt mortality. Consider that hatchery-based efforts may have a negative ramification in the context of potential pulse-abundance impacts (see above). Assess the hatchery management, harvest, and recovery implications to Chinook and Coho salmon of any action considered.

Action 7e. Continue research to further assess the pulse abundance and buffer prey hypotheses for hatchery fish impacts on steelhead early marine mortality and survival.

Action 7f. Determine whether pulse abundances of hatchery fish are affecting predator behavior and increasing predation on Puget Sound steelhead.

Action 7g. Consider mesocosm experiments that test the pulse abundance hypothesis in areas of high steelhead early marine mortality.

Strategy 8. Implement actions to address *Nanophyetus salmincola* in watersheds where the parasite is prevalent and at high enough intensities to influence the health and survival of out-migrating juvenile steelhead.

Action 8.a. Test the effectiveness of removing hatchery carcasses burdened with *N. salmincola* from nutrient enhancement efforts in problem watersheds.

Action 8.b. Filter or treat hatchery water supplies in rivers where *N. salmincola* is present.

Action 8.c. If water supplies cannot be treated, consider reducing or eliminating upstream passage of hatchery fish.

Action 8.d. Test the effectiveness of isolating *N. salmincola* hotspots and associated *juga* snail (intermediate host) colonies and employing actions to reduce the abundance of *Juga plicifera* snails.

Action 8.e. Determine the effectiveness of reducing juga snail abundance through habitat restoration, including variables such as water temperature, altered flow regimes, increased riparian vegetation to increase shade, and re-establishing historic gravel/cobble substrates that minimize bedrock and silt.

Strategy 9. Implement actions to identify and reduce/or eliminate contaminants suspected of affecting steelhead smolt condition.

Action 9.a. Reduce polybrominated diphenyl ethers (PBDEs) and other toxic chemicals in river basins with levels and sources known to impact steelhead.

Action 9.b. Assess other watersheds where contaminants may be of concern (e.g. Snohomish and Puyallup).

Action 9.c. Identify and implement actions to reduce contaminant loads in steelhead.

Strategy 10. Implement long-term monitoring protocol to continue to assess steelhead early marine mortality rates and distribution, and compare to freshwater and later ocean mortality.

Action 10.a. Select index streams for each major population group, taking into consideration where monitoring has or continues to occur.

Action 10.b. Fund maintenance of Puget Sound acoustic telemetry array to track migration patterns, survival rates, and locations of mortality.

Action 10.c. Continue to assess later marine mortality for the same steelhead populations to test whether early marine mortality is additive vs compensatory. Perform this monitoring in the context of tracking responses to environmental change and in the context of the other research considerations for specific factors affecting the early marine mortality of steelhead.

Action 10.d. Support efforts to improve monitoring and understanding of forage fish and other prey of historic importance (e.g., Pacific Hake and rockfish) to predators of concern.

3.11 Pressure: Climate Change

At various stages of their life cycle (Beechie et al. 2013), steelhead are predicted to be impacted by five climate change conditions:

1. warmer water temperatures,
2. higher peak flows,
3. lower base flows,
4. increased sediment, and
5. altered marine environment.

Recent climate models for Washington State and Puget Sound have consistently predicted wetter, warmer winters and hotter, drier summers. These changes are likely to affect water temperature, the magnitude and timing of low and peak flows, and other hydrologic variables including receding glaciers, shifts from basins being snow dominant to rain dominant, and increased sedimentation (Harvey et al. 2006; Isaak et al. 2012; Mauger et al. 2015; Montgomery 1996; Wenger et al. 2011; Wu et al. 2012). Wade et al. (2013; details below) predicted Puget Sound steelhead to be especially vulnerable to extreme low summer flows (up to 30 percent decreases between 2030 and 2059) and extreme high winter flows (up to 30 percent increases during the time period) under future climate change conditions. Water temperatures are expected to increase 1-2˚C during this time period. Even greater changes are expected by the end of the 21st century (Beechie et al. 2013). These changes are likely to impact adult steelhead river entry, pre-spawn mortality, spawning, egg incubation, and juvenile rearing of steelhead. Steelhead are especially vulnerable to these freshwater impacts due to their extended freshwater residency compared to other anadromous salmonids in Puget Sound. Summer steelhead are especially vulnerable to climate change because adults hold in streams and rivers during the summer and fall, and will be exposed to the warmest temperatures and lowest flows of the year.

Anticipated temperature increases in Puget Sound due to climate change are likely to move ambient stream temperatures closer to or above upper levels of tolerance thresholds for steelhead (Isaak et al. 2012; Wade et al. 2013; Wu et al. 2012). However, the elevation zone that provides optimal temperatures will shift upward with climate change, causing areas in the lower watershed to become less suitable, and areas in the upper watershed to become more suitable. Temperature increases will also impact the freshwater ecological community in which steelhead are a part, including their food web and potential predators (e.g., Kuehne et al. 2017; Lawrence et al. 2014; Rahel and Olden 2008; Sorte et al. 2013; Wade et al. 2013). Changes in stream flows, which are often harder to mitigate for than temperature changes (Wade et al. 2013), are likely to impact steelhead habitat availability, predation, food resources, and other conditions (Mantua et al. 2010; Tonkin et al. 2018) — except in river and stream reaches below storage reservoirs, where climate adaptation flows can be implemented in these reaches.

Wade et al. (2013) assessed whether steelhead across the Pacific Northwest were expected to be exposed to elevated temperatures and changes in flow at different life stages under future A1B carbon emissions scenario (IPCC 2007) climate conditions scenario for the years 2030–59. They modeled steelhead in nine Puget Sound rivers (Nooksack, Skagit, Sauk, Stillaguamish, Snohomish, Skykomish, Green, Puyallup, and Nisqually Rivers) and found that fish from two to five of the rivers were predicted to be exposed to very high temperatures during adult migration, spawning, and egg incubation, especially in lower-river areas. Fish in only one river (Snohomish River) were predicted to be exposed to very high temperatures during the rearing stage. However, steelhead in eight of the assessed rivers (all except the Puyallup River) were predicted to be exposed to greatly reduced flows during the summer (during rearing and migration) and, in all or parts of every system, high flows during migration and incubation.

Additionally, increasing ocean temperatures and shifting ocean conditions (including currents and offshore nutrient upwelling) due to climate change will likely impact the food web and ultimately the marine survival of steelhead. Recent early marine survival rates of several Puget Sound steelhead populations have been quite low (Moore et al. 2015 and M. Moore, NOAA Fisheries, unpublished data), and may be limiting the populations' productivity. A warming ocean is likely to further reduce marine survival of steelhead migrating from Puget Sound. These fish make extensive seasonal migrations across broad areas of the North Pacific Ocean. A recent study on tagged California steelhead suggests that the fish closely track preferred sea surface temperatures (and likely other conditions) during their marine migrations (Hayes et al. 2016). However, in certain cases steelhead have been documented remaining off the coast from their natal river and returning to the natal river just a few months after ocean entry. An increased and more wide-ranging prevalence of this life-history strategy may indicate thermally blocked marine migratory corridors or changing ocean conditions. Monitoring of steelhead abundance, spatial distributions in freshwater and the ocean, and life histories over time will help us to understand the impacts of climate change in both environments, and if and how the fish adapt to the environment.

A number of the recovery strategies and actions identified previously in this chapter to address pressures from residential, commercial and industrial development, timber management, transportation, water withdrawals, and other activities will also address impacts from climate change. In addition, we identify several climate adaptation strategies to be implemented by local watershed groups, planning groups, Puget Sound Partnership, WDFW, NMFS, and others, as appropriate, to address the impacts of climate change on steelhead largely through the lens of freshwater habitat protection and restoration. Climate adaptations for steelhead would seek to reduce the vulnerability of steelhead DIPs, and the ecosystems which they depend upon, to climate change impacts. As mentioned above, climate impacts will also affect the food web for steelhead in the Puget Sound (including prey and predators). This issue is largely addressed for early marine survival of steelhead in Puget Sound in Section 3.10. Continued research is critical to understanding the impacts of climate change on steelhead and their response to it. Addressing climate change and studying its impacts on steelhead are particularly important in a setting such as Puget Sound where the hydrology has been and will continue to be altered through land use conversions, increased impervious surfaces, and storm water pollution due to urbanization.

Strategies and Actions to Reduce Impacts of Climate Change

Strategy 1. By watershed, identify and prioritize climate change adaptation strategies and recovery actions that explicitly include climate change as a risk to steelhead.

> **Action 1.a.** Evaluate climate risk factors (stream temperature, hydrologic and sediment regimes).
>
> **Action 1.b.** Evaluate restoration actions under legacy, ongoing, and future climate change impacts by reach and sub-watershed to increase habitat diversity and resilience.
>
> **Action 1.c.** Identify and prioritize protection and acquisition strategies to reduce the risk to steelhead from climate change impacts (e.g., cool water refugia).

Strategy 2. Increase strategies or actions in other parts of the recovery plan that increase freshwater and fish connectivity, and thus increase life-history diversity, for populations and MPGs across Puget Sound.

> **Action 2.a**. Increase the number and scale of fish passage projects, particularly at key dams and culvert programs that open up habitat. Prioritize passage to higher elevation areas. At the watershed level, deprioritize passage to areas that may be too hot or have scour events not conducive for steelhead to survive.
>
> **Action 2.b**. Increase number and scale of floodplain connectivity projects, especially those associated with cold-water refuges, to provide refuge for steelhead during low flow and high flow events and provide hydrologic connections for flow and temperatures.

Action 2.c. Encourage habitat restoration projects that provide increased connectivity to groundwater and floodplain hyporheic zones. These projects will improve "vertical connectivity" (Beechie et al. 2013) that allows will help sustain base flows during dry periods. Prioritize these projects in basins especially vulnerable to low flows.

Strategy 3. Increase strategies and actions in other parts of the recovery plan that address stream temperatures and instream flows suitable for Puget Sound steelhead to maximize resiliency of aquatic systems to climate change.

Action 3.a. Identify and then prioritize high-resiliency sites for restoration in light of projected future climate changes. Identify and delineate cold water refuge areas from regional water temperature monitoring and climate change modeling efforts. Protection and restoration of these habitats will provide additional levels of resiliency to climate change for steelhead in the future. Encourage protection and restoration of these areas as part of state and federal habitat recovery funding (e.g., PCSRF, PSAR and SRFB grants). Focus local restoration efforts on groundwater contributions to stream flow and the creation of thermal refugia via hyporheic exchange.

Action 3.b. Seek input on estimating, developing, and maintaining appropriate instream flows (e.g., Donley et al. 2012) in streams from WDFW Water Science Team and WDOE Water Resources Program (for more details, see Water Withdrawals and Altered Flow section of the plan: Section 3.7).

Action 3.c. Consider water temperatures when addressing riparian buffer retention, mitigation, and restoration programs. Use models, such as NetMap, when selecting sites for riparian restoration to take into account solar input, aspect, and topography. Encourage restoration of riparian vegetation especially along streams that are susceptible to warming under climate change (e.g., as in Justice et al. 2017). Note that it may take several decades for riparian vegetation to mature to provide climate change resiliency benefits.

Action 3.d. Re-aggrading incised stream channels, using beaver dams and beaver dam analogs, can increase base flows. Additionally, water stored by beaver dams at stream's headwaters can increase flows during low-flow periods.

Action 3.e. To increase instream flows, work to increase irrigation efficiency (through programs like the Washington State Conservation Commission's Irrigation Efficiencies Grants Program) and promote the acquisition or change of water rights to keep more water instream during low flow periods (through programs such as the Washington Department of Ecology Trust Water Rights Program, Washington Water Trust, and the Trout Unlimited Washington Water Project).

Action 3.f. To reduce high peak stream flows, restore floodplain connectivity to push the water out onto higher ground, prevent storm water from draining directly into streams in urban areas, and prevent runoff from forest roads draining directly into streams.

Strategy 4. Incorporate climate change adaptations into other steelhead recovery strategies and actions where appropriate. Some examples include:

Action 4.a. Identify opportunities for using hydroelectric dams and major storage reservoirs to buffer increased hydrological and water temperature variability in downstream streams and rivers. Existing dams and storage reservoirs can be used to reduce peak flows during major flood events, and supplement base flows during dry periods. Cold water stored in major reservoirs can be used to reduce water temperatures in downstream mainstem areas when they exceed critical thresholds for steelhead.

Action 4.b. Encourage habitat restoration projects that provide increased resilience to climate change by providing "refuge habitats" during peak flow and low flow events. For example, side channel habitats will become increasingly important for protecting juvenile steelhead during peak flow events. Habitat projects that result in deep pools will help protect adult summer-run steelhead and juvenile steelhead during dry and warm periods.

Action 4.c. Incorporate predicted climate change effects in the culvert passage projects as recommended by Climate Impact Group (CIG), WDFW (https://wdfw.wa.gov/publications/01867/), and tribal culvert climate changes studies. Culverts should be appropriately sized to convey flows and sediment under future climate change conditions to provide long-term benefits to steelhead.

Action 4.d. Identify forest management practices, especially road and culvert best management practices, to address their increased sediment inputs, landslide risks, and impacts to flow expected under climate change.

Action 4.e. Identify forest management practices, including silvicultural and pest management, which reduce risks of wildfires in private, state, and federal forests. Increased forest fires resulting from climate change represent a major threat to steelhead populations in the forested headwater areas of the Puget Sound.

Strategy 5. At the MPG or population scale, use decision support tools available to prioritize and fund projects for both the 4-year work plan and annual funding rounds. All restoration projects submitted for funding should be required to demonstrate how they consider climate change and how they are designed to ensure, as much as possible, desired outcomes given future climate projections.

Action 5.a. Modify the Climate Adaptation Decision Framework developed by EcoAdapt and others to quantify a population's or watershed's climate vulnerabilities, including habitat suitability, connectivity, and food web shifts, of greatest risk to steelhead. With this information, develop strategies and actions to prioritize limited funding at the MPG or DIP scale.

Action 5.b. Address future impacts of climate change on freshwater habitat and steelhead using qualitative (e.g., Klein et al. 2017 - South Fork Nooksack River is an excellent example) and quantitative (e.g., WA DOE's temperature TMDL) assessments. Klein et al.'s (2017) qualitative assessment started by evaluating climate risk from temperature, hydrologic, and sediment regimes and then modeling the impacts of restoration strategies on future conditions.

Action 5.c. Use the Puget Sound Partnership tool: Planning for the Effects of Climate Change on Protection and Restoration Projects, which has been used for Chinook recovery, in designing restoration projects to accommodate future climate scenarios.

Strategy 6. Monitor steelhead abundance, productivity, diversity, and spatial scale to detect specific impacts of climate change.

Action 6.a. Work with partners, such as U.S. Geological Survey (USGS), to improve water temperature and flow monitoring in Puget Sound streams and rivers. Develop water temperature metrics that describe key life-stage specific sensitivities of steelhead to warming water temperatures that are predicted under climate change.

Action 6.b. Monitor age-class composition, growth, densities, and survival of juvenile steelhead in Puget Sound streams. Compare these juvenile abundance, age class structure, growth, and survival metrics in cold and warm streams to identify systems that are most vulnerable to climate change impacts, including those that support summer- as well as winter-run populations.

Action 6.c. Steelhead ocean age should be monitored so that if more steelhead are detected spending only a few months at sea and forgoing their ocean migration, scientists and managers can evaluate whether and how this is related to changing ocean conditions and connectivity to North Pacific waters.

3.12 Integrating Research, Monitoring, and Evaluations (RM&E)

Monitoring and research provide the fundamental information necessary to identify actions likely to improve steelhead population status, to measure the effectiveness of those actions, and to track progress towards recovery. In particular, long-term, annual estimates of adult abundance, adult age structure, and smolt abundance provide the data needed to monitor freshwater productivity and marine survival, essential information to understand trends abundance and predict the response to recovery actions. Unfortunately, such information is limited in Puget Sound relative to other species in this region (e.g., Chinook salmon) or steelhead in other regions (e.g., Interior Columbia basin). For example, in a recent analysis of steelhead marine survival, data were available from only three native populations in Puget Sound (Kendall et al. 2017); one was from a large river (Nisqually River) whereas the other two (Snow Creek and Big Beef Creek) are small creeks that are subsets of two different DIPs identified by Myers et al. (2015). Further, adult and juvenile abundance data for Puget Sound summer steelhead are nearly non-existent (WDFW 2018). Given the importance of large rivers to Puget Sound steelhead recovery, these are critical locations for improving our knowledge of the factors affecting population abundance and productivity.

An additional goal for research and monitoring is to improve our understanding of the factors affecting steelhead viability. The continued destruction of freshwater habitat is a primary cause for declining steelhead trends. Despite recent efforts to quantify habitat quality and landscape-scale human impacts on habitat (Beechie et al. 2017; NWIFC 2016), Puget Sound lacks a comprehensive long-term program to monitor the quality of salmon and steelhead habitat. Such a program is a high research priority. Focused research on topics such as the benefits afforded by habitat restoration, marine survival, hatchery and native-origin fish interactions, and climate change will help identify specific actions that have a high likelihood of benefitting steelhead viability and allow for adaptive management of the species. Fundamentally, it is important to enhance the resolution of information on these topics from broad generalizations (e.g., habitat restoration is good for steelhead) to specific actions (identifying restoration methods and locations that maximize the return on restoration investment). Finally, life-history diversity is a hallmark of steelhead biology, and there is a growing awareness that population and trait diversity are linked to population viability (e.g., Moore et al. 2014). Improving the quality of information on life-history traits such as run timing, spawn timing, size at age, iteroparity, and interactions with resident trout will help clarify linkages to population persistence, resilience, abundance and productivity. Knowledge gained through this research will help us focus our actions more effectively to reach recovery.

Strategies and Actions to Integrate Research, Monitoring, and Evaluations

Strategy 1. Significantly improve status and trends monitoring for estimation of steelhead freshwater productivity and marine survival (i.e., Fish In/Fish Out).

> **Action 1.a.** Establish and maintain long-term, annual monitoring of steelhead adult and kelt abundance, adult age structure, and smolt abundance and age in at least eight sites within Puget Sound: two in the Strait of Juan de Fuca and Hood Canal MPG, two in the Central and South Sound MPG and four in the North Cascades MPG. At least one site per MPG should be at the watershed scale of a large Puget Sound river. At least one of the eight sites should monitor a summer-run steelhead population where current monitoring efforts are sparse. Life table/Integral Projection Model analyses is valuable where these traits are feasible to monitor. All monitoring sites should meet or exceed Crawford and Rumsey's (2011) data quality guidelines.
>
> **Action 1.b.** Explore and expand alternative technologies for increasing accuracy and precision of adult abundance and life-stage-specific survival estimates, including SONAR and PIT tagging.

Strategy 2. Develop and maintain a long-term program to monitor the status and trends of steelhead habitat in Puget Sound.

> **Action 2.a.** Identify and track trends in habitat metrics associated with steelhead abundance, productivity, spatial distribution, and life-history diversity.

Strategy 3. Maintain and advance research programs intended to quantify the population viability benefits afforded by recovery actions.

Action 3.a. Support, maintain, and advance research designed to evaluate the effectiveness and population viability benefits afforded by habitat restoration and protection. The use of Intensively Monitored Watersheds has shown great promise in assessing the effectiveness of recovery actions and this model program should be expanded to include steelhead streams in each MPG.

Action 3.b. Support, maintain, and advance research designed to understand and address factors affecting steelhead marine survival.

Action 3.c. Support, maintain, and advance research designed to understand interactions between hatchery and native-origin steelhead, and assess the effectiveness of conservation hatchery programs.

Action 3.d. Predict climate change impacts to steelhead population viability and habitat suitability.

Strategy 4. Identify linkages between steelhead life-history diversity and population viability.

Action 4.a. Implement research and monitoring programs designed to improve our understanding of migration timing, spawn timing, iteroparity and interactions with resident *O mykiss*. These efforts will likely be linked to the monitoring activities of Action 1.a.

Action 4.b. Evaluate the degree to which life-history traits diversity enhances population productivity and confers resilience to uncertain environmental conditions.

Strategy 5. Implement long-term monitoring protocol to continue to assess steelhead early marine mortality rates and distribution, and compare to freshwater and later ocean mortality.

Action 5.a. Select index streams for each major population group, taking into consideration where monitoring has occurred or continues to occur.

Action 5.b. Fund maintenance of Puget Sound acoustic telemetry array to track migration patterns, survival rates, and locations of mortality.

Action 5.c. Continue to assess later marine mortality for the same steelhead populations to test whether early marine mortality is additive versus compensatory. Perform this monitoring in the context of tracking responses to environmental change, and in the context of the other research considerations for specific factors affecting the early marine mortality of steelhead.

Action 5.d. Support efforts to improve monitoring and understanding of forage fish and other prey of historic importance (e.g., Pacific Hake and rockfish) and predators of concern

4. Criteria for Delisting

This chapter describes how NMFS will determine whether recovery has been achieved and the species can be removed from the list of threatened and endangered species. Section 4.1 describes the ESA requirements for making a delisting determination and removing a species from the list, while Sections 4.2 and 4.3 discuss the two types of criteria (viability criteria and listing factors criteria) that NMFS will evaluate in making such a determination.

4.1 ESA Requirements

The ESA defines a "threatened species" as “any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.” When a “listed” species no longer meets this definition, NMFS can determine (based on relevant criteria) that ESA recovery has been achieved and remove the species from the list of threatened and endangered species — in other words “delist.”

The ESA requires that recovery plans; “…to the maximum extent practicable …, incorporate … objective, measurable criteria which, when met, would result in a determination in accordance with the provisions of the ESA that the species be removed from the Federal List of Endangered and Threatened Wildlife and Plants (50 CFR 17.11 and 17.12) …” NMFS can then use these criteria to determine if a species has achieved recovery (i.e., met recovery goals) and can then be removed from the list of threatened and endangered species — “delisted.”

In order to make a listing determination, NMFS applies two kinds of criteria. The first, *viability criteria* (Section 4.2), relate to the biological risk to the species. These viability criteria reflect the likelihood of persistence (probability of avoiding extinction over a specified time frame, typically 100 years) and the prospects for sustainability of the species (maintenance of its defining characteristics). The criteria assess a species’ viability in terms of its abundance, productivity, population spatial structure, and diversity (genetic, phenotypic, and demographic). The second set of criteria, the *listing factors criteria* (Section 4.3), are based on the five listing factors found in the ESA, section 4(a)(1), are affecting the species. The listing factors criteria address the human activities (pressures, or threats) that contributed to the decline in the status of the species and those that continue to impede recovery. The criteria for the five listing factors are discussed in Section 4.3 and constitute a major part of the framework for evaluating the status of the threats to the species. The listing factor criteria define the conditions under which the listing factors, or pressures, can be considered addressed or mitigated. Together, the viability criteria and listing factor criteria make up the “objective, measurable criteria” [hereinafter referred to as delisting criteria] required under section 4(f)(1)(B)(ii) for the delisting decision.

Criteria for Delisting

NMFS will remove the Puget Sound steelhead DPS from federal protection under the ESA when it determines that:

The species has achieved a biological status consistent with recovery, meaning the best available information indicates it has sufficient abundance, population growth rate, population spatial structure, and diversity to indicate it has met the biological recovery goals (see Section 4.2.2.1 for specific delisting metrics); and

Factors that led to ESA listing have been reduced or eliminated to the point where federal protection under the ESA is no longer needed, and there is reasonable certainty that the relevant regulatory mechanisms are adequate to protect Puget Sound steelhead viability (see Section 4.3 for specific delisting metrics).

Figure 9 shows how the recovery actions and research, monitoring, and evaluation (on the left) inform the analyses and assessments NMFS considers when making species delisting determinations. The analysis of the five listing factors is shown across the top. The viability assessments of the populations are shown to be aggregated to the left to the major population group level, which are aggregated at the species level. The role of adaptive management in the process is shown at the bottom of Figure 9. The scroll on the right shows that we will consider both the listing factor analysis and species viability assessment when we make a decision to list or delist a species.

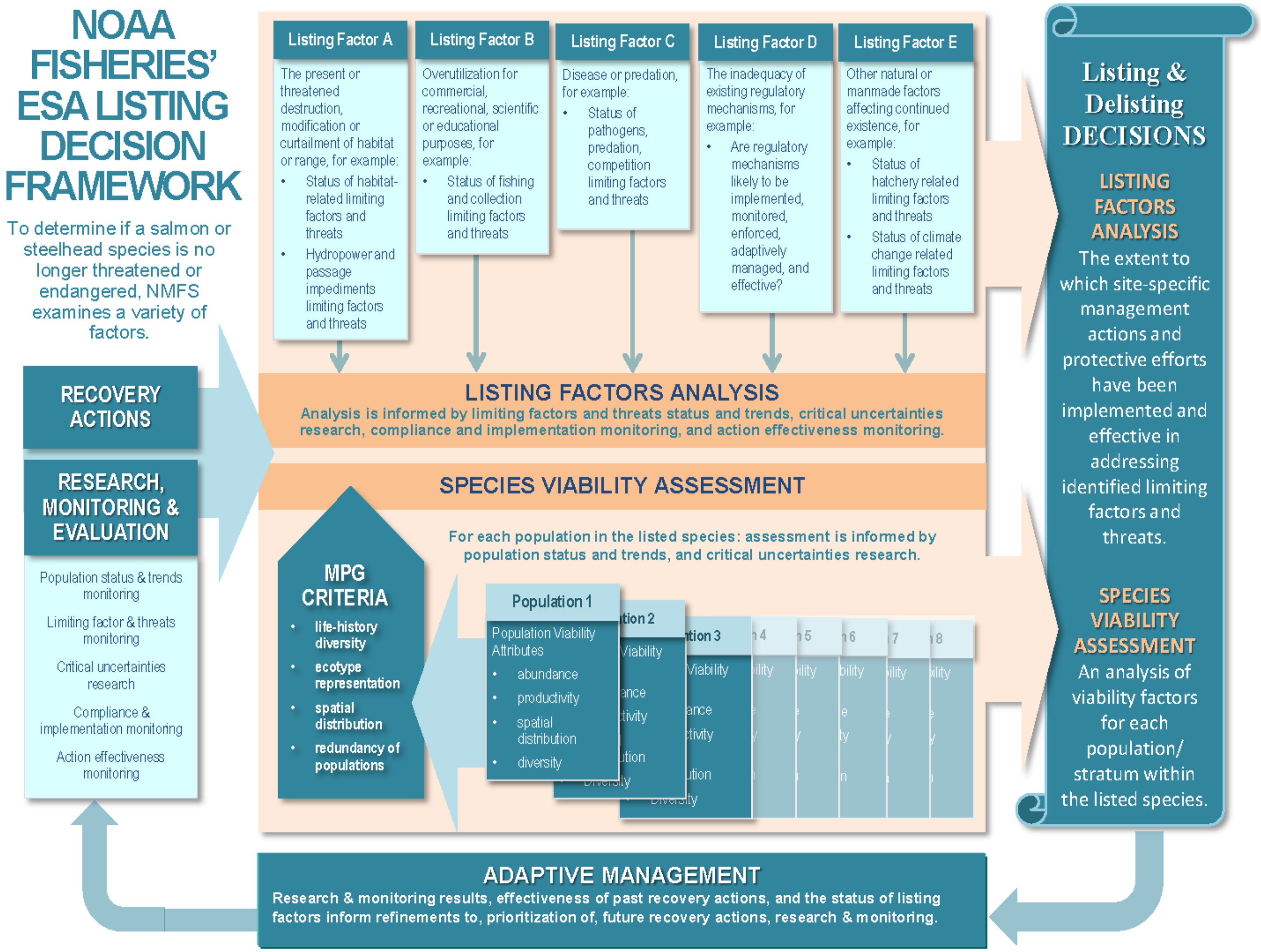

Figure 9. Flow diagram outlining the decision framework used by NMFS to assess the status of viability criteria and listing factor criteria.

4.2 Delisting Criteria for Puget Sound Steelhead Viability

The biological goals and delisting criteria apply to anadromous steelhead. The technical foundation for these criteria is the PSSTRT's Viability Criteria (Hard et al. 2015), and work done by the Puget Sound Steelhead Recovery Team and other sources that constitutes the best scientific and commercial information available. These criteria are established at the DPS level, but are based on consideration of criteria at the major population group and demographically independent population scales.

The over-arching viability criterion for Puget Sound steelhead is that the DPS "has a negligible risk of extinction due to threats from demographic variation, local environmental variation, and genetic diversity changes over a 100-year time frame" based on the status of the MPGs and DIPs, and supporting ecosystems (McElhany et al. 2000). A self-sustaining viable population has a negligible risk of extinction due to reasonably foreseeable changes in circumstances affecting its abundance, productivity, spatial structure, and diversity characteristics and achieves these characteristics without dependence upon artificial propagation. In future listing decisions, NMFS will consider the specific criteria presented in this section and other available information to determine if this criterion has been met.

As described in detail in Section 3.8, under appropriate circumstances, hatcheries can support salmonid recovery. Under the ESA, artificial propagation (hatchery programs) can be used to assist the recovery of Puget Sound steelhead, and a self-sustaining population may include artificially propagated fish. However, hatchery programs can pose risks to long-term recovery and a self-sustaining population must not be dependent upon propagation measures to achieve or maintain its viable characteristics. Artificial propagation may contribute to recovery, but is not a substitute for addressing the underlying factors (threats) causing or contributing to a species' decline.

4.2.1 Viable Salmonid Populations

Viability is a key concept within the context of the Endangered Species Act. NMFS' technical memorandum, *Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units,* (McElhany et al. 2000) provides guidance for assessing viability. It describes a Viable Salmonid Population as an independent population of any Pacific salmon or steelhead that has a negligible risk of extinction due to threats from demographic variation, local environmental variation, and genetic changes over a 100-year time frame (McElhany et al. 2000). NMFS scientists measure salmon recovery in terms of four parameters, called viable salmonid population (VSP) parameters that influence the biological viability and long-term resilience of a salmonid population: abundance, productivity, spatial structure, and diversity. These parameters are closely associated, such that improvements in one parameter typically cause, or are related to, improvements in another parameter. For example, improvements in productivity might depend on increased diversity or habitat quality, and be accompanied by increased abundance and spatial structure.

Abundance and Productivity

Abundance and productivity are linked. Populations with low productivity can still persist if they are sufficiently large, and small populations can persist if they are sufficiently productive. A viable population needs sufficient abundance to maintain genetic health and to respond to normal environmental variation, and sufficient productivity to enable the population to quickly rebound from periods of poor ocean conditions or freshwater perturbations.

Abundance is often expressed in terms of natural-origin spawners (adults on the spawning ground), measured over a time series, i.e., some number of years. The PSSTRT defined the measure of current abundance of all life stages of the species.

Productivity is a measure of the population growth rate over the entire life cycle. It is often measured as the average number of surviving offspring (recruits) per parent (spawner), or as the long term population growth rate (λ). Productivity is an indicator of the population's ability to sustain itself. Population-specific estimates of abundance and productivity are derived from time series of annual estimates, which are typically subject to a high degree of annual variability and sampling-induced uncertainties.

Spatial Structure and Diversity

A population's spatial structure is made up of both the geographic distribution of individuals in the population and the processes that generate that distribution (McElhany et al. 2000). Spatial structure refers to the amount of habitat available, the organization and connectivity of habitat patches, and the relatedness and exchange rates of adjacent populations. Diversity refers to the distribution of life-history, behavioral, and physiological traits within and among populations. Some of these traits are completely genetically based, while others, including nearly all morphological, behavioral, and life-history traits, vary as a result of a combination of genetic and environmental factors (McElhany et al. 2000). Spatial structure and diversity considerations are combined in the evaluation of a salmonid population's status because they are so interrelated. Spatial structure influences the viability of steelhead because populations with restricted distribution and few spawning areas are at a higher risk of extinction as a result of catastrophic environmental events, such as a landslide, fires, floods, or droughts than are populations with more widespread and complex spatial structures. A population with a complex spatial structure, including multiple spawning areas, experiences more natural exchange of gene flow and life-history characteristics.

Steelhead exhibit considerable diversity within and among populations, and this variation can have important effects on population viability (Boughton et al. 2007). There are three general reasons why biological diversity is important for population (and DPS) viability. First, it allows a population to use a wider array of habitats under changing environmental conditions than they could without it. Second, diversity protects against short-term spatial and temporal changes in the environment. Third, genetic diversity provides the raw material for adapting to long-term environmental change.

The precise role that diversity plays in salmonid population viability and the relationship of spatial processes to viability is incompletely known (Myers et al. 2015; Hard et al. 2015). Accordingly, the PSSTRT adopted the principle from McElhany et al. (2000) that historical spatial structure and diversity should be preserved on the assumption that historical, natural populations did survive many environmental changes and therefore must have had adequate spatial structure and diversity.

Figure 10 is from the PSSTRT viability criteria developed in Hard et al. (2015), and shows how these characteristics can be applied hierarchically to viability criteria from the DIP level, to the MPG level, to the Puget Sound steelhead DPS. At the DIP level, the framework describes criteria that are partitioned between persistence and sustainability factors related to VSP components. For example, for both winter- and summer-run life histories, the framework considers spawner abundance, productivity, occupancy and fish density in suitable habitat by adults and juveniles, frequency of iteroparity, and sources of human-induced mortality as factors that primarily influence demography and, therefore, DIP persistence. Effective population size, influence of hatchery fish (both genetic and ecological impacts), age variation in spawners, and variation in spawn timing as factors that primarily influence diversity and, therefore, population sustainability.

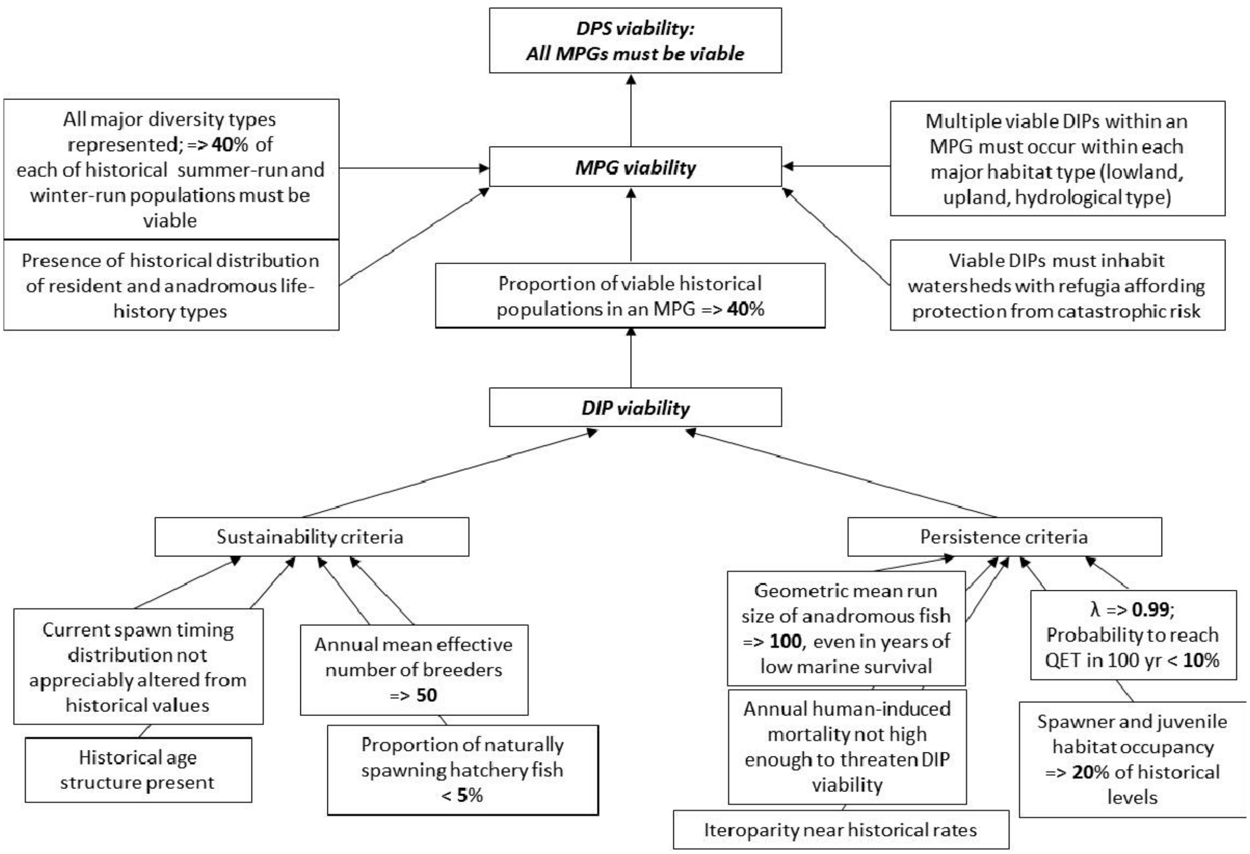

Figure 10. The Puget Sound Steelhead Technical Recovery Team's recommended viability criteria for the steelhead DPS. The chart shows how DIPs are aggregated to MPGs, and then to the larger DPS. See also Hard et al. 2015, Figure 56.

4.2.2 DPS Viability Criteria

NMFS staff and the Puget Sound Steelhead Recovery Team (including the PSSTRT chair and members) modified the PSSTRT viability criteria to produce the viability criteria for Puget Sound steelhead, as described below.

4.2.2.1 DPS-Level Viability

- All three MPGs must be viable.
  This criterion is based on a PSSTRT Viability Criterion (see Hard et al. 2015). The three MPGs differ substantially in key biological and habitat characteristics that contribute in distinct ways to the overall viability, diversity and spatial structure of the DPS.
- There must be sufficient data available for NMFS to determine that each MPG is viable.

4.2.2.2 MPG-Level Viability

This sub-section presents (1) specific criteria required for MPG viability, (2) specific DIPs needed for viability in each of the three MPGs, and (3) additional attributes that contribute to steelhead viability at the MPG level.

1) Specific criteria required for MPG viability

- At least 50 percent of steelhead populations in the MPG achieve viability.
- Natural production of steelhead from tributaries to Puget Sound that are not identified in any of the 32 identified populations provides sufficient ecological diversity and productivity to support DPS-wide recovery.
- In addition to the minimum number of viable DIPs (50%) required above, all DIPs in the MPG must achieve an average MPG-level viability that is equivalent to or greater than the geometric mean (averaged over all the DIPs in the MPG) viability score of at least 2.2 using the 1–3 scale for individual DIPs described under the DIP viability discussion in the PSSTRT Viability Criteria document (Hard et al. 2015). This criterion is intended to ensure that MPG viability is not measured (and achieved) solely by the strongest DIPs, but also by other populations that are sufficiently healthy to achieve MPG-wide resilience. An alternative evaluation method to that in Hard et al. (2015) may be developed and used to assess MPG viability.

2) Specific DIPs in each of the three MPGs must be viable

<u>Central and South Puget Sound MPG</u>
Four of the eight DIPs must be viable. The four DIPs described below must be viable to meet this criterion:

- Green River Winter-Run;
- Nisqually River Winter-Run;
- Puyallup/Carbon Rivers Winter-Run, or the White River Winter-Run; and
- At least one additional DIP from this MPG: Cedar River, North Lake Washington/Sammamish Tributaries, South Puget Sound Tributaries, or East Kitsap Peninsula Tributaries.

  <u>Rationale:</u> Steelhead inhabiting the Green, Puyallup and Nisqually River watersheds currently represent the core extant steelhead populations and these watersheds contain important diversity of stream habitats in the MPG.

Figure 11 shows the Central and South Puget Sound MPG and the DIPs that must be viable to support DPS delisting.

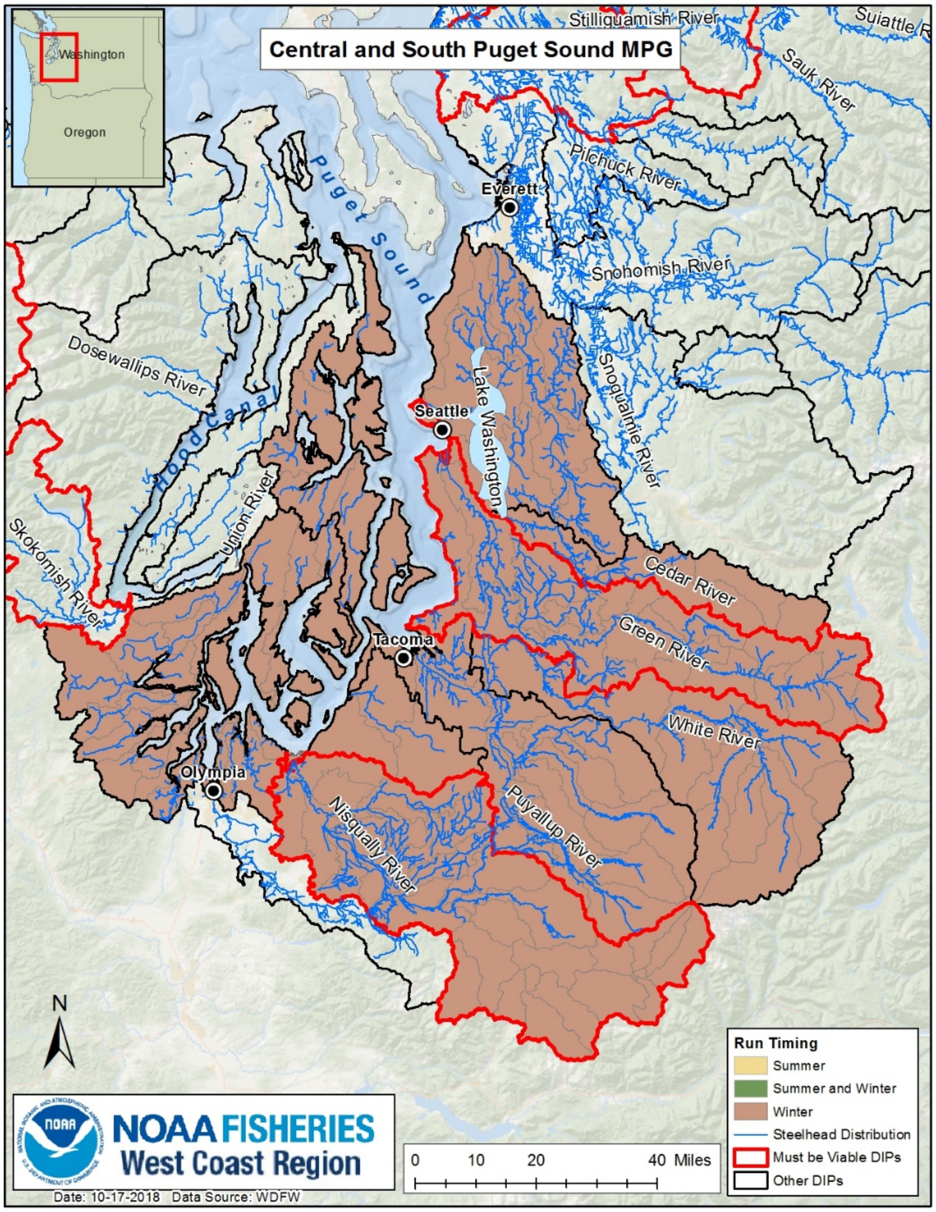

Figure 11. Central and South Puget Sound MPG and DIPs that must be viable to support DPS delisting.

<u>Hood Canal and Strait of Juan de Fuca MPG</u>

Four of the eight DIPs must be viable. The four DIPs described below must be viable to meet this criterion:

- Elwha River Winter/Summer-Run;
- Skokomish River Winter-Run;
- One from the remaining Hood Canal populations: West Hood Canal Tributaries Winter-Run, East Hood Canal Tributaries Winter-Run, or South Hood Canal Tributaries Winter-Run; and
- One from the remaining Strait of Juan de Fuca populations: Dungeness Winter-Run, Strait of Juan de Fuca Tributaries Winter-Run, or Sequim/Discovery Bay Tributaries Winter-Run.

Rationale: The Elwha and Skokomish Rivers are the two largest single watersheds in the MPG and bracket the geographic extent of the MPG. Furthermore, both Elwha and Skokomish populations have recently exhibited summer-run life histories, although the Dungeness River population was the only summer/winter run in this MPG recognized by the PSTRT in Hard et al. (2015). Two additional populations — one population from the Strait of Juan de Fuca area and one population from the Hood Canal area — are needed for a viable MPG to maximize geographic spread and habitat diversity.

Figure 12 shows the Hood Canal and Strait of Juan de Fuca MPG and the DIPs that must be viable to support DPS delisting.

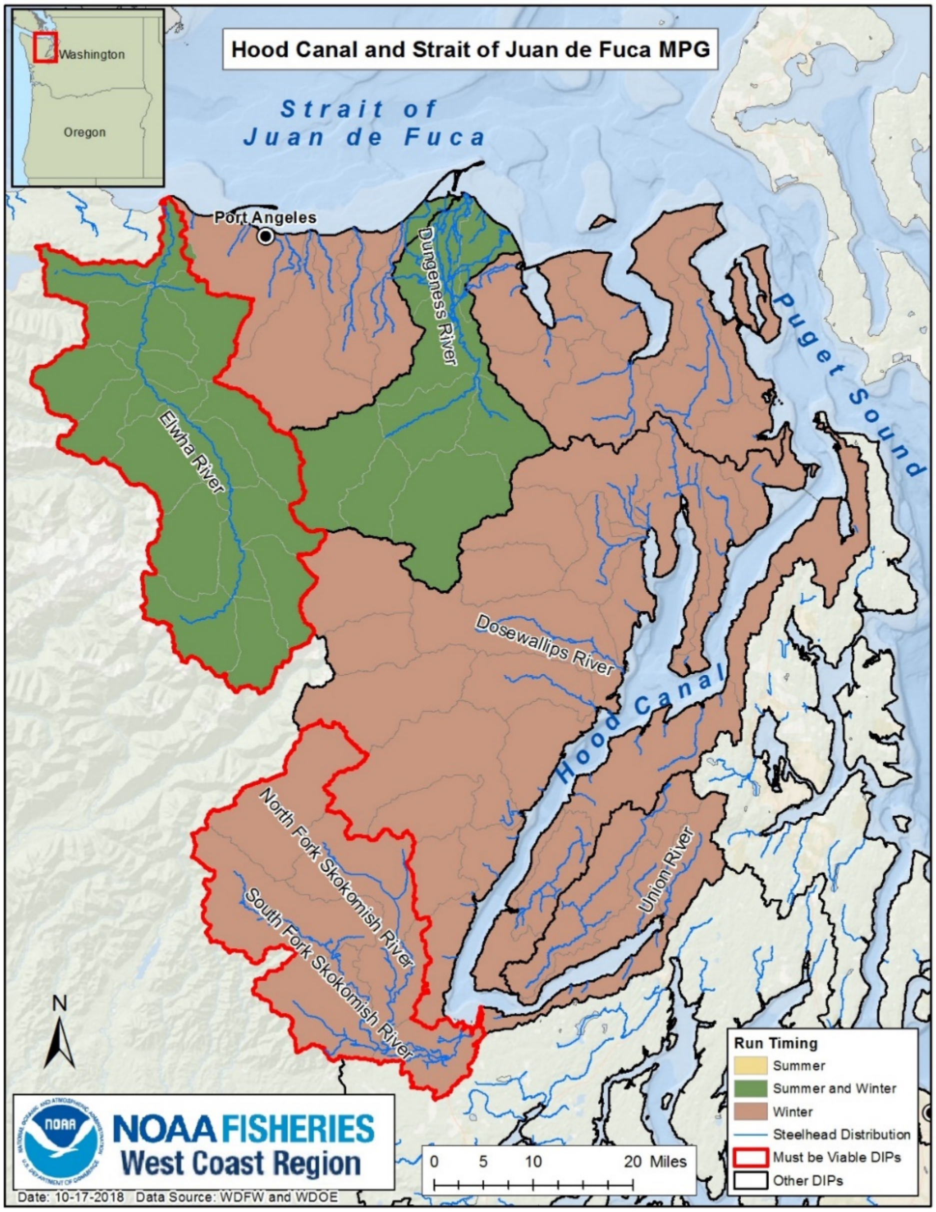

Figure 12. Hood Canal and Strait of Juan de Fuca MPG and DIPs that must be viable to support DPS delisting.

North Cascades MPG:
Eight of the sixteen DIPs must be viable. The eight DIPs described below must be viable to meet this criterion:

- Of the eleven DIPs with winter or winter/summer runs, five must be viable:
  - One from the Nooksack River Winter-Run;
  - One from the Stillaguamish River Winter-Run;
  - One from the Skagit River (either the Skagit River Summer-Run and Winter-Run or the Sauk River Summer-Run and Winter-Run);
  - One from the Snohomish River watershed (Pilchuck, Snoqualmie, or Snohomish/Skykomish River Winter-Run); and
  - One other winter or summer/winter run from the MPG at large.

  Rationale: There are four major watersheds in this MPG; one viable population from each helps ensure geographic spread and habitat diversity within core extant steelhead habitat.

- Of the five summer-run DIPs in this MPG, three must be viable representing in each of the three major watersheds containing summer-run populations (Nooksack, Stillaguamish, Snohomish Rivers)
  - South Fork Nooksack River Summer-Run;
  - One DIP from the Stillaguamish River (Deer Creek Summer-Run or Canyon Creek Summer-Run); and
  - One DIP from the Snohomish River (Tolt River Summer-Run or North Fork Skykomish River Summer-Run).

  Rationale: Ensuring that the viable summer-run populations do not all come from the same watershed reduces catastrophic risk and increases habitat/life-history diversity.

Figure 13 shows the North Cascades MPG and the DIPs that must be viable to support DPS delisting.

3) Additional Attributes — characteristics associated with a viable MPG

- All major diversity and spatial structure conditions are represented, based on the following considerations:
  - Populations are distributed geographically throughout each MPG to reduce risk of catastrophic extirpation;
  - Diverse habitat types are present within each MPG (one example is lower elevation/gradient watersheds characterized by a rain-dominated hydrograph and higher elevation/gradient watersheds characterized by a snow-influenced hydrograph);
  - Life-history diversity is represented within each MPG (e.g., summer-run and winter-run life-history types);
  - The summer-run life-history form is relatively rare within the DPS; MPGs with a population contiguously identified as “summer/winter-run” should have at least one viable “summer/winter-run” population.

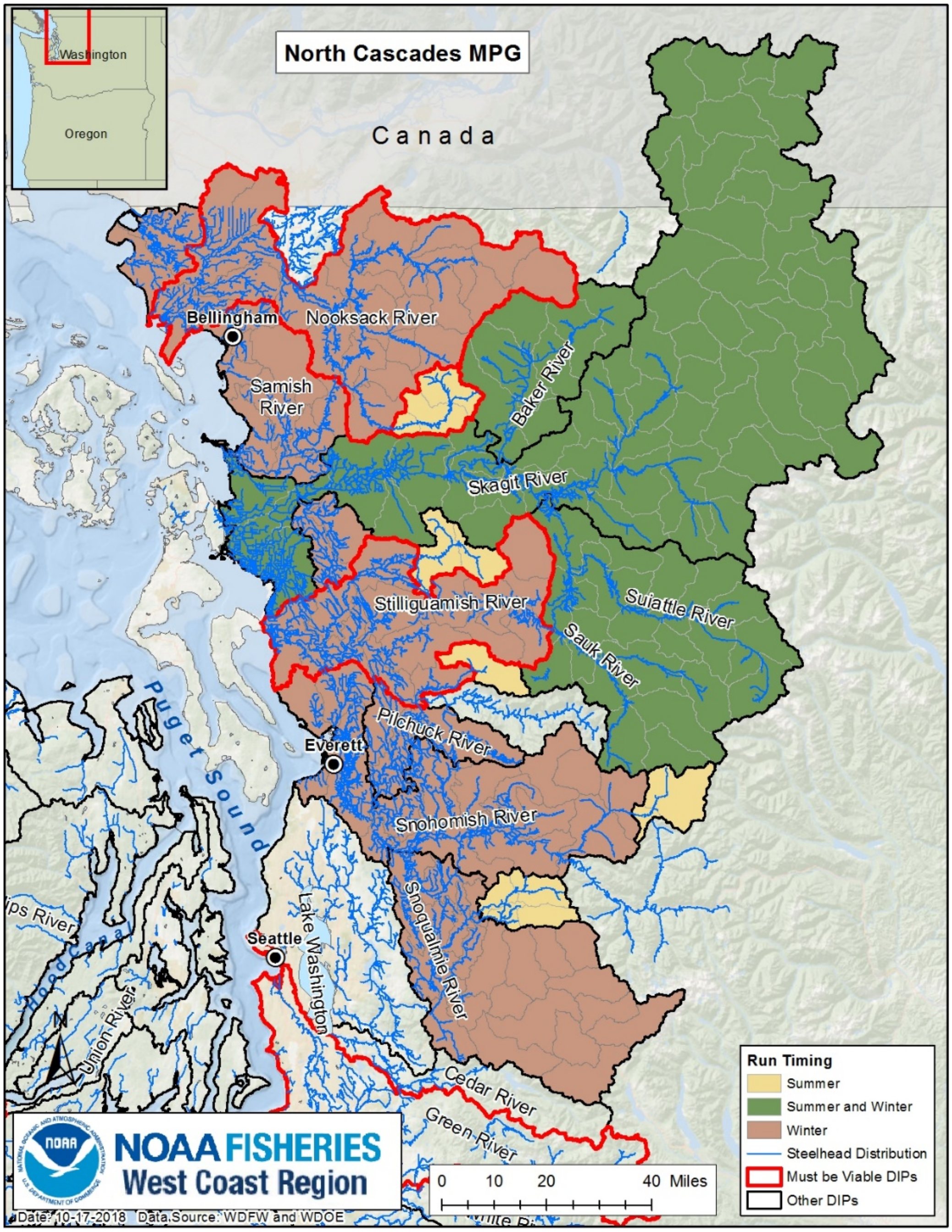

Figure 13. North Cascades MPG and DIPs that must be viable to support DPS delisting.

4.2.2.3 Demographically Independent Population (DIP) Level Viability

The goal of ESA section 4(f) recovery plans is achieve the conservation and survival of the listed species. To facilitate progress toward that goal, population-level goals may be included in a recovery plan. However, NMFS recognizes the challenges associated with describing exact thresholds for each DIP (i.e., single population goals), given the fact that recovery goals could be achieved by multiple scenarios, and abundance and productivity thresholds are interrelated.

Therefore, we employ planning targets which include measurable criteria for abundance and productivity. In other words, by describing ranges of targets for objective and measurable criteria, we are allowing for recovery scenarios that include tradeoffs between criteria. For example, abundance thresholds for recovery can be lower when productivity is consistently higher, and abundance thresholds can be relatively high when productivity is consistently low. This sub-section presents criteria (requirements) for DIP viability.

Approach to Abundance and Productivity Planning Targets and Ranges
Following the policy precedent established with Puget Sound Chinook salmon (NMFS 2006), we have established a range of abundance and productivity planning targets for Puget Sound steelhead populations. These planning targets are a range of paired abundance and productivity (recruits per spawner) values in which the upper end of the abundance range, paired with a low (replacement) productivity, is anchored to an estimate of 70 percent of historical abundance. Conversely, lower abundances consistent with recovery are paired with higher productivity values. The recovery target of 70 percent of historical abundance is based on an evaluation of stock-recruit productivity and capacity under properly functioning conditions, expressed as a proportion of historical conditions, derived from Ecosystem Diagnosis Treatment modeling in the Puget Sound Chinook salmon recovery plan. For Puget Sound steelhead, the estimated ratio of properly functioning to historical conditions typically ranges from 60-75 percent. The ratio of properly functioning to historical conditions for Puget Sound Chinook salmon, when applied to the estimates of historical steelhead abundance, provides abundance goals for recovery that combine available steelhead information with an established policy precedent (see Appendix 2 for details).

Historical Abundance Estimates
We used historical commercial fisheries catch data circa 1895 (Wilcox 1898), previously analyzed by Hard et al. (2007), to estimate historic abundance of each of the 32 demographically independent populations of Puget Sound steelhead (Myers et al. 2015). Hard et al. (2007) estimated a total abundance of adult steelhead of 327,592 – 545,987, assuming a 30 – 50 percent harvest rate and approximately 12 lbs. per fish. We used the midpoint of this range (N = 436,970 adult steelhead), and allocated total abundance to the 32 constituent populations based on proportional estimates of historical habitat availability in linear stream km. The historical habitat estimates, shown in Table 4, were initially generated from an intrinsic potential model of steelhead habitat (see Hard et al. 2015), and subsequently modified based on feedback from steelhead biologists in a series of meetings throughout Puget Sound. Appendix 2 includes additional information about aggregating DIPs and local recovery efforts.

Although Gayeski et al. (2011) also estimated historical abundance of Puget Sound steelhead based on this same 1895 catch data, we used the Hard et al. (2007) estimates for three reasons. First, Hard et al. (2007) employed a relatively simple analysis using arithmetic, which in our appraisal, matched the resolution and precision of the historical fishery data. Second, Gayeski et al. (2011) likely underestimated populations outside the Nooksack, Stillaguamish, Skagit and Snohomish Rivers, particularly in central and southern Puget Sound. Finally, when presented with our initial recovery goals, technical-policy groups were more comfortable with the lower numbers of the Hard et al. (2007) estimates rather than the higher numbers of the Gayeski et al. (2011) estimates.

We suspect that our methods overestimated the historical steelhead abundance of populations composed of many small independent streams relative to those in larger rivers. Our estimates of historical habitat availability weighted all streams equally, irrespective of habitat attributes such as stream size or gradient. Populations that are composed of many independent streams covering a large geographic area yielded big estimates of total linear stream kilometer, but these streams may not have been sufficiently large in size to support highly abundant steelhead populations. Notable examples include the North Lake Washington, East Kitsap Peninsula, South Puget Sound, Strait of Juan de Fuca, Discovery Bay, East Hood Canal, West Hood Canal, and South Hood Canal DIPs.

Recovery Goals as Productivity Curves
In order to establish the abundance and productivity curves, the 70 percent historical abundance estimates were set as the equilibrium point (S_0) on the stock-recruit curve where the population is neither increasing nor decreasing. Figure 14 shows this stock-recruit curve. We used the following form of the Beverton-Holt (1957) equation:

$$S = \frac{aS}{1+\frac{a}{b}S} \qquad \text{Equation 1}$$

Where *S* is the number of adult spawners, *R* is the number of adult recruits, *a* is the intrinsic productivity, and *b* is capacity. To estimate *a*, we used Buehrens' (2017) hierarchical analysis of spawner to smolt data from 15 populations of steelhead in western Washington, estimating an *a* value of 110. Assuming a 5 percent smolt to adult return rate, which is likely higher than current values (Kendall et al. 2017) but plausibly attainable given investment in recovery actions, we used an adult to adult *a* value of 5.5 (110 * 0.05 = 5.5). At the equilibrium point, S = R, one can solve for *b* given S_0 and *a*.

The high abundance / low productivity end of the recovery planning target range was set at S_0, the point where the stock-recruit curve crosses the replacement line, as illustrated in Figure 14. The low abundance / high productivity end of the recovery target range was set at the point of maximum productivity, also known as the point of maximum sustainable yield (S_{MSY}). S_{MSY} was calculated based on the approach of Hilborn and Walters (1992), where

$$b = \frac{aS_0}{a-1} \qquad \text{Equation 2}$$

We rounded the recovery goal abundance targets to the nearest 100 fish.

$$S_{MSY} = b\sqrt{\frac{1}{a}} - \frac{b}{a} \qquad \text{Equation 3}$$

For example, given a 70 percent historic abundance estimate for the Stillaguamish River winter-run population of 23,400 (Table 5), this yields a Beverton-Holt *b* value of 28,600. The low productivity (R/S = 1.0) / high abundance recovery goal is 23,400 adult steelhead, and the high productivity (R/S = 2.35) / low abundance recovery goal is 7,000. In Figure 14, these productivity estimates are shown below the curve. Similar calculations were made for each DIP in the Puget Sound steelhead DPS and are identified in Tables 5 and 6.

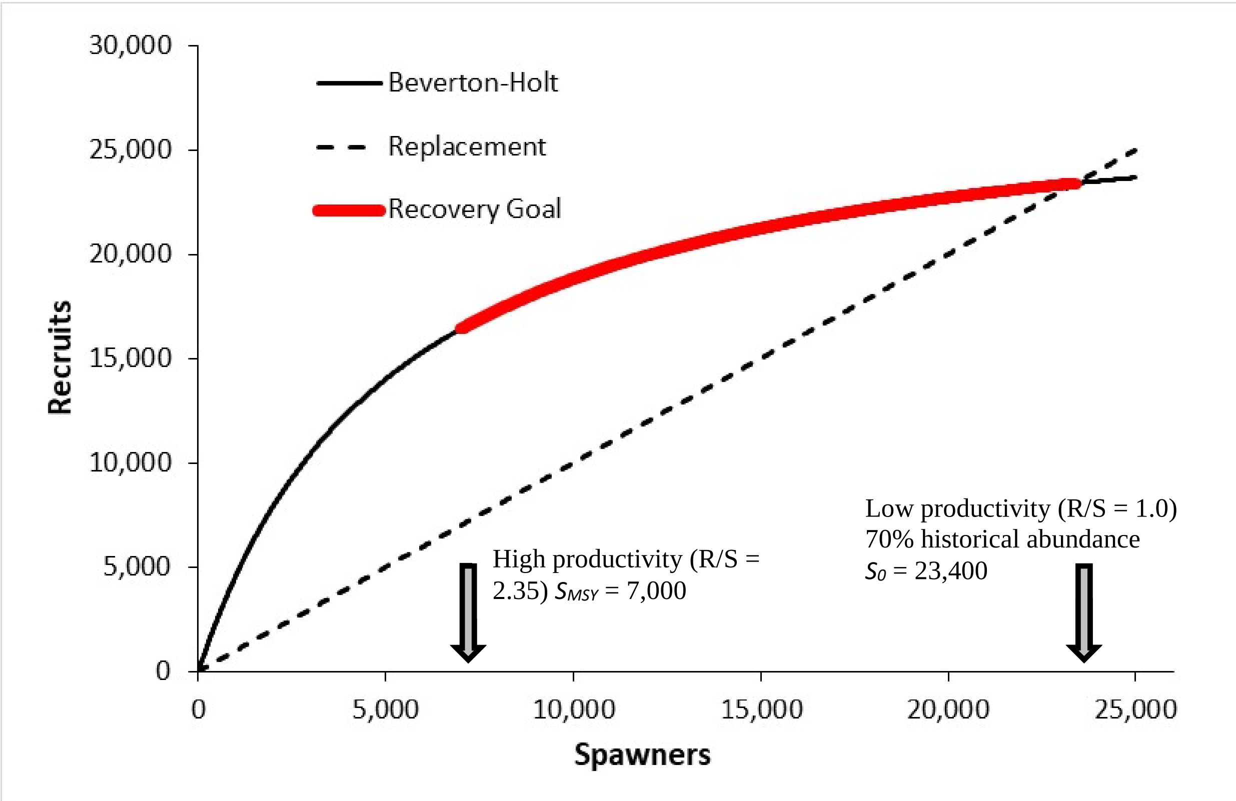

Figure 14. Recovery goal curve incorporating information on both abundance and productivity for the Stillaguamish River winter-run steelhead population.

Table 4. Historical abundance estimates for Puget Sound steelhead DIPs, modified from estimates in Hard et al. (2007, 2015).

	Demographically Independent Population	**Habitat (km)**	**Habitat Proportion**	**Historical Abundance**	**70% Historical Abundance**
North Cascades MPG	Drayton Harbor Tributaries	79	1.2%	5,231	3,661
	Nooksack River	468	7.1%	30,986	21,690
	South Fork Nooksack River (summer-run)	29	0.4%	1,920	1,344
	Samish River + independent tributaries	131	2.0%	8,674	6,071
	Skagit River	477	7.2%	31,582	22,108
	Sauk River	213	3.2%	14,103	9,872
	Nookachamps Creek	91	1.4%	6,025	4,218

	Demographically Independent Population	Habitat (km)	Habitat Proportion	Historical Abundance	70% Historical Abundance
	Baker River	83	1.3%	5,495	3,847
	Stillaguamish River	504	7.6%	33,370	23,359
	Canyon Creek (summer-run)	8	0.1%	530	371
	Deer Creek (summer-run)	50	0.8%	3,311	2,317
	Snohomish/Skykomish River	444	6.7%	29,380	20,566
	Pilchuck River	178	2.7%	11,785	8,250
	Snoqualmie River	247	3.7%	16,354	11,448
	Tolt River (summer-run)	25	0.4%	1,655	1,159
	North Fork Skykomish River (summer-run)	11	0.2%	728	510
Central/South Puget Sound MPG	Cedar River	86	1.3%	5,694	3,986
	North Lake WA Tributaries	346	5.2%	22,909	16,036
	Green River	403	6.1%	26,683	18,678
	Puyallup/Carbon River	326	4.9%	21,585	15,109
	White River	259	3.9%	17,148	12,004
	Nisqually River	443	6.7%	29,331	20,532
	East Kitsap	188	2.8%	12,448	8,713
	South Sound Tributaries	458	6.9%	30,324	21,227
Strait of Juan de Fuca/ Hood Canal MPG	Elwha River	122	1.8%	8,078	5,654
	Dungeness River	89	1.3%	5,893	4,125
	Strait of Juan de Fuca Independent Tributaries	108	1.6%	7,151	5,005
	Discovery Bay Tributaries	110	1.7%	7,283	5,098
	Skokomish River	157	2.4%	10,395	7,276
	West Hood Canal	181	2.7%	11,984	8,389
	East Hood Canal	133	2.0%	8,806	6,164
	South Hood Canal	153	2.3%	10,130	7,091
	Total	6,600	100.0%	436,970	305,879

Table 5. Current abundance and recovery goals for Puget Sound steelhead in the North Cascades Major Population Group. Current abundance is the five-year average terminal run size (escapement + harvest) for return years 2012 – 2016, unless otherwise noted. We suspect that our methods overestimated the historical steelhead abundance of populations composed of many small independent streams relative to those in larger rivers.

North Cascades MPG Populations		Recovery planning targets and ranges	
		Abundance under Beverton-Holt	
Population	Current abundance	High productivity (R/S = 2.3)	Low productivity (R/S = 1.0)
Drayton Harbor Tributaries	35[A]	1,100	3,700
Nooksack River	1,850	6,500	21,700
South Fork Nooksack River (summer-run)		400	1,300
Samish River + independent tributaries	1,090	1,800	6,100
Skagit River	8,278[B]	6,600	22,100
Sauk River		3,000	9,900
Nookachamps Creek		1,300	4,200
Baker River		1,100	3,800
Stillaguamish River	493[C]	7,000	23,400
Canyon Creek (summer-run)		100	400
Deer Creek (summer-run)		700	2,300
Snohomish/Skykomish River	1,066	6,100	20,600
Pilchuck River	878	2,500	8,200
Snoqualmie River	836	3,400	11,400
Tolt River (summer-run)	89	300	1,200
North Fork Skykomish River (summer-run)		200	500

[A] Restricted to Dakota Creek, return years 2014 – 2016.
[B] Combined abundance estimate for Skagit River, Sauk River, and Nookachamps Creek populations.
[C] Index of escapement for North Fork Stillaguamish River and tributaries upstream of Deer Creek, does not include entire watershed or population.

Table 6. Current abundance and recovery goals for Puget Sound steelhead in the Central and South Sound and Hood Canal and Strait of Juan de Fuca Major Population Groups. Current abundance is the five-year average terminal run size (escapement + harvest) for return years 2012 – 2016, unless otherwise noted. We suspect that our methods overestimated the historical steelhead abundance of populations composed of many small independent streams relative to those in larger rivers.

Population	Current abundance	Recovery planning targets and ranges	
		Abundance under Beverton-Holt	
		High productivity (R/S = 2.3)	Low productivity (R/S = 1.0)
Central and South Sound MPG Populations			
Cedar River	5	1,200	4,000
North Lake WA Tributaries		4,800	16,000
Green River	1,166	5,600	18,700
Puyallup/Carbon	740	4,500	15,100
White River	635	3,600	12,000

Population	Current abundance	Recovery planning targets and ranges	
		Abundance under Beverton-Holt	
		High productivity (R/S = 2.3)	Low productivity (R/S = 1.0)
Nisqually River	951	6,100	20,500
East Kitsap tributaries		2,600	8,700
South Sound Tributaries		6,300	21,200
Strait of Juan de Fuca MPG Populations			
Elwha River	1168[A]	2,619[B]	
Dungeness River	607[C]	1,200	4,100
Strait Juan de Fuca Independent Tributaries	123[D]	1,500	5,000
Sequim and Discovery Bay Tributaries	23	1,500	5,100
Skokomish River	921	2,200	7,300
West Hood Canal tributaries	109	2,500	8,400
East Hood Canal tributaries	89	1,800	6,200
South Hood Canal tributaries	61	2,100	7,100

[A] Restricted to return years 2014 – 2017 and includes both natural-origin and hatchery-origin fish.
[B] Peters et al. (2014) identified 2,619 adult steelhead as the goal to reach the Viable Population Phase, the last four sequential recovery phases following removal of two dams on the Elwha River. In contrast to other recovery goals presented here, the Elwha River goal is not in the context of a stock-recruit productivity curve.
[C] Restricted to return years 2013 – 2015.
[D] Estimate restricted to return years 2015 and 2016.

Relationship to Other Puget Sound Steelhead Recovery Goals

The goal of ESA section 4(f) recovery plans is achieve the conservation and survival of the listed species. To facilitate progress toward that goal, population-level goals may be included in a recovery plan. The recovery planning targets presented in Tables 5 and 6 apply a standard, uniform approach to all steelhead populations in Puget Sound. They are intended to aid recovery planning at its outset by providing an initial statement on the degree of population status improvement desired for Puget Sound steelhead. They are not intended to replace or obviate the need for local watershed efforts to establish recovery goals. Indeed, local groups in the Nisqually, Elwha, Skagit, Stillaguamish, Dungeness, Strait of Juan de Fuca Tributaries, Discovery Bay, and East Kitsap watersheds have undertaken efforts to develop recovery goals specific to individual populations. Watershed level recovery goals will likely use a variety of approaches and information, and these efforts are in varying stages of completion. For example, the Nisqually River Steelhead Recovery Plan (2014) stated a recovery goal of an annual treaty harvest of 2,500 adult steelhead, a value entirely consistent with the productivity curve. While ensuring some consistency in the long-term goals across Puget Sound despite different methodologies, we anticipate locally based recovery goals may replace estimates from the curves presented here when they become available and after they have been reviewed by NMFS. Appendix 2 includes additional information about aggregating DIPS and local recovery efforts.

Importance of Marine Survival

In order to demonstrate the importance of marine survival to achieving recovery goal curves (see Appendix 3), we assumed density independent marine survival *m*, and used the Beverton-Holt stock-recruit curve to describe freshwater productivity (i.e., smolts per spawner). We replaced R with S_0/m in the Beverton-Holt equation:

$$\frac{S_0}{m} = \frac{aS_0}{1+\frac{a}{b}S_0} \qquad \text{Equation 4}$$

And rearranged Equation 4 to calculated smolt capacity *b* as

$$b = \frac{S_0 a}{am-1} \qquad \text{Equation 5}$$

In this exercise, we chose *a* values to represent the median (*a* = 110) and 80 percent credible interval (*a* = 56 – 245) described by Buehrens (2017).

Furthermore, one can rearrange equation 5 to solve for *m*.

$$m = \frac{1+S_0\frac{a}{b}}{a} \qquad \text{Equation 6}$$

Thus, for a given S_0 and intrinsic productivity (*a*), one can calculate the relationship between marine survival (*m*) and smolt capacity (*b*). This allows us to express a recovery goal curve as a function of both *m* and *b.* Figure 15 shows the recovery goal curves for Puget Sound steelhead.

This exercise demonstrates that marine survival values > 5 percent are generally required to achieve recovery goal curves for populations with $S_0 \geq$ 5,000 adult steelhead. The curves in Figure 15 demonstrate strong inflection points; as marine survival decreases, the incremental increase in smolt capacity required to offset a 1 percent decrease in marine survival gets larger and larger. For example, a smolt capacity > 300,000 is needed to achieve S_0 = 5,000 if marine survival is < 5 percent (Figure 15). Interestingly, the curves in Figure 15 appear more sensitive to marine survival than *a* (alpha). This important outcome is reinforced repeatedly in the life cycle model analyses: early marine survival poses a demographic bottleneck for Puget Sound steelhead. Actions to address the early marine survival limiting factor are listed in Chapter 3.10.

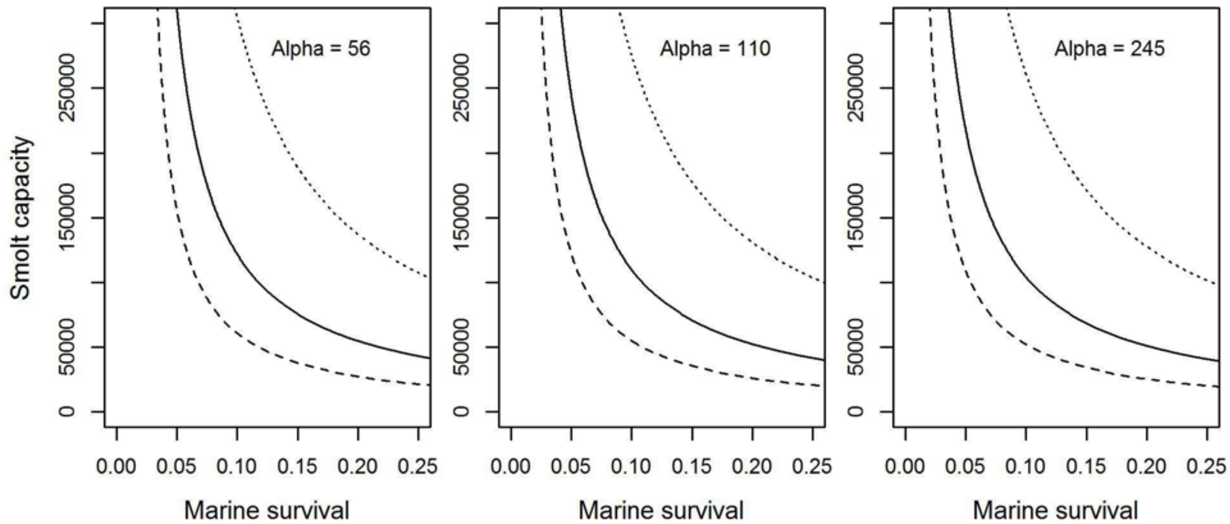

Figure 15. Recovery goal curves for Puget Sound steelhead reflecting different combinations of smolt capacity and marine survival across a range of alpha values. In each plot, dashed line (S_0=5,000), solid line (S_0=10,000), and dotted line (S_0=25,000).

4.3 Delisting criteria for the Five Listing Factors

4.3.1 Introduction to Listing Factor Criteria

As part of a future delisting determination, NMFS will evaluate implementation of the proposed actions described in the Plan and the extent to which each of the section 4(a)(1) listing factors has been addressed. To assist in this examination, NMFS will use criteria described below, in addition to the evaluation of biological criteria and other relevant data, to determine whether the underlying causes of steelhead decline have been addressed and mitigated and are not likely to re-emerge in the foreseeable future. There are multiple combinations of strategies and actions that could meet the biological criteria and listing factors, and protective efforts, and there is no single, pre-established, approach to progress from threatened to recovered status for Puget Sound steelhead. Section 4.4 describes NMFS' approach in using these factors to make delisting decisions for Puget Sound steelhead.

NMFS recognizes that our understanding of pressures (human activities resulting in impairment to steelhead populations or their habitat), and their significance, can change over time due to changes in the natural environment or changes in the way human activities affect the entire life cycle of steelhead. In our recent 5-Year Review (NMFS 2016), NMFS determined that freshwater habitat is a dominant pressure on Puget Sound steelhead. We also recognized that newly identified threats, such as those posed by reduced early marine survival and climate change are limiting productivity of steelhead. Considering potential climate change scenarios and expected continued urban development, NMFS is concerned that the cumulative effect of all threats will have a continuing detrimental impact on the status of the Puget Sound steelhead DPS and the habitat upon which steelhead depend.

The criteria below describe the improvements in condition that, if realized, would provide evidence that the Listing Factors have been addressed.

4.3.2 Listing Factor A: The Present or Threatened Destruction, Modification, or Curtailment of a Species' Habitat or Range

Goal for Listing Factor A
Protect and restore the physical or biological features that are essential for the conservation of the species. This is in addition to the regulatory mechanism related to habitat described in Listing Factor D below.

Acknowledgment of Past and Ongoing Efforts
While this Plan describes serious loss of steelhead habitat as a major challenge to recovery, NMFS acknowledges that there has been, and continues to be, an enormous amount of work done to protect and restore salmon and steelhead habitat in Puget Sound. To be sure, despite heroic efforts to restore steelhead habitat, recent and ongoing efforts have not resulted in meaningful improvement of VSP parameters. DPS-wide protection and strategic restoration efforts must increase to recover Puget Sound steelhead because habitat remains the primary factor influencing their recovery. NMFS intends to continue to support and collaborate with many partners in Puget Sound to protect and restore habitat for steelhead and salmon.

4.3.2.1 Introduction to Habitat Criteria

Puget Sound steelhead have suffered from widespread loss and degradation of freshwater habitat and degradation of near-shore marine habitat (NMFS 2016). The reduced quantity and quality of freshwater habitat that limits the viability of steelhead in Puget Sound streams is the primary factor that led to the listing of Puget Sound steelhead. Unless habitat is more effectively protected and restored, Puget Sound steelhead are very unlikely to recover.

NMFS will need to determine that steelhead habitat condition is, and will likely continue to be, adequate to support a viable DPS before it can remove Puget Sound steelhead from the list of threatened species. Healthy freshwater and near-shore marine habitat conditions will be particularly important given the recent evidence of very low marine survival in the Salish Sea, which has led to recent periods of unprecedented low overall survival and productivity.

NMFS suggests that an overarching strategy that emphasizes certain, effective voluntary approaches to habitat protection and a strong regulatory framework to increase protection of Puget Sound steelhead habitat will be required to achieve recovery. Restoration activities must be sustained, and in some cases, dramatically increased for Puget Sound steelhead to achieve recovery. To be effective, protection and restoration activities must be consistent with the best available scientific information relating to high quality steelhead habitat and near-shore marine conditions. For purposes of ESA delisting (in particular, compatibility with Listing Factor D), NMFS will assess the adequacy of the combination of voluntary measures and "regulatory backstops" that are in place to ensure that the desired outcomes will be achieved, as described below.

4.3.2.2 Delisting Criteria for Steelhead Habitat Condition

The criteria below describe the improvements in condition that, if realized, would provide evidence that Listing Factor A has been addressed and no longer precludes recovery.

1. Passage obstructions are removed or modified to improve distribution (spatial structure and diversity), survival (abundance and productivity) and restore access to historically accessible habitat where necessary to support recovery goals. This includes steelhead passage conditions through hydropower and flood control systems (including dams and reservoirs) which should consistently meet or exceed NMFS performance standards[10] and (a) accurately account for total mortality (i.e., juvenile passage and adult passage mortalities); and (b) are implemented in such a way as to avoid deleterious effects on populations or negative effects on the abundance or distribution of populations. Consistent, accurate monitoring of the numbers of fish moving through, or whose migration is hindered by, passage obstructions is critical to assessing these criteria.

2. Flow conditions that support adequate rearing, spawning, and migration are achieved through management of mainstem and tributary municipal withdrawals, irrigation, and hydropower operations. Increased efficiency and conservation in consumptive water uses should be improved to ensure adequate quantities of water in streams.

3. Water quality (including temperature, dissolved oxygen, total dissolved gas, and turbidity and chemical parameters) should be improved to meet or exceed Clean Water Act standards. In the near-shore marine environment, measurable improvements to water quality from contaminants in the Puget Sound should be documented.

4. Near-shore habitat in the Puget Sound has been improved (protected and restored) to provide adequate spawning habitat for important forage fish and for refuge from predators during their early marine migration through Puget Sound to the ocean. Consistent with the Puget Sound Partnership target on shoreline armoring, increase the rate of armoring removal so that it exceeds new armoring. Where replacement armoring is necessary, increase "soft" approaches to maintain shoreline ecosystem processes.

5. Consistent with the Forests and Fish HCP, forest management practices must protect watershed and stream functions are implemented on federal, state, tribal, and private lands. The number of temperature impaired 303D-listed water bodies originating from forest lands should be reduced. Fish passage barriers should be reduced and the effectiveness of their replacements should be demonstrated. Increased instream flow, stream complexity, channel diversity, and large wood recruitment of substrate and large wood should be observed.

6. Agricultural practices, including farming and grazing, are managed in a manner that improves (protects and restores) riparian areas, floodplains, and stream channels, and protects water quality from fine sediment, pesticide, herbicide, and fertilizer runoff. Agriculture practices should contribute to exceeding Clean Water Act standards. Riparian areas should reveal improvement in meeting NMFS' buffer guidelines.

7. Urban and rural development (including land use conversion from agriculture and forestland to residential uses) does not reduce water quality or quantity, or impair natural stream conditions required to achieve recovery goals. Increased stormwater run-off

[10] https://www.westcoast.fisheries.noaa.gov/publications/hydropower/fish_passage_design_criteria.pdf

treatment from new and existing developments and transportation corridors should be demonstrated.

8. Channel function (including vegetated riparian areas, canopy cover, stream-bank stability, off-channel and side-channel habitats, natural substrate and sediment processes, and channel complexity) are protected or restored to provide adequate rearing and spawning habitat (*see also Listing Factor D*).
9. Floodplain function and the availability of floodplain habitats for steelhead are restored to support a viable DPS. This restoration should include connectedness between river and floodplain and the restoration of natural sediment delivery mechanisms and processes. Floodplain development should be curtailed to show a net increase in floodplain habitats for steelhead.
10. Local government, municipal, Federal, tribal, and state rules and regulations are effectively enforced and reported, including compliance with growth management and critical area ordinances.

4.3.3 Listing Factor B: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Goal for Listing Factor B

Ensure fishing activities are not impeding the recovery of Puget Sound steelhead.

Discussion

NMFS' proposal to list Puget Sound steelhead[11] concluded that "Although overutilization for recreational purposes was a factor that contributed to the present decline of Puget Sound steelhead populations, we do not believe that overutilization is a factor limiting the viability of the Puget Sound steelhead DPS into the foreseeable future."

To ensure that overutilization does not preclude delisting, fisheries as well as scientific or educational activities should be conducted in a manner consistent with the appropriate limits of the 4(d) rule to avoid jeopardizing the DPS, and go beyond that to ensure long term viability and recovery. Several of the Limit 4 criteria are discussed below with particular attention to factors constraining the conservation and survival of Puget Sound steelhead.

Delisting Criteria

In addition to the criteria relating to harvest regulatory mechanisms in Listing Factor D, ongoing utilization for tribal, commercial, recreational, scientific, or educational purposes should be managed as outlined below to address Listing Factor B:

Harvest management plans are designed and implemented using the best available information on habitat capacity, density dependence, and other relevant factors so they support DIP viability goals in all MPGs to ensure Puget Sound steelhead DPS viability, including:

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[11] 71 Federal Register 15666, 03/26/2006. Listing Endangered and Threatened Species and Designating Critical Habitat: 12–Month Finding on Petition to List Puget Sound Steelhead as an Endangered or Threatened Species under the Endangered Species Act

- Contributing to the maintenance or restoration of the historical frequency of repeat spawning.
- Contributing to the protection of resident life histories forms where they are present and important for the recovery of DIPs.
- Contributing to restoring or maintaining genetic and demographic diversity within and among DIPs, in conjunction with habitat and hatchery efforts.
- Contributing to restoring or maintaining run and spawn timing to historic ranges.

4.3.4 Listing Factor C: Disease or Predation

Goal for Listing Factor C

Ensure that diseases and predation and their effects on reproduction and survival are not a threat to the sustainability of the Puget Sound steelhead DPS.

Discussion

Based on the most recent status review for Puget Sound steelhead, (NMFS 2016) and supplemental information, NMFS is concerned about the following:

- Pinniped predation continues to increase and remains a concern for listed species in Oregon and Washington due to a general increase in pinniped populations along the West Coast.
- Since 2011, there has been a significant increase in the number of pinnipeds, especially harbor seals, Steller sea lions, and California sea lions in Puget Sound waters (NMFS 2014a; Wiles 2015).
- Research suggests that unprecedented steelhead smolt emigration mortality, likely from predation by seals, occurs in the Salish Sea (Moore et al. 2015). Berejikian et al. (2016) suggest that harbor seals contribute to predation of steelhead in Puget Sound and in major river deltas (See Appendix 3).
- The findings of the Salish Sea Marine Survival project indicate that parasitic and disease infections of steelhead, including *Nanophyetus salmincola* infection of smolts impact fish condition, and may increase mortality and impede recovery (See Appendix 3).

Delisting Criteria

NMFS will consider the goal for Listing Factor C to be met if there is evidence that predation effects are abated (reduced so that marine survival is sufficiently improved to support recovery) and disease and parasite influences do not impair recovery. To determine that the DPS is recovered, any disease or predation that threatens its continued existence should be addressed as outlined below (based in part on Crawford and Rumsey 2011):

1. Studies on the effectiveness of reducing predation by marine mammals, is undertaken in a way that allows for improved understanding of the contribution toward recovery of the Puget Sound steelhead DPS. NMFS recognizes the challenges associated with managing the predation of one federally protected species (Puget Sound steelhead) by other federally protected species (marine mammals).

2. State, tribal, and federal fish health experts monitor the risks to steelhead from disease and pathogens and ensure that diseases do not impede recovery of the Puget Sound steelhead DPS.

3. Early marine survival of steelhead smolts in Puget Sound is sufficiently understood and management efforts have been implemented to address them.

4.3.5 Listing Factor D: The Inadequacy of Existing Regulatory Mechanisms

Goal for Listing Factor D

The goal for addressing the inadequacy of existing regulations is to establish, reinforce, maintain, and implement regulatory mechanisms that support the recovery of the Puget Sound steelhead DPS. Listing Factor D pertains to multiple categories of regulatory mechanisms including habitat, predation, disease, hatcheries, and other factors. Regulatory mechanisms related to harvest are addressed in Listing Factor B (above). New regulatory mechanisms need to be added as necessary and ineffective regulatory mechanisms that impede recovery should be reduced or eliminated.

NMFS' general approach recognizes that the state of Washington and many stakeholders find that including voluntary approaches to achieving ESA recovery is more cost-effective than relying exclusively on a regulatory approach. A combination of voluntary and regulatory approaches is key to achieving recovery goals. However, in order to address ESA Listing Factor D, NMFS needs assurance that voluntary programs are "backed up" by regulatory mechanisms that ensure that the Puget Sound steelhead DPS is not threatened or endangered, nor will it become so, because of the present or threatened destruction, modification, or curtailment of its habitat or range. NMFS therefore accepts the concept of and need for a "regulatory backstop." This means we support the goal of achieving recovery with a strong voluntary effort, but we will look for evidence that regulatory mechanisms are in place to protect Puget Sound steelhead now and in the future.

4.3.5.1 Listing Factor D, Inadequacy of Regulatory Mechanisms Related to Habitat

NMFS can recommend, but does not have the legal authority to require, changes in local and state regulatory mechanisms in order to protect steelhead habitat. The criteria below describe regulatory mechanisms that would, if implemented, provide important contributions to recovery, so NMFS will look for evidence that these have been developed and implemented. To determine if the DPS is recovered there should be sufficient evidence that regulatory mechanisms are in place, are being implemented, and are effective to protect against further destruction, modification, or curtailment of the species' habitat or range. This needs to include a combination of the following:

Delisting Criteria

1. Federal agency actions under section 7(a)(1) and consultations section 7(a)(2) of the ESA consider cumulative effects of actions in order to minimize the risks from hundreds or thousands of separate actions that degrade steelhead habitat.

2. Regulatory mechanisms are in place that effectively reduce the development and conversion of areas that are ecologically important for steelhead recovery. This includes increased effort to: increase floodplain habitats, improve shoreline habitat and functioning marine feeder bluffs for forage fish, eelgrass, and wetlands; provide adequate riparian area protection; improve water quality, including control of toxic chemicals; maintain and improve connectivity between larger rivers, tributaries and wetlands; reduce stormwater runoff; and minimize impacts to natural channel processes from channel changes, pipeline crossings, and other projects.
3. Improved communication and integration of steelhead recovery needs are included in land use planning and construction project design. This includes linking planning, policies and regulatory actions through decision-making processes by different agencies and departments. For example, shoreline designations and associated uses should be consistent with specific watershed areas identified as protection or restoration priorities for steelhead.
4. Steelhead habitat areas are protected with riparian corridors consisting of mature, native trees and shrubs to ensure self-sustaining stream processes and riparian ecosystems are maintained (e.g., see WDFW riparian management recommendations).[12]
5. Plans for residential, municipal and commercial water withdrawals that may contribute to low flow stream conditions during summer months are reviewed for consistency with Clean Water Act criteria and increased instream flows to protect water quantity and quality.
6. Increased regulatory, incentive, and policy actions are installed or implemented to reduce stormwater runoff impacts to steelhead. This includes increased use of temporary erosion and sediment controls, designation of easements, and the use of low impact development approaches and techniques that manage stormwater.
7. Federal policies are aligned to improve shoreline habitat protection in marine and estuarine areas, such as applying the highest astronomical tide (HAT) as the landward jurisdictional extent of Clean Water Act section 404 and Section 10 of the Rivers and Harbors Act permitting.
8. Interagency coordination is strengthened and streamlined to improve the implementation and enforcement of land use laws and permitting processes among state, federal, and local government authorities.
9. Fund and make available federal and state agency scientists to local governments to increase efforts to assist local governments in integrating recovery strategies into local land use planning. For example, development is often located in low-gradient areas within a watershed that provide important habitat for steelhead. Urban growth in these environments can alter land surface, soil, vegetation and hydrology by increasing the area of impervious surface. Local governments need support to identify key steelhead habitats, and to define and implement plans, regulations and policies that protect the habitats and the ecosystem processes that maintain them.

[12] https://wdfw.wa.gov/publications/01987/

10. Restoration practitioners and habitat scientists educate communities about ways that they can develop and implement regulatory mechanisms to support steelhead recovery protection and restoration. For example, work with the real estate industry to provide information on buffers and wetlands that are constraints on developing properties.
11. Existing regulatory mechanisms are enforced and additional funding is provided for federal, state, and especially local governments to provide for sufficient habitat protection and restoration.
12. Federal and local government agencies improve protections for floodplain rearing habitats by implementing the NMFS Biological Opinion on the National Floodplain Insurance Program, to limit future loss of floodplain habitat in jurisdictions enrolled in that program.
13. Protection mechanisms are strengthened in state regulations to protect habitat conditions and watershed function where resource extraction such as gravel mining and gold mining impair spawning and rearing habitat and limit steelhead production.
14. Implementation and enforcement of existing regulatory laws and policies is increased to prevent additional exotic plant and animal species invasions to occur where they pose threats to steelhead.
15. Where instream water rights for fish habitat exist, they are protected and enforced. Where instream flows to protect steelhead are not in place, they should be prioritized for protection.

4.3.5.2 Listing Factor D, Inadequacy of Regulatory Mechanisms Related to Disease and Predation

Delisting Criteria

1. Predation by protected marine mammals and birds is managed in a way that allows for recovery of the Puget Sound steelhead DPS. NMFS recognizes the challenges associated with managing the predation of one federally protected species (Puget Sound steelhead) by other federally protected species (migratory birds and marine mammals).
2. State, tribal, and federal fish health experts implement protective regulatory mechanisms to reduce the risks to steelhead from disease and pathogens and ensure that diseases do not impede recovery of the Puget Sound steelhead DPS.
3. Hatchery operations do not subject targeted populations to deleterious diseases and parasites which could result in increased predation rates of natural-origin fish.

4.3.5.3 Listing Factor D, Inadequacy of Regulatory Mechanisms Related to Other Factors (Climate and Hatcheries)

Listing Factor D, inadequacy of regulatory mechanisms related to climate change

Goal for Listing Factor D for Climate Change

Development and implementation of regulatory mechanisms contain consideration of climate change in their adaptation to the rules and environment to protect and recover Puget Sound steelhead.

Delisting Criteria

1. Regulatory mechanisms related to climate change are developed and implemented to the maximum extent practicable in order to ensure that steelhead have adequate ecosystem conditions, including water temperature, quantity, sea level rise, and acidification.

Listing Factor D, inadequacy of regulatory mechanisms related to hatcheries

Goal for Listing Factor D for hatcheries
Regulatory mechanisms relating to hatchery programs are adequate, meaning they are effective in ensuring that hatchery programs do not impede the recovery of Puget Sound steelhead.

Delisting Criteria

1. To determine that the regulatory mechanisms related to hatchery production of steelhead in Puget Sound are adequate to support recovery, NMFS will need to ensure that ESA sections 7 and 10 and 4(d) rule (limits 5 and 6)[13] are implemented using the best available scientific information specifically related to the effects of steelhead hatchery programs on short and long-term viability of the DPS.

4.3.6 Listing Factor E: Other Natural or Human-made Factors Affecting the Species' Continued Existence

4.3.6.1 Listing Factor E Related to Climate Change

Goal for Listing Factor E related to climate change
NMFS intends to evaluate natural and human-made factors affecting the continued existence of Puget Sound steelhead for effects that impede recovery as well as actions taken to remove or reduce those effects. In particular, climate change threats have imposed a meaningful influence on the productivity of steelhead and these effects need to be reduced.

Discussion: Climate Change effects on Steelhead
The potential effects of global climate change have emerged as a critical concern for steelhead. A review by the NMFS's Northwest Fisheries Science Center (NWFSC) shows moderate certainty that the 30-year average temperature in the Northern Hemisphere is now higher than it has been over the past 1,400 years. High certainty exists that ocean acidity has increased with a drop in pH of 0.1 (NWFSC 2015). The trends in warming and ocean acidification are highly likely to continue during the next century (IPCC 2013).

NWFSC 2015 and NMFS 2016 summarize the expected climate change effects that may be pertinent to Puget Sound steelhead. In the near term, "the outlook for environmental conditions

[13] Limits 5 and 6 from 50 CFR 223.203(b)(5)(6)

affecting Puget Sound steelhead is not optimistic. Recent environmental trends not favorable to Puget Sound steelhead survival and production are expected to continue. The exceptionally warm marine waters in 2014 and 2015 and warm stream temperatures observed during 2015 were unfavorable for high marine or freshwater survival. The overall effects of these environmental conditions will not be known until adults return over the next few years. A positive pattern in the Pacific Decadal Oscillation, which has been in place since January 2014, is expected to continue, and current El Niño conditions may persist" over the next few years (NWFSC 2015). "These and other environmental indicators point to continued conditions of warming ocean temperatures, fragmented or degraded freshwater spawning and rearing habitat, reduced snowpack, altered hydrographs producing reduced summer river flows and warmer water, and low marine survival for salmonids in the Puget Sound. These conditions are almost certain to constrain any rebound in VSP parameters for Puget Sound steelhead in the near term" (NWFSC 2015).

Delisting Criteria
To determine if the DPS is recovered, a monitoring system should be in place that can evaluate the effects of climate change so that, to the extent practicable, effects can be minimized or adaptively managed to adjust to changing conditions.

1. The potential effects of climate change should continue to be evaluated and incorporated into management programs for hydropower, flood control, instream flows, water quality, fishery management, and hatchery management.
2. Watershed specific recovery plans should incorporate down-scaled model results of precipitation changes into protection and restoration strategies.
3. Early indicators of ocean conditions should be considered in harvest management plans where not already considered.
4. Habitat restoration projects should consider the effects of downscaled model results in their designs to facilitate resilience to altered flow and precipitation patterns.

4.3.6.2 Listing Factor E Related to Hatcheries

Goal for Listing Factor E related to hatcheries
Hatchery programs are managed effectively to ensure that they do not impede the recovery of Puget Sound steelhead.

Delisting Criteria
To determine if the DPS is recovered, regulatory mechanisms that protect steelhead from potential detrimental effects of hatcheries must include the following recovery actions:

1. The use of non-Puget Sound derived hatchery broodstock has been fully phased out.
2. Puget Sound steelhead hatchery programs are operated in a manner consistent with maintaining viability of the DPS, including control of demographic, genetic and ecological risks of hatchery operations, impacts of water withdrawal and discharge, and

fish health. For control of genetic risk, particular attention is paid to choice of appropriate Puget Sound broodstock and management of exposure to risk of domestication.

3. Monitoring and evaluation plans are implemented to measure population status, hatchery effectiveness, and compliance with ecological, genetic, and demographic risk containment measures.
4. The resource co-managers adaptively manage, using the most current scientific research, hatchery production levels, hatchery practices, and monitoring measures to insure the levels of risk are appropriate for viability and recovery of the DPS and its constituent populations and major population groups.

4.4 Making a Delisting Determination

At the time of a delisting decision for the Puget Sound steelhead DPS, NMFS will examine the extent to which each of the section 4(a)(1) listing factors has been addressed. To assist in this examination, NMFS will use the delisting framework described below and shown in Figure 9, in addition to evaluating the biological status relative to the recovery criteria and other relevant data and policy considerations. The threats need to have been addressed to the point that delisting is not likely to result in their re-emergence.

4.4.1 Biological Status and Pressure/Threats Review

NMFS recognizes that perceived threats, and their significance, can change over time due to changes in the natural environment or changes in the way threats affect the entire life cycle of salmon. Indeed, this has already happened. As discussed earlier, some threats to Puget Sound steelhead at the time of listing, such as harvest mortality and hatchery influence, have since been reduced through management adjustments and now pose less danger to species viability. Other threats, such as the condition of freshwater and nearshore marine habitats, continue to limit recovery progress, although conditions in some areas are improving through the work of volunteers and stakeholders. At the same time, new threats, such as those posed by climate change, may be emerging. During its next five-year reviews, NMFS will review the biological status and listing factor criteria.

As described in this chapter and portrayed in Figure 9, the delisting framework for Puget Sound steelhead combines our assessment of biological status, the five listing factors, recovery actions, and research, monitoring and evaluation. The combined results from these assessments provide NMFS with the information needed to fully assess the overall risk to the species in future listing determinations.

4.4.2 Applying the Delisting Framework for Puget Sound Steelhead

NMFS plans to consider all the factors portrayed in Figure 9 in future status reviews and when making future decisions regarding the overall risk of extinction of Puget Sound steelhead. As described earlier and based on the available information at the time this Plan was drafted, NMFS expects to give greater weight to freshwater habitat and early marine survival than the other factors. Status reviews will be based on the best scientific information available at that time and take into account the following:

- The viability criteria and listing factor criteria described above.
- The management programs in place to address the threats.
- Principles presented in the Viable Salmonid Populations paper (McElhany et al. 2000).
- Best available information on population and DPS status and new advances in risk evaluation methodologies.
- Other considerations, including: the number and status of extant spawning groups; the status of the major spawning groups; linkages and connectivity among groups; the diversity of life history and phenotypes expressed; and considerations regarding catastrophic risk.
- The concept of trade-offs[14] between the various objectives and criteria and efforts;
- The fact that the Puget Sound steelhead DPS is a complex structure with important processes operating at scales ranging from individual spawning grounds to the entire Puget Sound steelhead DPS.
- The threatened (future) destruction, modification, or curtailment of its habitat.[15]
- The uncertainties described in our listing determinations and multiple scientific reports.
- The reality is that there are multiple combinations of strategies and actions that could meet the biological criteria and listing factors, and protective efforts, and there is no single, pre-established, approach to progress from threatened to recovered status for Puget Sound steelhead.

The following tables show the factors that we will consider to determine the status of the biological health of the DPS and the status of the five listing factors, and assess the certainty that the goals and criteria have been met. These tables do not suggest a specific outcome or answer, instead they are intended to show what NMFS will consider in making future decisions.

- Table 7 presents the components of the listing determination framework in a manner that allows us to indicate the certainty we have that the viability and listing factor criteria have been met.
- Table 8 shows how the factors, particularly reduced habitat conditions and related habitat regulatory mechanisms, contributed to our threatened status determination in 2007.
- Table 9 describes the strongest case for delisting — if we had "complete certainty" that the biological viability and all the listing factors met their respective objectives and criteria.
- Table 10 shows a hypothetical characterization of how we might delist if we have certainty that a number of the criteria have been met, even if one criterion was not met. The ESA and NMFS guidance do not require the highest level of certainty that

[14] NMFS Recovery Guidance 2007.
[15] ESA Section 4(a)(1)(A).

all criteria have been met, nor do they specify exactly what the status of the species and the listing factors must be in order to delist.

- Table 11 illustrates the concept of trade-offs — how we could delist with different combinations of certainty that viability and listing factor criteria have been met.

Table 7. Components of the listing determination framework that NMFS will consider in evaluating the status of Puget Sound steelhead.

Degree of certainty that criterion for each column has been met	Biological Status (Is the DPS sustainable?)	Listing Factor (LF) A Is the habitat adequate for recovery?	LF B (Harvest)	LF C (Disease & Predation)	Listing Factor D The regulatory mechanisms for each listing factor (A,B,C, and E) are adequate to achieve and sustain recovery				LF E Other factors
					A	B	C	E	
High certainty the criterion has been met									
Moderate certainty the criterion has been met									
Low certainty it is met									
Uncertain									
Low certainty the criterion has not been met									
Moderate certainty the criterion has not been met									
High certainty criterion has not been met									

Table 8. Characterization of the determination to list Puget Sound steelhead in 2007.

Degree of certainty that criterion for each column has been met	Biological Status (Is the DPS sustainable?)	Listing Factor (LF) A Is the habitat adequate for recovery?	LF B (Harvest)	LF C (Disease & Predation)	Listing Factor D The regulatory mechanisms for each listing factor (A,B,C, and E) are adequate to achieve and sustain recovery					LF E Other factors(Climate and Hatcheries)	
					A	B	C	E			
								Hatchery	Climate	Hatchery	Climate
High certainty the criterion has been met											
Moderate certainty the criterion has been met											
Low certainty the criterion has been met											
Uncertain											
Low certainty the criterion has not been met				(Predation)			Predation				
Moderate certainty the criterion has not been met					Regulatory mechanisms for habitat						
High certainty criterion has not been met											

Table 9. The strongest case for delisting: "complete certainty" that the biological status and all the listing factors met their respective goals and protective efforts. were effective.

Degree of certainty that criterion for each column has been met	Biological Status (Is the DPS sustainable?)	Listing Factor (LF) A Is the habitat adequate for recovery?	LF B (Harvest)	LF C (Disease & Predation)	Listing Factor D The regulatory mechanisms for each listing factor (A,B,C, and E) are adequate to achieve and sustain recovery				LF E Other factors (Climate and Hatcheries)
					A	B	C	E	
High certainty the criterion has been met									
Moderate certainty the criterion has been met									
Low certainty the criterion has been met									
Uncertain									
Low certainty criterion has not been met									
Moderate certainty criterion has not been met									
High certainty criterion has not been met									

Table 10. Hypothetical characterization of how NMFS might delist: Despite remaining uncertain that the habitat is adequate for recovery, the biological status is strong and newly strengthened regulatory mechanisms are deemed sufficient to improve the habitat enough to warrant delisting.

Degree of certainty that criterion for each column has been met	Biological Status (Is the DPS sustainable?)	Listing Factor (LF) A Is the habitat adequate for recovery?	LF B (Harvest)	LF C (Disease & Predation)	Listing Factor D The regulatory mechanisms for each listing factor (A,B,C, and E) are adequate to achieve and sustain recovery	LF E Other factors (Climate and Hatcheries
High certainty the criterion has been met						
Moderate certainty the criterion has been met						
Uncertain						
Low certainty criterion has not been met						
Moderate certainty criterion has not been met						
High certainty criterion has not been met						
High certainty criterion has not been met						

Table 11. Hypothetical characterization of trade-offs (combinations of how NMFS could delist): If there was a high certainty that the habitat and regulatory mechanisms were adequate to sustain recovery, NMFS could consider delisting with a lower score for biological sustainability.

Degree of certainty that criterion for each column has been met	Biological Status We might not need high certainty the DPS is sustainable if listing factors are in good shape.	Listing Factor (LF) A Certain the habitat is adequate for recovery	Certain B criteria are met	Certain C criteria are met	Listing Factor D The regulatory mechanisms for each listing factor (A,B,C, and E) are adequate to achieve and sustain recovery				LF E Other factors are consistent with recovery	
High certainty the criterion is met										
Moderate certainty the criterion is met										
Low Certainty it is met										
Uncertain										
Low Certainty criterion is not met										
Moderate certainty criterion is not met										
High certainty criterion is not met										

5. Time and Cost Estimates

ESA section 4(f)(1) requires that recovery plans, to the maximum extent practicable, include "estimates of the time required and the cost to carry out those measures needed to achieve the plan's goal and to achieve intermediate steps toward that goal" (16 U.S.C. 1531-1544, as amended). This chapter is intended to meet this ESA requirement.

5.1 Time Estimates

The time to recover Puget Sound steelhead will likely depend on how much funding and resources are delivered to recovery efforts, and how the strong influence of early marine survival is ultimately addressed. Under any scenario, the time to recovery will take many decades and will depend on several variables, including the following:

- Whether ongoing habitat protection and restoration actions continue to be effectively implemented and adapted;
- how Puget Sound steelhead respond to protection and restoration actions;
- whether regulatory mechanisms to protect habitat are implemented;
- whether resources that benefit Puget Sound Chinook and Hood Canal summer Chum salmon can be sustained while additional resources are implemented in a timely manner to benefit steelhead;
- whether an adequately funded adaptive management program can be sustained to inform key uncertainties;
- whether natural-origin steelhead respond to new and ongoing hatchery management improvements;
- whether effective actions to improve early marine survival of Puget Sound steelhead can be successfully implemented; and
- how ecological factors, such as changing ocean conditions and climate, impact the species.

Factors inhibiting the recovery of Puget Sound steelhead are disproportionately influential and likely require different levels of effort and time to remedy. The early marine survival of steelhead in Puget Sound has been very low in recent years leading to unsustainable productivity. If remedies to pinniped predation in Puget Sound can be overcome within a decade, steelhead trends in abundance and productivity may slowly rebound thereafter.

In freshwater, fish passage at major dams and blockages such as Baker River (Skagit River), Howard Hansen (Green River), the Nooksack diversion (Middle Fork Nooksack River), Mud Mountain, Buckley Diversion Dam (White River), and the Ballard Locks (Lake Washington/ Cedar) provide the greatest and timeliest opportunity to increase VSP criteria for steelhead in Puget Sound. Fish passage around major structural features like dams can take a decade or more to plan and implement, but measurable steelhead abundance response to newly available, high quality habitat can be occur within several generations (12-20 years).

Hatchery improvements in recent years, including Hatchery Genetic Management Plans (HGMPs) and the use of conservation hatcheries, have steadily improved the outlook for diversity of steelhead. These improvement efforts continue as more HGMPs and other hatchery practice modifications are anticipated over the next year. How quickly steelhead respond from hatchery practice improvements is largely unknown.

Habitat protection and restoration efforts comprise the largest potential gains for steelhead VSP criteria. However, despite gradual improvement through time with increased funding, 100 years may be needed before full protection and restoration efforts would lead to recovery.

5.2 Cost Estimates

Consistent with ESA recovery planning guidelines, this section provides estimates of cost, to the maximum extent practicable, to achieve the Plan's goal to delist the Puget Sound steelhead DPS (NMFS and USFWS 2018). Staff from NMFS' West Coast Region in coordination with the Recovery Team, identified ongoing and potential additional actions to recover ESA-listed Puget Sound steelhead. These recovery strategies and actions were developed using the most up-to-date assessment information for the species without consideration of cost or potential funding.

While continued programmatic actions in the management of habitat, hatcheries, hydropower, and harvest will warrant additional expenditures beyond the first ten years, NMFS believes it is impracticable to estimate all projected actions and costs over 50 to 100 years given the large number of economic, biological, and social variables involved. Instead, NMFS believes it is most appropriate to focus on the first 10 years of action implementation and rely on the adaptive management framework's structured process to conduct monitoring to improve the science and on periodic plan reviews, to evaluate the status of the species and add, eliminate, or modify actions based on new knowledge. The adaptive management process will continue to frame decision making to gain needed information and use it to alter our course of action strategically until such time as the protection under the ESA is no longer required.

All yearly costs are presented in present-year dollars (that is, without adjusting for inflation). Costs are estimates for the Fiscal Year (FY) in millions of dollars ($M). The total costs are the sum of the yearly costs without applying a discount rate. Unless otherwise noted, the costs are direct, incremental costs, meaning that they are (1) out-of-pocket costs that a public or private interest would pay to initiate and complete a management action, and (2) costs that are in addition to the baseline costs for existing programs and activities. This approach is consistent with NMFS West Coast Region guidance on cost estimates for ESA recovery plans.

Protection and restoration efforts to recover Puget Sound Chinook and Hood Canal summer Chum salmon have been underway since before 1999. In our 2006 Supplement to the Puget Sound Salmon Recovery Plan, NMFS concurred that $120 million per year would be needed over 10 years to place Puget Sound Chinook salmon on a trajectory toward recovery within a 50- to 100-year recovery timeframe (NMFS 2006). The Puget Sound region received approximately $516 million in state and federal funding ($52 million per year on average) during the ensuing 10 years (2006-2016) (GSRO 2016). Despite historic restoration efforts during that period, steelhead and Chinook salmon abundance has not appreciably improved (NMFS 2016).

Updated cost estimates to recover Puget Sound Chinook and Hood Canal Summer Chum salmon were developed by the Washington Governor's Salmon Recovery Office. The total estimated cost to implement the Puget Sound Chinook and Chum salmon recovery plans (capital and non-capital costs) is approximately $200 million per year, or $2 billion total over the next 10 years (GSRO 2016).

To develop cost estimates for Puget Sound steelhead recovery, we assume that actions to recover Chinook and Chum salmon are fully funded and implemented. Costs that apply more directly to steelhead recovery and less to Chinook and Chum salmon include correcting fish passage barriers at road crossings, providing passage at (or removing) dams, addressing early marine survival impediments (which was not accounted for in the Chinook or Chum salmon recovery plans), and additional monitoring and adaptive management.

Steelhead ascend rivers and streams further than Chinook and Chum salmon, and commonly occupy headwater streams that are not used by these species. In fact, most stream reaches occupied by Chinook and Chum salmon are subsets of the steelhead-occupied reaches within the same watersheds. Therefore, we assumed that current non-fish passage repair efforts to restore Chinook and Chum salmon also benefit steelhead when these activities occur in the same watershed. In addition, steelhead are known to have occupied some streams where Chinook and Chum salmon are not known to have existed. Conservatively, the historic habitat used by steelhead is more than twice the length of habitat known to have supported Chinook salmon.

Fish passage barriers at road crossings are a pervasive impediment to Puget Sound steelhead recovery. The WDFW estimates that between 6,700 and 8,000 anadromous barriers exist in Puget Sound streams which would otherwise provide access to habitat for steelhead and Coho salmon (WDFW 2018). We assume that 70 percent of these barriers need to be corrected to meet our recovery goals. Concurrent with the estimated number of barriers reported, WDFW also estimated approximate costs to repair the barriers. Table 12 shows the estimated costs, by entity, to repair the fish passage barriers.

Table 12. Estimated costs to remedy fish passage barriers in anadromous streams of Washington by entity. Costs do not include inflation.

Entity	Est. Cost to remedy	Data source used
Private	$114,000	Average FFFPP[1] project cost
County	$582,018	Average County project cost on FBRB[2] 17-19BN[3] List
State - non-WSDOT	$348,009	Average State - non-WSDOT project cost on FBRB 17-19BN List
City	$686,145	Average City project cost (FBRB 17-19BN)
Special Districts	$582,018	Average County project cost (FBRB 17-19BN)
Other/Unknown	$582,018	Average County project cost (FBRB 17-19BN)
Ports	$582,018	Average County project cost (FBRB 17-19BN)
Tribal	Not provided	Not included
Federal	Not provided	Not included
State - WSDOT	$5,052,000	WSDOT 2017[4]

[1] FFFPP (Family Fish Passage Program) is a family forest grant program.

[2] FBRB (Fish Barrier Removal Board) is Washington State program to remove anadromous barriers.
[3] 17-19BN (Biennial budget for fiscal years 2017-2019).
[4] WSDOT Presentation to the Washington State Transportation Commission, 3/21/2017, estimated draft value.

To estimate the cost of repairing fish passage barriers in Puget Sound, we took the mean of the WDFW estimate number of barriers (7,350) and assumed that 70 percent of those barriers were associated with steelhead habitat and were necessary to recover the species. We then applied the mean cost to repair private, city, and county road crossings (about $460,000) to the resulting estimated number of barriers (5,145). If costs are amortized over the next 100 years, the estimated costs to repair steelhead barriers at road crossings in Puget Sound over the next 10 years is $237M. We assume that fish passage over a minimum of two Puget Sound dams would be necessary over the next 10 years (Howard Hanson and one additional dam) at a cost of $100M each. The total cost of providing fish passage (dams and culverts) to historic reaches of Puget Sound steelhead, as shown in Table 13, is estimated at $437M over the next 10 years.

The costs to remedy early marine survival impacts to steelhead are currently unknown. As adaptive management continues to improve our understanding of early marine migration impediments to recovery, costs will be developed and included with future iterations of this planning effort.

The costs associated with additional monitoring and adaptive management for steelhead recovery are assumed to be 1 percent of the additional Puget Sound steelhead recovery costs. Although we assume that monitoring efforts for Chinook and Chum salmon will contribute to some of the necessary steelhead monitoring needs, we estimate that 4.4M/year is needed to monitor and adaptively manage steelhead for the next 10 years.

Table 13. Summary of recovery costs for Puget Sound steelhead.

Activity	Annual cost	10-Year cost (2020-2030)
Stream restoration and protection[1]	$200 Million	$2.0 Billion
Fish passage at road crossings[2]	$23.7 Million	$237 Million
Fish passage at dams	$20 Million	$200 Million
Monitoring and adaptive management	$4.4 Million	$44 Million

[1] Governor's Salmon Recovery Office (GSRO) 2016.

[2] Washington's Fish Barrier Removal Board (FBRB) 2018.

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List of Appendices

Appendix 1. Terms and Definitions

Abundance	In the context of salmon recovery, abundance refers to the number of natural-origin adult fish returning to spawn.
Adaptive Management	The process of adjusting management actions and/or directions based on new information.
All-H Approach	The idea that actions could be taken to improve the status of a species by reducing adverse effects of the hydropower system, predators, hatcheries, habitat, and/or harvest.
Anadromous Fish	Species that are hatched in freshwater, migrate to and mature in salt water, and return to freshwater to spawn.
Biogeographical Region	An area defined in terms of physical and habitat features, including topography and ecological variations, where groups of organisms (in this case, salmonids) have evolved in common.
Brood Cycles	Steelhead mature at different ages so their progeny return as spawning adults over several years. When all progeny at all ages have returned to spawn, the brood cycle is complete.
Conservation Gap	The difference between a population's baseline status and its target status.
Contributing Population	A population for which some restoration will be needed to achieve the MPG-wide average viability recommended by the Interior Columbia Technical Recovery Team.
Critical Habitat	Specific areas that contain the physical or biological features that are essential for the conservation of endangered or threatened species, and that may require special management considerations or protection.
Demographically Independent Population (DIP)	A group of fish of the same species that spawns in a particular lake or stream (or portion thereof) at a particular season and which, to a substantial degree, does not interbreed with fish from any other group spawning in a different place or in the same place at a different season.
Distinct Population Segment (DPS)	A steelhead DPS is a distinctive group of steelhead that is uniquely adapted to a particular area or environment. Two criteria define a DPS of steelhead listed under the ESA: (1) discreteness of the population segment in relation to the remainder of the species to which it belongs, and (2) significance of the population segment to the species to which it belongs. DPSs may contain multiple populations that are connected by some degree of migration, and hence may have a broad geographic range across watersheds, river basins, and political jurisdictions.

Diversity	All the genetic and phenotypic (life history, behavioral, and morphological) variation within a population. Variations could include anadromy versus lifelong residence in freshwater, fecundity, run timing, spawn timing, juvenile behavior, age at smolting, age at maturity, egg size, developmental rate, ocean distribution patterns, male and female spawning behavior, physiology, molecular genetic characteristics, etc.
Endangered Species	A species in danger of extinction throughout all or a significant portion of its range.
ESA Recovery Plan	A plan to recover a species listed as threatened or endangered under the U.S. Endangered Species Act (ESA). The ESA requires that recovery plans, to the extent practicable, incorporate (1) objective, measurable criteria that, when met, would result in a determination that the species is no longer threatened or endangered; (2) site-specific management actions that may be necessary to achieve the plan's goals; and (3) estimates of the time required and costs to implement recovery actions.
Essential Fish Habitat	As defined by the U.S. Congress in the Magnuson-Stevens Fishery Conservation and Management Act, Essential Fish Habitat (EFH) describes all waters and substrate necessary for fish for spawning, breeding, feeding, or growth to maturity.
Evolutionarily Significant Unit (ESU)	A group of Pacific salmon or steelhead trout that is (1) substantially reproductively isolated from other conspecific units and (2) represents an important component of the evolutionary legacy of the species. Equivalent to a distinct population segment (DPS) and treated as a species under the Endangered Species Act.
Extinct	No longer in existence. No individuals of this species can be found.
Factors for Decline	Five general categories of causes for decline of a species, listed in the Endangered Species Act section 4(a)(1)(b): (A) the present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; or (E) other natural or human-made factors affecting its continued existence.
Flow Augmentation	Water released from system storage at targeted times and places to increase streamflows to benefit migrating juvenile salmon and steelhead
Functionally Extirpated	Describes a species or population that has so few remaining individuals that there are not enough fish or habitat in suitable condition to support a fully functional population.
Hyporheic Zone	The hyporheic zone is a region beneath and alongside a stream bed where shallow groundwater and surface water mix.
Independent Population	Any collection of one or more local breeding units whose population dynamics or extinction risk over a 100-year time period is not

	substantially altered by exchanges of individuals with other populations.
Indicator	A variable used to forecast the value or change in the value of another variable.
Intrinsic Potential	The estimated relative suitability of a habitat for spawning and rearing of anadromous salmonid species under historical conditions inferred from stream characteristics including channel size, gradient, and valley width.
Intrinsic Productivity	Productivity at very low population size; unconstrained by density.
Interoparity	The ability to reproduce more than once during a lifetime.
Juvenile salmon	Juvenile salmon is the term applied to a salmonid fish between the egg and adult stages. Juvenile salmonid stages include sac fry or alevin, fry, parr, and smolts. The juvenile stage last until the fish are grown and sexually mature.
Legacy Effects	Impacts from past activities (usually a land use) that continue to affect a stream or watershed in the present day.
Major Population Group (MPG)	An aggregate of independent populations within an ESU that share similar genetic and spatial characteristics.
Morphology	The form and structure of an organism, with special emphasis on external features.
Natural-origin Fish	Fish that were spawned and reared in the wild, regardless of parental origin.
Peak Flow	The maximum rate of flow occurring during a specified time period at a particular location on a stream or river.
Phenotype	Any observable characteristic of an organism, such as its external appearance, development, biochemical or physiological properties, or behavior.
Piscivorous	Describes any animal that preys on fish for food.
Pressure	Human activities or natural events (e.g., road building, floodplain development, fish harvest) that cause or contribute to a decline in a species' viability.
Productivity	The average number of surviving offspring per parent. Productivity is used as an indicator of a population's ability to sustain itself or its ability to rebound from low numbers. The terms "population growth rate" and "population productivity" are interchangeable when referring to measures of population production over an entire life cycle. Can be expressed as the number of recruits (adults) per spawner or the number of smolts per spawner.
Recovery Goals	Goals incorporated into a locally developed recovery plan. These goals may go beyond the requirements of ESA de-listing by including other legislative mandates or social values.

Recovery Strategy	A statement that identifies the assumptions and logic—the rationale—for the species' recovery program.
Redd	A nest constructed by female salmonids in streambed gravels where eggs are deposited and fertilization occurs.
Resident Fish	Fish that are permanent inhabitants of a water body. Resident fish include trout, bass, and perch.
Riparian Area	Area with distinctive soils and vegetation between a stream or other body of water and the adjacent upland. It includes wetlands and those portions of floodplains and valley bottoms that support riparian vegetation.
Runoff	Precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water.
Salmonid	Of, belonging to, or characteristic of the family Salmonidae, which includes salmon, steelhead, trout, and whitefish. In this document, it refers to listed steelhead distinct population segments (DPS) and salmon evolutionarily significant units (ESU).
Self-sustaining	A self-sustaining viable population has a negligible risk of extinction due to reasonably foreseeable changes in circumstances affecting its abundance, productivity, spatial structure, and diversity characteristics over a 100- year period and achieves these characteristics without dependence upon hatcheries. Hatcheries may be used to benefit threatened and endangered species and a self-sustaining population may include hatchery fish, but a self-sustaining population must not be dependent upon hatchery measures to achieve its viable characteristics. Hatcheries may contribute to but is not a substitute for addressing the underlying factors (threats) causing or contributing to a species' decline.
Smolt	A juvenile salmon or steelhead migrating to the ocean and undergoing physiological changes to adapt from freshwater to a saltwater environment.
Spatial structure	The geographic distribution of a population or the populations in an ESU.
Stabilizing Population	A population that is targeted for maintenance at its baseline persistence probability, which is likely to be low or very low.
Stock	An aggregation of fish spawning in a particular stream or lake during a particular season which to a substantial degree do not interbreed with any group spawning at a different time.
Streamflow	Streamflow refers to the rate and volume of water flowing in various sections of the river. Streamflow records are compiled from measurements taken at particular points on the river.
Stressors	Biological, physical, or chemical conditions and ecological processes, such as disease, riparian alteration or sediment, that apply stress on the fish and limit viability.

Technical Recovery Team (TRT)	Teams convened by NOAA Fisheries to develop technical products related to recovery planning. Technical Recovery Teams are complemented by planning forums unique to specific states, tribes, or regions, which use TRT and other technical products to identify recovery actions.
Threatened Species	A species likely to become endangered within the foreseeable future throughout all or a significant portion of its range.
Threats	Human activities or natural events (e.g., road building, floodplain development, fish harvest, hatchery influences, volcanoes) that cause or contribute to limiting factors. Threats may exist in the present or be likely to occur in the future.
Viability criteria	Criteria defined by NOAA Fisheries-appointed Technical Recovery Teams based on the biological parameters of abundance, productivity, spatial structure, and diversity, which describe a viable salmonid population (VSP) (an independent population with a negligible risk of extinction over a 100-year time frame) and which describe a general framework for how many and which populations within an ESU should be at a particular status for the ESU to have an acceptably low risk of extinction. See SCA section 7.3 for a discussion of how TRT information is considered in these biological opinions.
Viability Curve	A curve describing combinations of abundance and productivity that yield a particular risk of extinction at a given level of variation over a specified time frame.
Viable Salmonid Population (VSP)	An independent population of any Pacific salmon or steelhead that has a negligible risk of extinction due to threats from demographic variation (random or directional), local environmental variation, and genetic diversity change (random or directional) over a 100-year time frame.
VSP Parameters	Abundance, productivity, spatial structure, and diversity. These describe characteristics of salmonid populations that are useful in evaluating population viability. See NOAA Technical Memorandum NMFS-NWFSC-42, Viable salmonid populations and the recovery of evolutionarily significant units (McElhany et al. 2000).

Appendix 2. Background to Abundance and Productivity Targets

Abundance and Productivity Recovery Goals for Puget Sound steelhead

Joseph Anderson, WDFW
Phil Sandstrom, WDFW
Neala Kendall, WDFW
Ken Currens, NWIFC
Jim Scott, WDFW
Jeff Hard, NOAA
Anne Marshall, WDFW

DRAFT
October 26 2017

Development of recovery goals is fundamentally a science-informed policy decision. Science can provide information on patterns of abundance, productivity, spatial structure and diversity, but it cannot determine the levels of these metrics that an agency, tribe, or society hopes to achieve. At their core, recovery goals are a value judgment -- more abundant and diverse steelhead are desirable; how many are enough and what level of diversity do we want to conserve?

Here, we describe our overall approach to establishing abundance and productivity goals for Puget Sound steelhead recovery. First, we estimate historical abundance of 32 populations based on fishery data collected in 1895. Next, we express recovery goals as a percentage of that historical abundance. We use the concept of "properly functioning conditions" to identify the fraction of historical abundance that would likely represent a healthy ecosystem for Puget Sound steelhead. Next, we describe a method for expressing recovery goals as a series of curves relating freshwater intrinsic productivity (smolts per spawner), freshwater capacity, and marine survival. Finally, we present current estimates of these same population parameters to provide a perspective on current population status relative to recovery goals.

Historical abundance

Methods

Historical Puget Sound steelhead abundance estimates are best represented by fishery catch data because time series of spawner abundance are only available since the late 1970s. Hard et al. (2007) and Gayeski et al. (2011) both provide estimates of Puget Sound winter steelhead abundance (catch plus spawner abundance) using commercial fishery data from its peak harvest in 1895. Although these authors use the same original fishery data, they arrived at different estimates of steelhead abundance, with Gayeski et al.'s point estimate of 621,700 exceeding the range of 327,592 – 545,987 reported by Hard et al. (2007). This discrepancy can be explained by differences in assumptions within each analysis: Gayeski et al. (2011) assumed smaller-bodied steelhead and larger unreported catch than Hard et al. (2011). To encompass the range of possible values, we use the midpoint of Hard et al.'s (2007) analysis (436,790) and the Gayeski et al. (2011) model estimate (621,700) to bound our analysis.

Gayeski et al. (2011) present estimates for four major northern Puget Sound watersheds (Nooksack, Skagit, Stillaguamish, and Snohomish) plus the "remainder of Puget Sound" (Table A2-1). The four northern watersheds represent 14 historical populations identified by Myers et al. (2015). Similarly, the "remainder of Puget Sound" group includes 18 historical populations, primarily from central and southern Puget Sound, Hood Canal, the U.S. portion of the Strait of Juan de Fuca, plus the Samish River and Drayton Harbor tributaries in northern Puget Sound. Hard et al. (2007) provided only a single estimate for total Puget Sound abundance.

It is important to note that some decline in abundance may have occurred prior to the peak harvest observed in 1895. Gayeski et al. (2011) note that commercial fishing began in 1853, was initially centered in the Seattle-Tacoma area, and subsequently expanded northward. As a result, estimates circa 1895 for the major river systems in central and southern Puget Sound, chiefly the Green, Puyallup and Nisqually Rivers, may be underestimated in the "rest of Puget Sound" group.

We proportionally allocated historical abundance estimates to the 32 constituent Puget Sound steelhead populations based estimates of historical habitat availability. To map historical steelhead distribution, we started with the steelhead distribution within NOAA's 100K intrinsic potential layer (see Appendix C, Hard et al. 2015) and modified it based on the feedback from Puget Sound steelhead biologists. Input on steelhead distribution was provided in a series of meetings (Table A2-2) in which biologists' provided comments on a steelhead distribution map, specifying which reaches to add or remove based on their knowledge of each watershed.

Although describing steelhead distribution more than 100 years ago was an inherently challenging task, several key guidelines directed the exercise. First, our goal was to develop a coarse estimate of steelhead habitat, commensurate with the degree of uncertainty in the Gayeski et al. (2011) and Hard et al. (2007) estimates of historical abundance. We were primarily concerned with the differences between small vs. large watersheds. Second, we generally erred on the side of inclusion. We reasoned that if a stream or reach was historically accessible to anadromous fish, and is currently known or thought to support resident trout (*O. mykiss or O. clarkii*), it was likely historically occupied by steelhead. Finally, we relied on local biologists' knowledge of natural barriers to define the upstream extent of steelhead distribution.

This exercise resulted in a total length of stream km of historical steelhead habitat. Hard et al.'s (2015) historical steelhead estimate was allocated proportionally across all populations in the DPS, concordant with the scale of the abundance estimate. By contrast, Gayeski et al. (2011) estimated steelhead abundance within four major north Puget Sound watersheds plus the "rest of Puget Sound"; we allocated abundance to populations according to proportional estimates of habitat availability within these five population groupings.

Although the harvest data are from fisheries that specifically targeted winter steelhead, we included summer-run populations in our analysis for several reasons. First, the total quantity of habitat estimated in the five summer-run populations was a small proportion of the total (1.9 %), so this had a relatively small impact on the estimated abundance of winter populations. Furthermore, the uncertainty in the estimates of historical abundance exceeded the estimated abundance of the summer-run populations. In other words, the number of summer-run fish subtracted from the total winter-run estimate remained within the estimated range of the winter populations. Finally, we sought consistency in our estimates of historical abundance and hence recovery goals, and thus we did not want to pursue different methods for different populations.

Results

Population scale estimates of historic abundance ranged from 530 – 120,343 (Table A2-3, A2-4, and A2-5). However, relatively few populations, predominantly those associated large mainstem Puget Sound rivers (e.g., Nooksack, Skagit, Stillaguamish, Snohomish/Skykomish Rivers), had estimates exceeding 30,000 adult steelhead. However, conglomerate populations encompassing many small streams over a wide geographic area also had large abundances, in some cases exceeding large river systems (e.g., South Sound Tributaries > Nisqually). Within the Nooksack, Skagit, Stillaguamish and Snohomish basins, estimates based on Gayeski et al. (2011) were substantially larger than those based on Hard et al. (2007). However, for populations within the rest of Puget Sound, estimates based on Hard et al. (2007) were larger than those based on Gayeski et al. (2011). This was because the Hard et al. (2007) estimates were allocated proportionally across the entire Puget Sound region, whereas the Gayeski et al. (2011) estimates were allocated within five geographic groupings. Populations within the "rest of Puget Sound" group represented 57 percent of the total habitat, but only 30 percent of the total Puget Sound abundance estimated by Gayeski et al. (2011).

Recovery goals as a proportion of historical abundance

Our approach to recovery goal setting relies on identifying a proportion of estimated historical steelhead abundance that can be supported by healthy terrestrial, freshwater, and marine ecosystems within Puget Sound. To quantify this proportion, we rely on the policy precedent set by Puget Sound Chinook salmon recovery goals. The process to Chinook salmon recovery goals used the Ecosystem Diagnosis Treatment (EDT) model to estimate productivity and capacity under current conditions, properly functioning conditions, and historical conditions. Estimates for properly functioning conditions were used to set Puget Sound Chinook salmon recovery goals.

In the case of Puget Sound steelhead, we use the ratio of properly functioning to historical conditions to begin the discussion of recovery goals (Table A2-4). Although we do not have EDT runs to estimate properly functioning conditions for steelhead, the Chinook salmon properly functioning to historical conditions ratio, when applied to the estimates of historical steelhead abundance presented here, provides recovery goals that combine available steelhead information with an established policy precedent. Estimates of the ratio of properly functioning to historical conditions typically range from 60 – 75 percent across Puget Sound (Table A2-6).

We acknowledge that EDT is sensitive to parameter inputs (McElhany et al. 2010) and is not embraced throughout the salmon recovery community. However, in this case, we emphasize the policy nature of the recovery goal exercise, which places a value judgment on the abundance and diversity of fish. EDT was used to arrive at Chinook salmon recovery goals, and we are merely using the foundation of Chinook salmon goals to initiate the discussion for steelhead.

Expressing recovery goals in terms of freshwater productivity and marine survival

Although expressing recovery goals as adult abundance has the benefit of simplicity, articulating recovery goals in terms of life-stage specific demographic parameters can help identify which portions of the life cycle to focus on in order to achieve recovery goals. Below, we describe a procedure for relating historical abundance estimates to freshwater productivity (intrinsic productivity and capacity) and marine survival. This approach permits use of the life-cycle model developed to inform recovery strategies because the model is parameterized in terms of these same metrics.

https://pugetsoundlcm.shinyapps.io/Steelhead/

First, we set historical abundance as equilibrium spawner abundance (S_0) of the stock-recruit curve. This is the point at which the population is neither increasing nor decreasing. For a given marine survival rate and value of intrinsic productivity, S_0 is the value of spawners where the replacement line crosses the stock-recruit curve (Figure A2-1).

Given S_0, the number of smolts (R), a marine survival rate (m), and an intrinsic productivity (a), one can calculate capacity (b) and use this relationship to express a recovery goal as a curve.

Specifically, for the replacement line:

$$R * m = S_0 \qquad \text{Equation 1}$$

For the Beverton-Holt curve:

$$R = \frac{aS_0}{1+\frac{a}{b}S_0} \qquad \text{Equation 2}$$

To calculate capacity at equilibrium (where stock-recruit curve crosses replacement line), rearrange equation 1 and set equal to equation 2:

$$\frac{S_0}{m} = \frac{aS_0}{1+\frac{a}{b}S_0} \qquad \text{Equation 3}$$

Solve for capacity (*b*):

$$b = \frac{S_0 a}{am-1} \qquad \text{Equation 4}$$

Using this approach, for a given S_0, one can calculate a range of stock-recruit curves that vary according to intrinsic productivity, capacity, and marine survival (Figure A2-2). In this exercise, we chose a values to represent the median (a = 110) and 80 percent credible interval (a = 56 – 245) described by Buehrens (2016), who conducted a hierarchical analysis of spawner-smolt data from 15 populations of steelhead in Western Washington using the Beverton-Holt function.

Furthermore, one can rearrange equation 4 to solve for *m*.

$$m = \frac{1+S_0\frac{a}{b}}{a} \qquad \text{Equation 5}$$

Thus, for a given S_0 and an assumed intrinsic productivity (a), one can calculate the relationship between marine survival (*m*) and smolt capacity (*b*). This allows us to express a recovery goal curve as a function of both *m* and *b* (Figure A2-3).

Given an estimated range of historical abundance, one can generate a series of recovery goal curves, similar to those in Figure A2-3, for each population of Puget Sound steelhead.

Current estimates of freshwater productivity and marine survival in Puget Sound steelhead populations

In outlining a path to recovery, one must consider the improvement in population demographic parameters required to reach a recovery goal. Comparing current estimates of freshwater intrinsic productivity, freshwater capacity, and marine survival to those described by a recovery goal curve will quantify the degree of improvement in any of the three variables needed to reach recovery goals. Furthermore, a life-cycle model was developed to explore scenarios in which these parameters incrementally increase towards recovery goals (Sandstrom et al. in prep).

Below we describe estimates of contemporary freshwater intrinsic productivity, freshwater capacity, and marine survival**.**

Freshwater intrinsic productivity

The most comprehensive assessment of intrinsic productivity relevant to Puget Sound steelhead is the hierarchical stock-recruit analysis conducted by Buehrens (2017). Using spawner-smolt data from 15 steelhead populations in western Washington, Buehrens (2017) estimated intrinsic productivity using hockey stick and Beverton-Holt stock-recruit models. A series of covariates were used to account for differences in habitat availability among watersheds. The hockey stick function produced a median estimate of productivity of 63 (80% credible interval = 35 – 124) whereas the Beverton-Holt models produced a median intrinsic productivity estimate of 110 (80% CI = 56 – 245).

Freshwater capacity

We present several different approaches to estimating steelhead populations' smolt capacity, or the density dependent limits on smolt abundance. Many of these approaches are applied in systems beyond the location where they were initially developed or where data were collected, but all approaches were intended to estimate potential production of a watershed.

It is important to note that these methods operate at different scales. Consequently, the scale of fish and habitat data required to estimate capacity also varies by method. Similarly, the resolution of capacity estimates, and the ability to provide prescriptive diagnosis of the actions needed to achieve recovery, also varies according to the scale of each method. Of the methods described below, the Buehrens (2017) stock-recruit analysis and PSSTRT estimates operate at the coarsest scale – they can be widely applied throughout Puget Sound but also lack information specific to reaches or tributaries. The Ecosystem Diagnosis Treatment (EDT) model and habitat-stratified juvenile density methods operate at the finest spatial scale and have the ability to identify specific reaches or tributaries where restoration might increase capacity.

Below, we provide an overview of the approaches to estimating capacity presented in Tables A2-8, A2-9, and A2-10.

<u>Hierarchical stock-recruit</u> – As described above, Buehrens (2017) developed a stock-recruit analysis based on spawner-smolt data from 15 steelhead populations in western Washington. Because the analysis employed covariates describing habitat availability, the model can be used to estimate capacity in basins without spawner and smolt monitoring data. These predictions, for both the hockey stick and Beverton-Holt models, are presented in Tables A2-8, A2-9 and A2-10.

<u>Habitat stratified juvenile densities</u> – In this approach, juvenile steelhead densities are measured empirically in a subset of each of several habitat classes. Then, for each class, this density estimate is multiplied by the area of habitat available. Finally, total areas are summed across habitat classes for each watershed (Beechie et al. 1994).

The major advantages of this approach is that it uses existing habitat data, can identify specific geographic locations and actions for restoration, and predicts ensuing increases in capacity (Beechie et al. 2014). Through recent advances in spatial analysis and imaging, the use of high-quality GIS layers or aerial photography can provide a high-resolution assessment habitat availability within a watershed. The habitat stratified juvenile densities approach is currently being used by the Skagit River steelhead recovery working group to estimate capacity and potential increases to capacity afforded by restoration.

Several estimates of capacity, those of Gibbons et al. (1985) and Hard et al. (2015), are essentially special cases of habitat stratified juvenile densities.

<u>Gibbons et al. (1985)</u> –In an effort to establish maximum sustainable harvest steelhead escapement goals for Western Washington populations, Gibbons et al. (1985) developed a method to estimate total potential parr production for river systems or sub-basins in western

Washington. Their goal was to then equate this value with the number of spawners needed to produce the parr, followed by the establishment, with tribal co-managers, of escapement goals per steelhead management unit.

Gibbons et al. (1985) estimated parr production separately for drainages they defined as tributaries or as river mainstems. For tributaries, they used empirical data on parr density available from earlier studies and calculated average values per river system. They collected parr density data for river mainstem areas by surveying in August and September 1984 under summer low-flow conditions. Based on results showing that parr densities increased with increasing gradient, they used average parr densities for specific gradient zones when calculating total system parr production. Data for river or stream lengths and widths per gradient zone were used to calculate total available area for parr production. Average parr per 100 m^2 values that they generated for tributary areas and for mainstem areas were applied to calculated available area of either habitat type to estimate total parr production per drainage. Total potential parr production was calculated for eight Puget Sound river systems: Nooksack, Samish, Skagit, Snohomish, Green, Puyallup, Nisqually, and Skokomish (see Table 15 in Gibbons et al. 1985).

Average parr density values for some tributary areas and for mainstem gradient zones were changed in 1986 and these values were documented in Washington Department of Game memos (Gibbons 1986). Total parr production was recalculated for the eight Puget Sound river systems mentioned above, and for six other systems or rivers (Stillaguamish, Lake Washington, Tahuya, Dewatto, Morse Creek and Elwha Rivers). Tables in the March 1986 memo (Gibbons 1986) also provide total parr production estimates for subbasins within systems (e.g., South Fork Nooksack; Snoqualmie; Cedar) that correspond to Puget Sound recovery populations.

Gibbons et al. (1985) used total potential parr production estimates to modify (“adjust”) a Beverton-Holt spawner-recruits equation to produce estimates of number of spawners for maximum sustained yield or harvest. In a 1986 Washington Department of Game memo, based on changes to parr production estimates mentioned above and their application to their spawner-recruits model, Gibbons et al. (1985) proposed escapement goals for 14 Puget Sound systems. They did not report any evaluation or modeling of parr to smolt survival per river or of smolt to adult (marine) survival. Escapement estimates produced were single values with no estimates of uncertainty.

The total parr production estimation process of Gibbons et al. (1985) is perhaps strongest where empirical parr density estimates for tributaries were available over multiple years (several streams draining to Strait of Juan de Fuca, and tributaries of Green River and Puyallup River). Mainstem area parr production estimates were available for only one year, and, for Puget Sound, only from the Green, Snoqualmie, and Tolt Rivers and South Prairie Creek (in Puyallup basin). No confidence limits were calculated for averages from multi-year parr density estimates for tributaries. Applying the point estimates for average parr density from this base to other Puget Sound localities may not have yielded accurate total potential parr production estimates. For example, the Nisqually River total parr production estimate, 64,924 (Gibbons 1986) is essentially identical to the average Nisqually River smolt production over five recent years (64,782 smolts, 2009-2013).

Data on parr production values for Puget Sound rivers that were observed during the 1980s would provide valuable information for evaluating and determining recovery goals. While some of the data presented in Gibbons et al. (1985) are likely to be useful reference points, others may involve too much uncertainty. We treat these estimates as 'current' rather than 'historical' because they are based on densities measured in the 1980s, nearly 100 years after the 1895 historical abundance estimates presented in Tables A2-3, A2-4 and A2-5. It would be very useful to measure current parr production in selected Puget Sound drainages for comparisons with the earlier estimates, as parr production and density per habitat types are important indicators of habitat quality and potential for recovery to desired spawner levels.

In our presentation of Gibbons et al. (1985) parr production estimates, we made no effort to adjust for parr-to-smolt survival due to a lack of data. Thus, one might expect the Gibbons et al. (1985) estimates of parr capacity to exceed estimates of smolt capacity.

Hard et al. (2015) TRT estimates – The Puget Sound Steelhead Technical Recovery Team (TRT) estimated freshwater smolt production using an intrinsic potential (IP) model adapted to Puget Sound streams and applied to historical populations in the DPS (Hard et al. 2015; see Appendix C). This approach used a stream habitat rating matrix and an average value of parr production per square meter. The habitat matrix was built on three stream gradient classes and three bank-full width classes with the nine resulting habitat categories rated for high, medium, or low parr production potential. Parr productivity relationships with Puget Sound stream characteristics reported by Gibbons et al. (1985) informed the habitat ratings. The TRT only used the total amount of habitat (m^2) in the medium and high production categories to estimate parr production. An average parr/m^2 value was calculated from three published estimates including a value from Gibbons et al. (1985). Total parr production for the estimated amount of habitat was multiplied by a parr-to-smolt survival value of 0.30 (Chapman 1981) to calculate total smolts that a given habitat would yield. Several potential SAR rates (1%, 5%, and 20%) were applied to total smolt estimates to provide total adult return values representing different viability thresholds. For example, for recovery planning purposes the TRT suggested that calculations using a 5 percent SAR provided a reasonable estimate of the abundance threshold for a viable population (Hard et al. 2015).

An advantage to the TRT approach is that it can be uniformly applied across the entire DPS. Furthermore, this approach allows for considerations of habitat improvement or reconnection through the use of the IP model and geographic information system (GIS) mapping capabilities. Drawbacks of this approach are that it makes broad assumptions of parr densities throughout Puget Sound despite considerable variation in habitat quality in this region, does not deal with variation in parr–to-smolt survival, and there are no estimates of variation around the point estimates. We treat these TRT estimates as a blend between historical and current: the IP model represents landscape attributes that are associated with historical land condition, but the fish densities are more representative of contemporary observations than historical populations in the late 19th century.

Gayeski et al. (2016) – Gayeski et al. (2016) used a life-table approach to estimate the number of smolt produced in the Stillaguamish River circa 1895. The authors used the modal historical adult run size of 69,000 circa 1895 estimated by Gayeski et al. (2011), combined with a series of data-informed assumptions regarding fecundity and life-stage specific survival, to estimate watershed capacity of steelhead parr and smolts. The authors also compared estimates of historical parr rearing densities to contemporary estimates, concluding that enhancing capacity in mainstem and tributary habitats has substantial potential to benefit recovery efforts.

Ecosystem Diagnosis Treatment (EDT) – EDT has been widely applied in salmon recovery planning. The Nisqually recovery plan followed a similar method as the Puget Sound TRT viability analysis. Smolt capacity was estimated based upon the quantity of available habitat. Marine survival has the potential to impact smolt capacity in that when survival is high, fish are allowed to spawn in lower quality habitat and when marine survival is low, fish are assumed to only spawn in higher quality habitat (Nisqually Steelhead Recovery Team 2014).

One of the strengths of EDT is that it is prescriptive and focuses restoration on specific geographic locations and actions. It also utilizes available habitat information. One of its weaknesses is that it is largely opinion based and requires a large number of inputs even when watershed-specific information is not available. In addition, the EDT approach makes no estimate of variance around the smolt capacity point estimate.

Marine survival

Data used to estimate rates of Puget Sound steelhead marine survival, specifically smolt-to-adult return (SAR) rates, included the number of wild or hatchery smolts out-migrating to the ocean (X), the number of adults spawning in natural environments for wild populations or returning to hatcheries for hatchery ones (N), the number of wild or hatchery adult fish caught (C), and the age composition of the adults. Using the adult age data we assigned the adults to a given ocean entry years (OEY) cohort (i.e., 1980-2011). We compared the number of total adults in a given cohort ($N_i + C_i$) to the number of smolts from that OEY cohort (X_i) to estimate the SAR for that cohort:

$$SAR_i = (N_i + C_i)/X_i. \qquad \text{Equation 6}$$

SAR estimates of wild steelhead populations are sparse throughout Puget Sound (Kendall et al. 2017; Table 10). Big Beef Creek and Nisqually River have wild fish SAR estimates in recent years while only Snow Creek has wild fish SARs going back to 1978. These wild fish data provide annual SAR estimates ranging from 3.7-19.7 percent. Inclusion of hatchery SAR data, available for 10 populations, broadens the range to 0.05-19.7 percent annually.

Kendall et al. (2017) gathered SAR data not only from Puget Sound populations, but also those whose watersheds drain into the Strait of Juan de Fuca, the Pacific Ocean in Oregon and Washington, the lower Columbia River in Oregon and Washington, and Johnstone Strait in British Columbia, Canada. An analysis of which populations’ SAR time series were most similar to each other found four groupings: Puget Sound and Johnstone Strait populations, Strait of Juan de Fuca populations, coastal populations, and lower Columbia River populations. This suggests different marine survival rate patterns for Snow Creek and other Strait of Juan de Fuca steelhead than those for steelhead entering marine waters in Puget Sound proper (Kendall et al. 2017).

Linear regression analysis and examination of breakpoints in the OEY 1982-2011 SAR data (Kendall et al. 2017) also found that the average Puget Sound and Johnstone Strait steelhead SAR time series (average annual values) was best fit with four separate linear regression models: a period of decline (1982-1996), two stable periods (1997-2000 and 2001-2006), and a period of increasing values (2007-2012). However, the average Strait of Juan de Fuca steelhead SAR time series was stable during the entire period of analysis and fit best with a single linear regression model. Thus, we again find differences in the SARs of steelhead populations entering Puget Sound vs. the Strait of Juan de Fuca.

Additionally, Kendall et al. (2017) suggested a relatively small spatial scale of steelhead populations' SAR synchrony. This provides support for the hypothesis that important processes, including much of the marine mortality of steelhead smolts, occur during their early marine life. Thus, when assessing environmental conditions and factors associated with steelhead marine survival, we should examine indicators affecting steelhead in their early marine life stage and that vary at smaller spatial scales.

Moore et al. (2015) proposed that one of the primary drivers of the decline of Puget Sound steelhead populations has been poor survival during smolts' relatively brief migration within Puget Sound. Telemetry work indicates that steelhead smolts move through Puget Sound at rates of 10 to 30 km/day, and survivors are typically detected in the Strait of Juan de Fuca an average of 6.2 to 15 days, depending on their population or origin, from when they exit the river mouth (Moore et al. 2015). Despite the brief migration, Puget Sound smolts exhibit high mortality during this period (Moore et al. 2010; Goetz et al. 2014; Moore et al. 2015). By synthesizing data from multiple populations, Moore et al. (2015) demonstrated that smolt survival through Puget Sound was related to migration route, as smolts travelling greater distances within Puget Sound generally tended to experience higher mortality than those with short migrations through Puget Sound. This information, in combination with that reported by Kendall et al. (2017), suggest that further analysis of factors affecting smolts in Puget Sound will be very important.

Discussion

We present methods for establishing abundance and productivity recovery goals for Puget Sound steelhead populations. We have explored a range of methods used to generate abundance estimates necessary for this exercise. Specifically, we describe an approach to estimating historical abundance, the concept of setting recovery goals as a fraction of this historical abundance, and a method for expressing recovery goals in terms of freshwater productivity and marine survival rates. We describe current freshwater productivity and marine survival rates to put the recovery goals into perspective. However, we emphasize that the recovery goals themselves are a policy decision reflecting a desired future population status informed by the information presented here.

At some level, recovery will require viability of populations for which we do not currently have any monitoring data on abundance or productivity. A prime example is the five summer-run steelhead populations identified in the North Cascades MPG (South Fork Nooksack, Canyon, Deer, NF Skykomish, and Tolt). Adult snorkel and redd counts exist for the Tolt population; the other four do not have any consistently collected abundance monitoring data. In practice, for many populations, an evaluation of whether or not recovery goals are being met will require additional, future investment in monitoring. The quality of existing monitoring data may be a criterion for determining the role that each populations plays towards ESU-wide recovery.

Table A2-1. Historical abundance of Puget Sound steelhead, circa 1895, estimated by Gayeski et al. (2011).

Watershed	Mode	Central 90%
Nooksack	127,800	101,400 – 169,000
Skagit	86,700	70,000 – 149,000
Snohomish	153,000	114,000 – 224,000
Stillaguamish	69,200	51,700 – 100,000
Rest of Puget Sound	185,000	148,000 – 287,700

Table A2-2. List of meetings for improving accuracy of estimates of historical steelhead habitat.

Watershed(s)	Meeting Date
Nooksack, Drayton Harbor Tributaries, Samish, Bellingham Bay Tributaries	Jan 17 2017
Snohomish	Jan 30 2017
Elwha	Feb 14 2017
Stillaguamish	Feb 17 2017
Lake Washington and Green	Mar 21 2017
Dungeness, Strait of Juan de Fuca Independents, Discovery Bay Tributaries	Mar 27 2017
Nisqually, South Sound Tributaries, East Kitsap Tributaries	Mar 29 2017
Puyallup	July 28 2017

Table A2-3. Estimates of historical habitat availability and abundance within the Northern Cascades Major Population Group of Puget Sound steelhead.

			Habitat proportion		Estimated Historical Abundance	
Watershed	**Population**	**Habitat (km)**	**Across ESU**	**Within Gayeski regions**	**Hard et al. (2007)**	**Gayeski et al. (2011)**
Independent	Drayton Harbor Tribs	79	1.2%	2.1%	5,231	3,875
Nooksack	Nooksack	468	7.1%	94.2%	30,986	120,343
	SF Nooksack (summer)	29	0.4%	5.8%	1,920	7,457
Samish	Samish River + Independent Tribs	131	2.0%	3.5%	8,674	6,425
Skagit	Skagit	477	7.2%	55.2%	31,582	47,866
	Nookachamps	91	1.4%	10.5%	6,025	9,132
	Baker	83	1.3%	9.6%	5,495	8,329
	Sauk	213	3.2%	24.7%	14,103	21,374
Stillaguamish	Stillaguamish	504	7.6%	89.7%	33,370	62,058
	Canyon (summer)	8	0.1%	1.4%	530	985
	Deer (summer)	50	0.8%	8.9%	3,311	6,157
Snohomish	Snohomish/Skykomish	444	6.7%	49.0%	29,380	75,041
	Pilchuck	178	2.7%	19.7%	11,785	30,101
	Snoqualmie	247	3.7%	27.3%	16,354	41,770
	Tolt (summer)	25	0.4%	2.8%	1,655	4,228
	NF Skykomish (summer)	11	0.2%	1.2%	728	1,860

Table A2-4. Estimates of historical habitat availability and abundance within the Central and South Sound Major Population Group of Puget Sound steelhead.

Watershed	Population	Habitat (km)	Habitat Proportion: Across ESU	Habitat Proportion: Within Gayeski regions	Estimated Historical Abundance: Hard et al. (2007)	Estimated Historical Abundance: Gayeski et al. (2011)
Lake Washington	Cedar River	86	1.3%	2.3%	5,694	4,218
	North Lake Washington Tribs	346	5.2%	9.2%	22,909	16,970
Green	Green River	403	6.1%	10.7%	26,683	19,765
Puyallup	Puyallup/Carbon Rivers	326	4.9%	8.6%	21,585	15,989
	White River	259	3.9%	6.9%	17,148	12,703
Nisqually	Nisqually River	443	6.7%	11.7%	29,331	21,727
Independent	East Kitsap	188	2.8%	5.0%	12,448	9,221
	South Sound Tribs	458	6.9%	12.1%	30,324	22,463

[A] Placeholder value pending further analysis – does not reflect adjustments to map based on biologist feedback

Table A2-5. Estimates of historical habitat availability and abundance within the Hood Canal and Strait of Juan de Fuca Major Population Group of Puget Sound steelhead.

			Habitat proportion		Estimated Historical Abundance	
Watershed/Region	**Population**	**Habitat (km)**	**Across ESU**	**Within Gayeski regions**	**Hard et al. (2007)**	**Gayeski et al. (2011)**
Elwha	Elwha River	122	1.8%	3.2%	8,078	5,984
Dungeness	Dungeness River	89	1.3%	2.4%	5,893	4,365
Independent JDF	Strait Juan de Fuca Ind Tribs	108	1.6%	2.9%	7,151	5,297
	Discovery Bay Tribs	110	1.7%	2.9%	7,283	5,395
Skokomish	Skokomish River	157	2.4%	4.2%	10,395	7,700
Independent Hood Canal	West Hood Canal	181	2.7%	4.8%	11,984	8,877
	East Hood Canal	133	2.0%	3.5%	8,806	6,523
	South Hood Canal	153	2.3%	4.1%	10,130	7,504

Table A2-6. Stock-recruit productivity and capacity under properly function conditions, expressed as a proportion of historical conditions, derived from Ecosystem Diagnosis Treatment modeling in the Puget Sound Chinook salmon recovery plan.

Population	Productivity	Capacity
North Cascades		
North Fork Nooksack	59%	66%
South Fork Nooksack	67%	70%
Upper Cascade	60%	72%
Suiattle	59%	78%
Upper Sauk	64%	76%
Lower Skagit	72%	74%
Upper Skagit	61%	75%
Lower Sauk	65%	75%
North Fork Stillaguamish	68%	74%
South Fork Stillaguamish	69%	77%
Snoqualmie	77%	76%
Snohomish	72%	76%
Central and South Sound		
Puyallup	56%	59%
Nisqually	72%	80%
Hood Canal and Strait of Juan de Fuca		
Dosewallips	58%	66%
Duckabush	57%	66%
Hamma	59%	72%
Dungeness	62%	61%
Morse	59%	61%
Average	64%	71%

Table A2-7. Freshwater capacity estimates for the North Cascades MPG of Puget Sound steelhead. For the methods, HSR-HS = hierarchical stock-recruit hockey stick, HSR-BH = hierarchical stock recruit Beverton-Holt, HSJD = habitat stratified juvenile densities, HSJD-IP = habitat stratified juvenile densities based on the intrinsic potential habitat model, LCM = life cycle model.

Watershed	Population(s)	Method	Era	Life Stage	Estimate	Reference
Independent	Drayton Harbor Tribs	HSR-HS	Current	Smolt	7,495 (2,291-25,495)	A
Independent	Drayton Harbor Tribs	HSR-BH	Current	Smolt	9,241 (2,579-35,463)	A
Independent	Drayton Harbor Tribs	HSJD-IP	Current/historic	Smolt	24,300	D
Nooksack	Nooksack	HSR-HS	Current	Smolt	52,662 (16,098-179,137)	A
Nooksack	Nooksack	HSR-BH	Current	Smolt	64,928 (18,119 – 249,174)	A
Nooksack	Nooksack	HSJD-IP	Current/historic	Smolt	220,500	D
Nooksack	Nooksack	HSJD	Current	Parr	184,141	B
Nooksack	SF Nooksack (summer)	HSR-HS	Current	Smolt	2,961 (905-10,071)	A
Nooksack	SF Nooksack (summer)	HSR-BH	Current	Smolt	3,650 (1,019-14,008)	A
Nooksack	SF Nooksack (summer)	HSJD-IP	Current/historic	Smolt	1,200	D
	Samish + Bell. Bay Tribs	HSR-HS	Current	Smolt	21,357 (6,529-72,650)	A
	Samish + Bell. Bay Tribs	HSR-BH	Current	Smolt	26,332 (7,348-101,054)	A
	Samish + Bell. Bay Tribs	HSJD-IP	Current/historic	Smolt	31,900	D
Samish	Samish[1]	HSJD	Current	Parr	27,514	B
Skagit	Skagit	HSR-HS	Current	Smolt	90,926 (27,795-309,296)	A

Watershed	Population(s)	Method	Era	Life Stage	Estimate	Reference
Skagit	Skagit	HSR-BH	Current	Smolt	112,105 (31,283-430,221)	A
Skagit	Skagit	HSJD-IP	Current/historic	Smolt	647,800	D
Skagit	Nookachamps	HSR-HS	Current	Smolt	9,928 (3,035-33,770)	A
Skagit	Nookachamps	HSR-BH	Current	Smolt	12,240 (3,416-46,973)	A
Skagit	Nookachamps	HSJD-IP	Current/historic	Smolt	12,300	D
Skagit	Baker	HSR-HS	Current	Smolt	15,919 (4,866-54,152)	A
Skagit	Baker	HSR-BH	Current	Smolt	19,627 (5,477-75,323)	A
Skagit	Baker	HSJD-IP	Current/historic	Smolt	50,300	D
Skagit	Sauk	HSR-HS	Current	Smolt	36,089 (11,032-122,763)	A
Skagit	Sauk	HSR-BH	Current	Smolt	44,496 (12,417-170,759)	A
Skagit	Sauk	HSJD-IP	Current/historic	Smolt	232,300	D
Skagit	Skagit, Nookachamps, Sauk	HSJD	Current	Parr	403,682	B
Stillaguamish	Stillaguamish	HSR-HS	Current	Smolt	47,246 (14,443-160,715)	A
Stillaguamish	Stillaguamish	HSR-BH	Current	Smolt	58,251 (16,255-223,549)	A
Stillaguamish	Stillaguamish	HSJD-IP	Current/historic	Smolt	191,200	D
Stillaguamish	Stillaguamish	HSJD	Current	Parr	110,431	B
Stillaguamish	Stillaguamish	LCM	Historic	Smolt	330,397 – 577,802	C

Watershed	**Population(s)**	**Method**	**Era**	**Life Stage**	**Estimate**	**Reference**
Stillaguamish	Deer	HSR-HS	Current	Smolt	6,844 (2,092-23,279)	A
Stillaguamish	Deer	HSR-BH	Current	Smolt	8,438 (2,355-32,381)	A
Stillaguamish	Deer	HSJD-IP	Current/historic	Smolt	15,700	D
Stillaguamish	Canyon	HSR-HS	Current	Smolt	251 (77-854)	A
Stillaguamish	Canyon	HSR-BH	Current	Smolt	309 (86-1,187)	A
Stillaguamish	Canyon	HSJD-IP	Current/historic	Smolt	1,200	D
Snohomish	Snohomish/Skykomish	HSR-HS	Current	Smolt	53,170 (16,254-180,866)	A
Snohomish	Snohomish/Skykomish	HSR-BH	Current	Smolt	65,555 (18,293-251,579)	A
Snohomish	Snohomish/Skykomish	HSJD-IP	Current/historic	Smolt	213,900	D
Snohomish	Pilchuck	HSR-HS	Current	Smolt	20,052 (6,130-68,208)	A
Snohomish	Pilchuck	HSR-BH	Current	Smolt	24,722 (6,899-94,876)	A
Snohomish	Pilchuck	HSJD-IP	Current/historic	Smolt	51,900	D
Snohomish	Snoqualmie	HSR-HS	Current	Smolt	25,506 (7,797-86,762)	A
Snohomish	Snoqualmie	HSR-BH	Current	Smolt	31,447 (8,775-120,683)	A
Snohomish	Snoqualmie	HSJD-IP	Current/historic	Smolt	167,400	D
Snohomish	Snoh./Skykomish, Pilchuck, Snoqualmie	HSJD	Current	Parr	218,900	B
Snohomish	Tolt (summer)	HSR-HS	Current	Smolt	2,314 (708-7,873)	A

Watershed	Population(s)	Method	Era	Life Stage	Estimate	Reference
Snohomish	Tolt (summer)	HSR-BH	Current	Smolt	2,854 (796-10,951)	A
Snohomish	Tolt (summer)	HSJD-IP	Current/historic	Smolt	3,200	D
Snohomish	NF Skykomish (summer)	HSR-HS	Current	Smolt	735 (225-2,501)	A
Snohomish	NF Skykomish (summer)	HSR-BH	Current	Smolt	906 (253-3,478)	A
Snohomish	NF Skykomish (summer)	HSJD-IP	Current/historic	Smolt	6,600	D

1 Exclusive of Bellingham Bay independent tributaries

References

A Buehrens (2017). Uncertainty estimates represent 80% credible interval.
B Gibbons et al. (1985), with later modifications described in Bob Gibbons memo, May 28, 1986.
C Gayeski et al. (2016)
D Hard et al. (2015)

Table A2-8. Freshwater capacity estimates for the Central and South Sound Major Population Group of Puget Sound steelhead. For the methods, HSR-HS = hierarchical stock-recruit hockey stick, HSR-BH = hierarchical stock recruit Beverton-Holt, HSJD = habitat stratified juvenile densities, HSJD-IP = habitat stratified juvenile densities based on the intrinsic potential habitat model, EDT = Ecosystem Diagnosis Treatment model.

Watershed	Population(s)	Method	Era	Life Stage	Estimate	Reference
Lake Wash	Cedar River	HSR-HS	Current	Smolt	8,390 (2,565-28,538)	A
Lake Wash	Cedar River	HSR-BH	Current	Smolt	10,344 (28,86-39,695)	A
Lake Wash	Cedar River	HSJD-IP	Current/historic	Smolt	59,500	D
Lake Wash	N Lake Wash Tribs	HSR-HS	Current	Smolt	27,612 (8,441-93,924)	A
Lake Wash	N Lake Wash Tribs	HSR-BH	Current	Smolt	34,043 (9,500-13,0646)	A
Lake Wash	N Lake Wash Tribs	HSJD-IP	Current/historic	Smolt	52,700	D
Lake Wash	Cedar, N Lake Wash Tribs	HSJD	Current	Parr	49,208	B
Green	Green River	HSR-HS	Current	Smolt	32,922 (10,064-111,987)	A
Green	Green River	HSR-BH	Current	Smolt	40,590 (11,327-155,771)	A
Green	Green River	HSJD-IP	Current/historic	Smolt	197,700	D
Green	Green River	HSJD	Current	Parr	65,960	B
Puyallup	Puyallup/Carbon	HSR-HS	Current	Smolt	36,589 (11,185-124,462)	A
Puyallup	Puyallup/Carbon	HSR-BH	Current	Smolt	45,111 (12,588-173,122)	A
Puyallup	Puyallup/Carbon	HSJD-IP	Current/historic	Smolt	147,200	D
Puyallup	White River	HSR-HS	Current	Smolt	29,928 (9,149-101,803)	A

Watershed	Population(s)	Method	Era	Life Stage	Estimate	Reference
Puyallup	White River	HSR-BH	Current	Smolt	36,899 (10,297-141,605)	A
Puyallup	White River	HSJD-IP	Current/historic	Smolt	174,900	D
Puyallup	Puyallup/Carbon, White	HSJD	Current	Parr	160,813	B
Nisqually	Nisqually	HSR-HS	Current	Smolt	39,936 (12,208-135,849)	A
Nisqually	Nisqually	HSR-BH	Current	Smolt	49,239 (13,740-188,962)	A
Nisqually	Nisqually	HSJD-IP	Current/historic	Smolt	153,300	D
Nisqually	Nisqually	HSJD	Current	Parr	64,924	B
Nisqually	Nisqually	EDT	Current	Smolt	94,410	C
Nisqually	Nisqually	EDT	Historic	Smolt	131,710	C
Independents	East Kitsap	HSR-HS	Current	Smolt	5,302 (1621-18035)	A
Independents	East Kitsap	HSR-BH	Current	Smolt	6,537 (1824-25087)	A
Independents	East Kitsap	HSJD-IP	Current/historic	Smolt	15,600	D
Independents	South Sound Tribs	HSR-HS	Current	Smolt	53,940 (16,489-183,483)	A
Independents	South Sound Tribs	HSR-BH	Current	Smolt	66,504 (18,558-255,219)	A
Independents	South Sound Tribs	HSJD-IP	Current/historic	Smolt	98,500	D

Reference
A Buehrens (2017). Uncertainty estimates represent 80% credible interval.
B Gibbons et al. (1985)
C Nisqually Steelhead Recovery Team (2014)
D Hard et al. (2015)

Table A2-9. Freshwater capacity estimates for the Hood Canal and Strait of Juan de Fuca Major Population Group of Puget Sound steelhead. For the methods, HSR-HS = hierarchical stock-recruit hockey stick, HSR-BH = hierarchical stock recruit Beverton-Holt, HSJD = habitat stratified juvenile densities, HSJD-IP = habitat stratified juvenile densities based on the intrinsic potential habitat model.

Watershed	Population(s)	Method	Era	Life Stage	Estimate	Reference
Elwha	Elwha	HSR-HS	Current	Smolt	15,435 (4718-52505)	A
Elwha	Elwha	HSR-BH	Current	Smolt	19,031 (5,311-73,033)	A
Elwha	Elwha	HSJD-IP	Current/historic	Smolt	71,200	D
Elwha	Elwha	HSJD	Current	Parr	5,398[1]	B
Dungeness	Dungeness	HSR-HS	Current	Smolt	7,387 (2,258-25,127)	A
Dungeness	Dungeness	HSR-BH	Current	Smolt	9,107 (2,541-34,951)	A
Dungeness	Dungeness	HSJD-IP	Current/historic	Smolt	24,600	D
Independent	Str JDF Ind Tribs	HSR-HS	Current	Smolt	5,423 (1,658-18,446)	A
Independent	Str JDF Ind Tribs	HSR-BH	Current	Smolt	6,686 (1,866-25,657)	A
Independent	Str JDF Ind Tribs	HSJD-IP	Current/historic	Smolt	7,300	D
Independent	Discovery Bay Tribs	HSR-HS	Current	Smolt	4,687 (1,433-15,942)	A
Independent	Discovery Bay Tribs	HSR-BH	Current	Smolt	5,778 (1,612-22,175)	A
Independent	Discovery Bay Tribs	HSJD-IP	Current/historic	Smolt	5,100	D
Skokomish	Skokomish	HSR-HS	Current	Smolt	14,534 (4,443-49,440)	A
Skokomish	Skokomish	HSR-BH	Current	Smolt	17,919 (5,000-68,769)	A

Watershed	Population(s)	Method	Era	Life Stage	Estimate	Reference
Skokomish	Skokomish	HSJD-IP	Current/historic	Smolt	100,300	D
Skokomish	Skokomish	HSJD	Current	Parr	41,013	B
Independent	West Hood Canal	HSR-HS	Current	Smolt	12,736 (3,893-43,324)	A
Independent	West Hood Canal	HSR-BH	Current	Smolt	15,703 (4,382-60,262)	A
Independent	West Hood Canal	HSJD-IP	Current/historic	Smolt	36,100	D
Independent	East Hood Canal	HSR-HS	Current	Smolt	5,033 (1,538-17,119)	A
Independent	East Hood Canal	HSR-BH	Current	Smolt	6,205 (1,731-23,812)	A
Independent	East Hood Canal	HSJD-IP	Current/historic	Smolt	12,700	D
Independent	East Hood Canal[2]	HSJD	Current	Parr	4,976	A
Independent	South Hood Canal	HSR-HS	Current	Smolt	9,049 (2,766-30,783)	A
Independent	South Hood Canal	HSR-BH	Current	Smolt	11,157 (3,113-42,818)	A
Independent	South Hood Canal	HSJD-IP	Current/historic	Smolt	29,900	D
Independent	South Hood Canal[3]	HSJD	Current	Parr	8,519	A

1 Estimate restricted to area downstream of former Elwha Dam site.
2 Estimate restricted to Dewatto River.
3 Estimate restricted to Tahuya River.

References

A Buehrens (2017). Uncertainty estimates represent 80% credible interval.
B Gibbons et al. (1985)
D Hard et al. (2015)

Table A2-10. Geometric mean (geomean) and standard error of the mean (SE) smolt-to-adult return (SAR) rates estimated by Kendall et al. 2017for wild and hatchery Puget Sound steelhead populations with available data during five time periods between 1977 and 2013.

Population	Years	Geomean	SE
All	1977-1986	3.79%	0.53%
All	1987-1996	1.18%	0.31%
All	1997-2000	0.93%	0.47%
All	2001-2006	0.51%	0.13%
All	2007-2013	0.70%	0.30%
Big Beef Creek winter-run wild	1977-1986		
Big Beef Creek winter-run wild	1987-1996		
Big Beef Creek winter-run wild	1997-2000		
Big Beef Creek winter-run wild	2001-2006	3.06%	1.76%
Big Beef Creek winter-run wild	2007-2013	1.92%	1.90%
Elwha River winter-run hatchery	1977-1986	4.13%	NA
Elwha River winter-run hatchery	1987-1996	2.03%	0.99%
Elwha River winter-run hatchery	1997-2000	0.61%	0.10%
Elwha River winter-run hatchery	2001-2006	0.51%	NA
Elwha River winter-run hatchery	2007-2013		
Green River summer-run hatchery	1977-1986		
Green River summer-run hatchery	1987-1996	0.64%	0.27%
Green River summer-run hatchery	1997-2000	0.81%	0.13%
Green River summer-run hatchery	2001-2006	0.69%	0.14%
Green River summer-run hatchery	2007-2013	0.88%	0.27%
Green River winter-run hatchery	1977-1986	5.00%	0.94%
Green River winter-run hatchery	1987-1996	0.93%	0.16%
Green River winter-run hatchery	1997-2000	0.51%	0.09%
Green River winter-run hatchery	2001-2006	0.43%	0.10%
Green River winter-run hatchery	2007-2013	0.31%	0.12%
Nisqually River winter-run wild	1977-1986		
Nisqually River winter-run wild	1987-1996		
Nisqually River winter-run wild	1997-2000		
Nisqually River winter-run wild	2001-2006		
Nisqually River winter-run wild	2007-2013	0.79%	0.61%
Nooksack River winter-run hatchery	1977-1986		
Nooksack River winter-run hatchery	1987-1996		
Nooksack River winter-run hatchery	1997-2000	1.27%	0.22%
Nooksack River winter-run hatchery	2001-2006	0.39%	0.11%
Nooksack River winter-run hatchery	2007-2013	0.16%	0.05%
Puyallup River winter-run hatchery	1977-1986	2.49%	0.76%
Puyallup River winter-run hatchery	1987-1996	0.45%	0.11%
Puyallup River winter-run hatchery	1997-2000	0.19%	0.04%
Puyallup River winter-run hatchery	2001-2006	0.11%	0.03%
Puyallup River winter-run hatchery	2007-2013		
Samish River winter-run hatchery	1977-1986	1.84%	0.60%

Population	Years	Geomean	SE
Samish River winter-run hatchery	1987-1996		
Samish River winter-run hatchery	1997-2000		
Samish River winter-run hatchery	2001-2006		
Samish River winter-run hatchery	2007-2013		
Skagit River winter-run hatchery	1977-1986	2.44%	0.30%
Skagit River winter-run hatchery	1987-1996	0.88%	0.33%
Skagit River winter-run hatchery	1997-2000	0.33%	0.13%
Skagit River winter-run hatchery	2001-2006	0.28%	0.05%
Skagit River winter-run hatchery	2007-2013	0.33%	0.10%
Snohomish River summer-run hatchery	1977-1986		
Snohomish River summer-run hatchery	1987-1996	2.11%	0.16%
Snohomish River summer-run hatchery	1997-2000	2.28%	0.32%
Snohomish River summer-run hatchery	2001-2006	1.12%	0.14%
Snohomish River summer-run hatchery	2007-2013	1.83%	0.34%
Snohomish River winter-run hatchery	1977-1986	3.65%	NA
Snohomish River winter-run hatchery	1987-1996	2.18%	0.63%
Snohomish River winter-run hatchery	1997-2000	1.75%	0.41%
Snohomish River winter-run hatchery	2001-2006	1.27%	0.23%
Snohomish River winter-run hatchery	2007-2013	0.87%	0.28%
Snow Creek winter-run wild	1977-1986	6.02%	1.04%
Snow Creek winter-run wild	1987-1996	2.98%	1.56%
Snow Creek winter-run wild	1997-2000	4.88%	4.16%
Snow Creek winter-run wild	2001-2006	1.61%	0.74%
Snow Creek winter-run wild	2007-2013	2.98%	0.72%
Stillaguamish River summer-run hatchery	1977-1986		
Stillaguamish River summer-run hatchery	1987-1996	0.30%	NA
Stillaguamish River summer-run hatchery	1997-2000	1.41%	0.95%
Stillaguamish River summer-run hatchery	2001-2006	0.15%	0.02%
Stillaguamish River summer-run hatchery	2007-2013	0.25%	0.12%
Stillaguamish River winter-run hatchery	1977-1986		
Stillaguamish River winter-run hatchery	1987-1996	0.42%	0.12%
Stillaguamish River winter-run hatchery	1997-2000	1.01%	0.18%
Stillaguamish River winter-run hatchery	2001-2006	0.55%	0.04%
Stillaguamish River winter-run hatchery	2007-2013	0.24%	0.13%

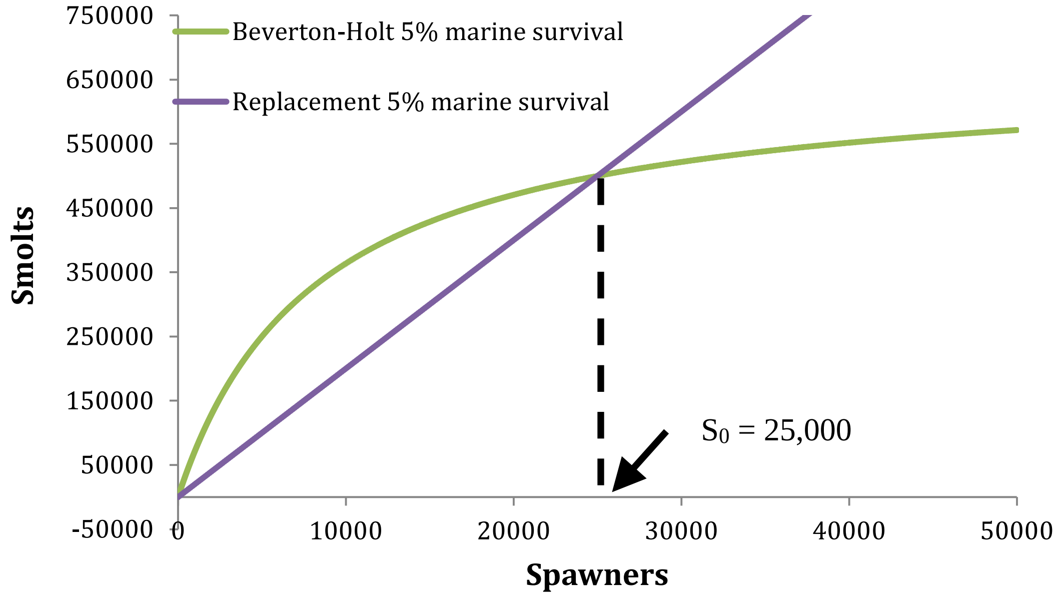

Figure A2-1. Equilibrium abundance (S0) on a Beverton-Holt stock recruit curve, assuming 5% marine survival, an intrinsic productivity of 110 smolts / spawner, and a historical abundance of 25,000 adult steelhead.

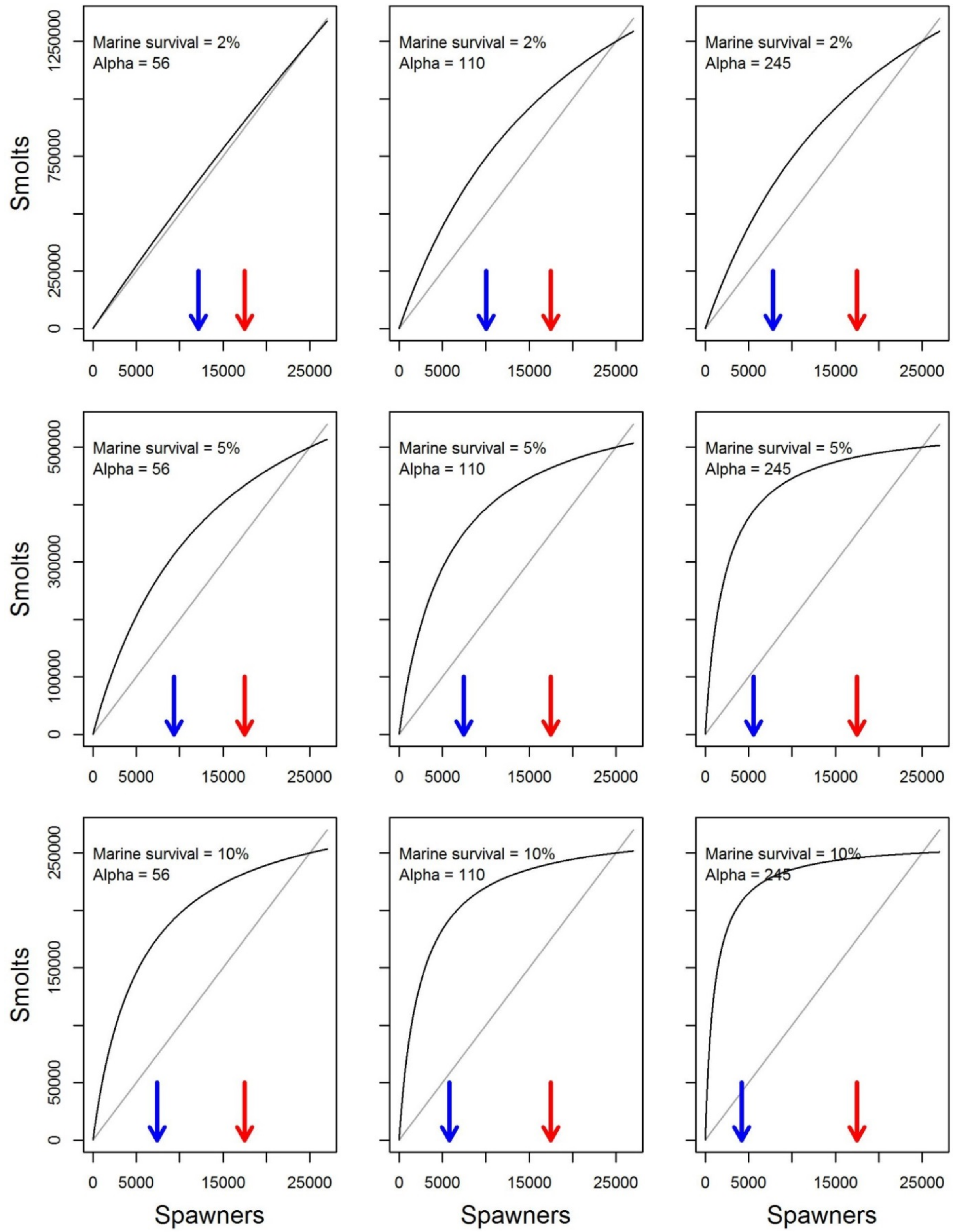

Figure A2-2. Stock recruit curves for historical abundance (S0)=25,000 adult steelhead. Red arrows represent spawners at 70% of historical abundance (S0), blue arrows represent spawners at MSY.

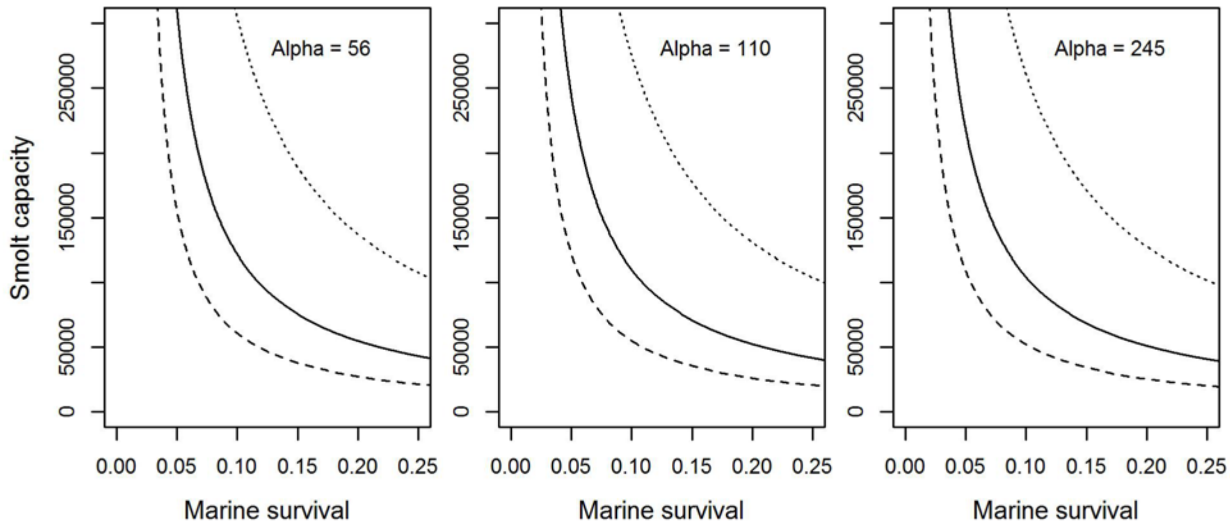

Figure A2-3. Recovery goal curves for Puget Sound steelhead reflecting different combinations of smolt capacity and marine survival across a range of alpha values. In each plot, dashed line (S0)=5,000, solid line (S0)=10,000, and dotted line (S0)=25,000.

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Appendix 3. Puget Sound Steelhead Early Marine Mortality: Adaptive Management Strategies and Actions

Report by Michael Schmidt and Susan O'Neil – Long Live the Kings

With reference to the work of and with support by members of the Puget Sound Steelhead Marine Survival Workgroup of the Salish Sea Marine Survival Project

Contents reviewed by the Puget Sound Steelhead Marine Survival Workgroup and Salish Sea Marine Survival Project Coordinating Committee

Puget Sound Steelhead Marine Survival Workgroup (all research phases, combined)

Barry Berejikian, NOAA Northwest Fisheries Science Center
Chris Ellings, Nisqually Indian Tribe
Ed Connor, Seattle City Light
Erik Neatherlin, Washington Department of Fish and Wildlife
Jed Moore, Nisqually Tribe
Joseph Anderson, Washington Department of Fish and Wildlife
Ken Warheit, Washington Department of Fish and Wildlife
Matt Klungle, Washington Department of Fish and Wildlife
Martin Chen, Contractor
Megan Moore, NOAA Northwest Fisheries Science Center
Neala Kendall, Washington Department of Fish and Wildlife
Paul Hershberger, US Geological Survey, Marrowstone Marine Field Station
Sandra O'Neill, Washington Department of Fish and Wildlife
Scott Pearson, Washington Department of Fish and Wildlife
Steve Jeffries, Washington Department of Fish and Wildlife

Salish Sea Marine Survival Project Coordinating Committee

David Troutt, Nisqually Tribe
Erik Neatherlin, Washington Department of Fish and Wildlife
G.I. James, Lummi Nation
Jacques White, Long Live the Kings
Jill Rolland, US Geological Survey Western Region Fisheries Research Center
Ken Currens, Northwest Indian Fisheries Commission
Kevin Werner, NOAA Northwest Fisheries Science Center
Paul McCollum, Port Gamble S'Klallam Tribe
Penny Dalton, Washington Sea Grant, U. of Washington
Peter Murchie, Environmental Protection Agency
Scott Redman, Puget Sound Partnership
Terry Williams, Tulalip Tribes
Alan Chapman (alternate), Lummi Nation
Lisa Chang (alternate), Environmental Protection Agency
Mark Strom (alternate), NOAA Northwest Fisheries Science Center
Mike Crewson (alternate), Tulalip Tribes

Background on adaptively managing early marine mortality

This document serves as the formal report to summarize the current state of knowledge on Puget Sound steelhead early marine mortality. The early marine mortality of Puget Sound steelhead smolts is considered a primary limiting factor. This appendix describes a hypothesis-driven approach to address the causes of low early marine survival via an adaptive management framework. The information below represents our best understanding of the issue as of fall 2018, which aligns with deadlines related to NOAA's steelhead recovery plan. The strategies and actions in the recovery plan and elaborated upon in this appendix are built around the need to test and evolve management actions while continuing to build our understanding of early marine mortality. The specific actions recommended below are those currently agreed upon to address the hypotheses with the most supporting evidence and require monitoring to test their efficacy. In addition, some are only relevant to certain DIPs or MPGs where the issue is known to exist. Other strategies are more broad or may warrant additional research before taking action. This work was coordinated by Long Live the Kings and developed, reviewed, and vetted by the Puget Sound Steelhead Marine Survival Workgroup and the Coordinating Committee of the Salish Sea Marine Survival Project. See references below and the website for updates and the most recent published findings: https://marinesurvivalproject.com/.

Severity of early marine mortality throughout Puget Sound, and what levels may facilitate recovery

High early marine mortality in Puget Sound

Puget Sound steelhead early marine mortality is generally defined as mortality that occurs as steelhead smolts (juveniles) migrate downstream and through Puget Sound to the Pacific Ocean. There are multiple lines of data suggesting that mortality occurring during the early marine phase is significantly impacting Puget Sound steelhead survival.[16]

Spatially explicit trends in steelhead abundance and smolt-to-adult survival rates (a.k.a. marine survival rates) were developed for hatchery and wild populations from Puget Sound, the Washington coast and the Columbia River, dating back to the 1970s (Kendall et al. 2017). MARSS (Multivariate Auto-Regressive State-Space) models were used to assess whether the time series trends vary among the regions. The results illustrate that Puget Sound steelhead populations have distinct trends compared to populations from other nearby regions: Puget Sound steelhead marine survival rates have generally been lower and have not varied as much.

[16] This section does not address factors affecting adult marine or freshwater mortality, or juvenile freshwater mortality above the estuary.

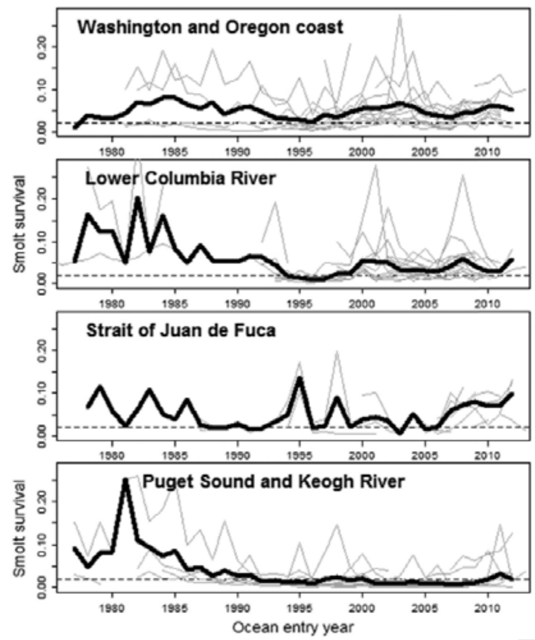

Figure A3-7. Time series of steelhead smolt survival for the four groupings supported by the MARSS model. Thin grey lines are individual population time series, while the thick black line is the mean value across all populations. A thin dashed black line at 0.02 is provided to facilitate comparison among groupings. (Figure 3. in Kendall et al 2017)

Puget Sound early marine mortality has been directly measured using acoustic telemetry. Several studies referenced in this report are dependent upon this technology (Moore et al. 2010; Moore et al. 2013; Moore et al. 2015; Moore et al. 2017; Berejikian et al. 2016; Moore unpublished data). Acoustic transmitters have been implanted in outmigrating juvenile steelhead in rivers about between 10k and 100k upstream of saltwater entry. Pings from these transmitters are received via stationary arrays that cross river mouths and at different points within Puget Sound. The last receiver line spans the Strait of Juan de Fuca at Pillar Point. The number of smolts detected at each receiver line and mark-recapture models are used to estimate spatially specific survival.

From 2006 to 2009, early marine survival rates from eight Puget Sound and Hood Canal rivers, defined here as survival from river mouth through the Strait of Juan de Fuca, ranged from 0.8% to 39.3%, and averaged 16.0% for wild smolts and 11.4% for hatchery smolts over four years (Moore et al. 2015). In 2014, early marine survival rates remained low, 5.9 ± 4.2% and 17.4 ± 7.1%, for wild steelhead released from the Nisqually and Green Rivers, respectively (Moore et al. 2017). In 2016 and 2017, early marine survival rates for Nisqually wild steelhead increased substantially, to 37.2% and 38.6%, respectively (Moore et al. unpublished data).

Locations of greatest steelhead mortality in Puget Sound

Steelhead telemetry data has also provided us some perspective regarding where early marine mortality is greatest. When early marine mortality was highest, in 2006-2009 and again in 2014 (compared to 2015-2017), steelhead smolts suffered greater rates of instantaneous mortality[17] in the south and central regions of Puget Sound (NAR and CPS to ADM receiver lines) and from the north end of Hood Canal through Admiralty Inlet (HCB to ADM receiver lines) than in other monitored migration segments (see Figure A3-2, below; Moore et al. 2015, Moore et al. 2017).

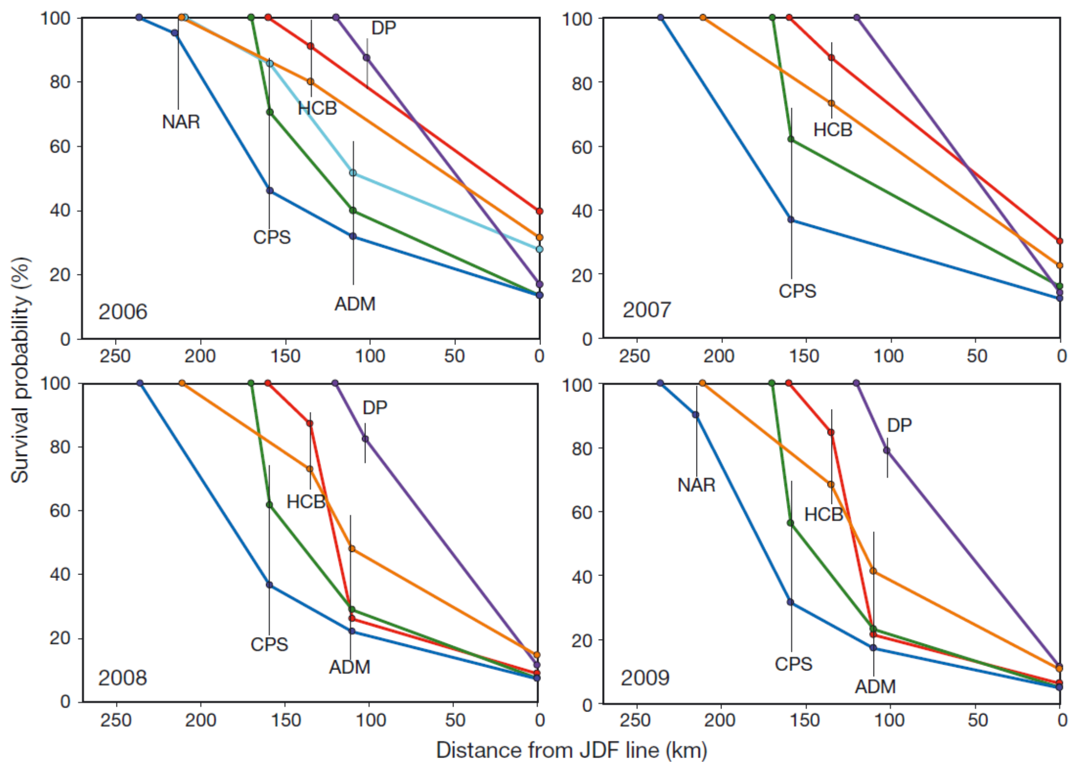

Figure A3-8. Estimated survival probabilities for steelhead plotted at each receiver array along the marine migration pathway for years 2006 to 2009. Survival estimates are shown for only wild smolts from Big Beef Creek (red), Green River (green), Nisqually River (dark blue), Skagit River (purple), Skokomish River (orange), and the Puyallup River (light blue). (Figure 5 from Moore et al. 2015)

Major Population Group Risk Assessment

To inform recovery planning, three wild steelhead populations (Nisqually, Skokomish, and Skagit) with early marine survival datasets ranging from 2006-present were chosen to assess the impact of early marine mortality on the persistence of Puget Sound steelhead, using the Steelhead Life Cycle Model[18] created for steelhead recovery planning.[19] Each population represents one of the three Puget Sound steelhead major populations groups (Northern Cascades, Central and South Puget Sound, and Hood Canal and Strait of Juan de Fuca), with

[17] Instantaneous mortality is the percent mortality per kilometer traveled, based upon the overall modeled mortality between two acoustic receiver arrays divided by the distance between those arrays.

[18] https://pugetsoundlcm.shinyapps.io/Steelhead/ - Created by Joseph Anderson and Phil Sandstrom, Washington Department of Fish and Wildlife for Puget Sound steelhead recovery planning

[19] Assessment performed by Michael Schmidt (Long Live the Kings), Joe Anderson and Neala Kendall (Washington Department of Fish and Wildlife), and Megan Moore (NOAA Fisheries).

the exception that the Skokomish population only represents Hood Canal and not both Hood Canal and the Strait of Juan de Fuca. Although index populations were chosen for the purposes of this risk assessment, data from other populations throughout Puget Sound, hatchery and wild, are available and provide additional information regarding the range of early marine survival rates experienced (Moore et al 2015; Moore et al 2017).

Adult and juvenile freshwater phase mortality was held constant and a 35-year average of open ocean survival was used to isolate the effects of early marine mortality. Open ocean survival was estimated using Washington and Oregon coastal steelhead populations where smolt-to-adult survival and downriver survival data were both present (Romer et al. 2013; Johnson et al. 2010). Downriver survival was deducted from smolt-to-adult survival, leaving estimates of open ocean survival.

Table A3-1. Ocean survival rates calculated from coastal populations.

Year	Smolt-to-adult survival (z)	Freshwater survival (x)	Ocean survival (y)
1975			
1980	0.137	0.51	0.267
1985	0.134	0.51	0.262
1990	0.107	0.51	0.209
1995	0.104	0.51	0.204
2000	0.118	0.51	0.230
2005	0.075	0.51	0.146
2010	0.094	0.51	0.183
all years	0.106	0.51	**0.207**

* These values are specific to Washington and Oregon coastal steelhead from Kendall et al. 2016.

** Ocean survival (y) was estimated by dividing the known total average smolt-to-adult survival rate (z) for each year assessed by a known freshwater survival rate (x) determined by averaging data from acoustic telemetry studies by Romer et al. 2013 and Johnson et al. 2010. All years were then averaged to provide a late ocean survival rate for the risk assessment.

To be consistent with the data used to estimate open ocean survival, early marine survival here includes survival from release to the river mouth. However, the survival from release to the river mouth averages 84.2% (range 70%-92.5%) for the three rivers and therefore does not contribute greatly to early marine mortality (A3-2). Early marine survival rates across the rivers were averaged within five groups for modeling: 4%, 6%, 11%, 14%, and 26% (Table A3-2).

Table A3-2. Calculating and grouping early marine survival rates for three wild steelhead populations in Puget Sound.

Population	Year	CJS model survival probability: release to river mouth	km from tagging site to estuary	CJS model survival probability: river mouth to Pillar Point in Strait of Juan de Fuca	Early marine mortality (estimate includes release to river mouth)	Early marine mortality (averages for 5 groups)
Green	2009	73.18%	55	5.01%	3.66%	4%
Nisqually	2009	76.09%	20	4.85%	3.69%	
Skokomish	2010	79.40%	13.5	6.70%	5.32%	6%
Nisqually	2014	91.22%	20	5.88%	5.36%	
Green	2008	77.40%	55	7.43%	5.75%	
Nisqually	2008	79.98%	20	7.27%	5.82%	
Skagit	2009	81.94%	10	9.00%	7.37%	
Skokomish	2009	86.94%	13.5	10.68%	9.28%	11%
Skagit	2008	85.07%	10	11.47%	9.75%	
Nisqually	2007	80.12%	20	12.21%	9.78%	
Green	2006	83.52%	55	13.49%	11.27%	
Nisqually	2006	85.53%	20	13.42%	11.48%	
Skagit	2007	85.18%	10	14.01%	11.94%	
Green	2007	77.56%	55	16.02%	12.42%	14%
Skokomish	2008	89.31%	13.5	14.62%	13.05%	
Nisqually	2015	90.70%	20	16.26%	14.75%	
Skagit	2006	89.39%	10	16.86%	15.07%	
Green	2014	91.22%	49	17.39%	15.87%	
Skokomish	2007	89.40%	13.5	22.45%	20.07%	26%
Skokomish	2017	87.99%	13.5	23.27%	20.47%	
Nisqually	2016	70.00%	20	37.90%	26.53%	
Skokomish	2006	92.51%	13.5	31.47%	29.12%	
Nisqually	2017	89.80%	20	38.16%	34.26%	

Downriver survival	Average	84.06%
	Min	70.00%
	Max	92.51%

Smolt outmigrant groups of 10k, 50k, and 150k were created to emulate a range of Puget Sound population sizes. Model runs were performed for each of the five early marine survival rates across each of the three population sizes. Results depict the percent risk of extinction[20] and growth or decline in abundance over a fifty-year period, by year where early marine survival data exist. No attempt was made to assess early marine survival based upon recovery goals. Instead, the approach was to determine at what rate early marine mortality is no longer hindering recovery.

The results suggest that early marine survival of 6% or less in small steelhead populations leads to a risk of extinction of greater than 50% (A3-3). Geographically, south Puget Sound

[20] In the Puget Sound Steelhead Life Cycle Model, the extinction rate is the percentage of all simulations in which adult spawner abundance drops below the quasi-extinction threshold for three consecutive years. Quasi-extinction thresholds (an abundance considered to be tantamount to functional extinction) were determined by the Puget Sound Steelhead Technical Recovery Team (Hard et al. 2015)

populations have higher extinction risks. For all population sizes and locations, if open ocean survival remains as it has for the past 35 years, population growth is negative or zero unless early marine survival exceeds 14 to 16%.[21]

Table A3-3. Steelhead major population group risk assessment table.

Risk Assessment: Pops. of 10k ,50k ,100k outmigrants					% risk of extinction after 50 years			% change in abundance after 50 years		
Index Population (MPG)	Year	Early marine survival	Early marine survival grouping	***Average open ocean survival***	10k	50k	100k	10k	50k	100k
Nisqually (South/Central Puget Sound)	2006	11.5%	11.0%	*20.7%*	22.7%	0%	0%	-30%	-20%	-20%
	2007	9.8%	11.0%	*20.7%*	22.7%	0%	0%	-30%	-20%	-20%
	2008	5.8%	6.0%	*20.7%*	60.1%	0.3%	0.02%	-50%	-50%	-50%
	2009	3.7%	4.0%	*20.7%*	76.1%	1.5%	0.12%	-60%	-60%	-60%
	2014	5.4%	6.0%	*20.7%*	60.1%	0.3%	0.02%	-50%	-50%	-50%
	2015	14.7%	14.0%	*20.7%*	18.0%	0%	0%	-10%	0%	0%
	2016	26.5%	26.0%	*20.7%*	0%	0%	0%	100%	100%	100%
	2017	34.3%	26.0%	*20.7%*	0%	0%	0%	100%	100%	100%
Skokomish (Hood Canal, not inc. Strait of Juan de Fuca)	2006	29.1%	26.0%	*20.7%*	0%	0%	0%	100%	100%	100%
	2007	20.1%	26.0%	*20.7%*	0%	0%	0%	100%	100%	100%
	2008	13.1%	14.0%	*20.7%*	18.0%	0%	0%	-10%	0%	0%
	2009	9.3%	11.0%	*20.7%*	22.7%	0%	0%	-30%	-20%	-20%
	2010	5.3%	6.0%	*20.7%*	60.1%	0.3%	0.02%	-50%	-50%	-50%
	2017	20.5%	26.0%	*20.7%*	0%	0%	0%	100%	100%	100%
Skagit (North Cascades)	2006	15.1%	14.0%	*20.7%*	18.0%	0%	0%	-10%	0%	0%
	2007	11.9%	11.0%	*20.7%*	22.7%	0%	0%	-30%	-20%	-20%
	2008	9.8%	11.0%	*20.7%*	22.7%	0%	0%	-30%	-20%	-20%
	2009	7.4%	6.0%	*20.7%*	60.1%	0.3%	0.02%	-50%	-50%	-50%

Identifying and prioritizing sources of mortality to address

This section is intended to provide guidance regarding where to focus recovery efforts to address the early marine mortality of Puget Sound steelhead. The guidance provided in this section and throughout the report is based primarily upon the research of the Puget Sound Steelhead Marine Survival Workgroup (2013-2019).[22] Research is ongoing, and new information should periodically be reviewed for its potential influence on priorities.

The Puget Sound Steelhead Marine Survival Workgroup separated possible causes of mortality between proximate (direct) and ultimate (root/underlying) in their research

[21] Growth of the 10k outmigrant population group remains constrained at 14%. A separate model run was performed to find the point at which this group is no longer constrained, about 16% early marine survival.
[22] Reports and publications available at www.marinesurvivalproject.com/resources

framework.[23] Further, ultimate causes were separated between factors that affect fish condition or behavior (freshwater and marine derived) and environmental factors that drive predator-prey relationships. Evidence was reviewed in these categories, and specific factors were roughly ranked based upon their likelihood of contributing to high early marine mortality rates. Finally, a qualitative analysis described whether the factors most likely leading to early marine mortality are likely proximate or ultimate;[24] the extent of evidence suggesting this factor is leading to steelhead mortality; and which populations are most likely affected by each factor. This is summarized in Figure A3-3 and Table A3-4, below.

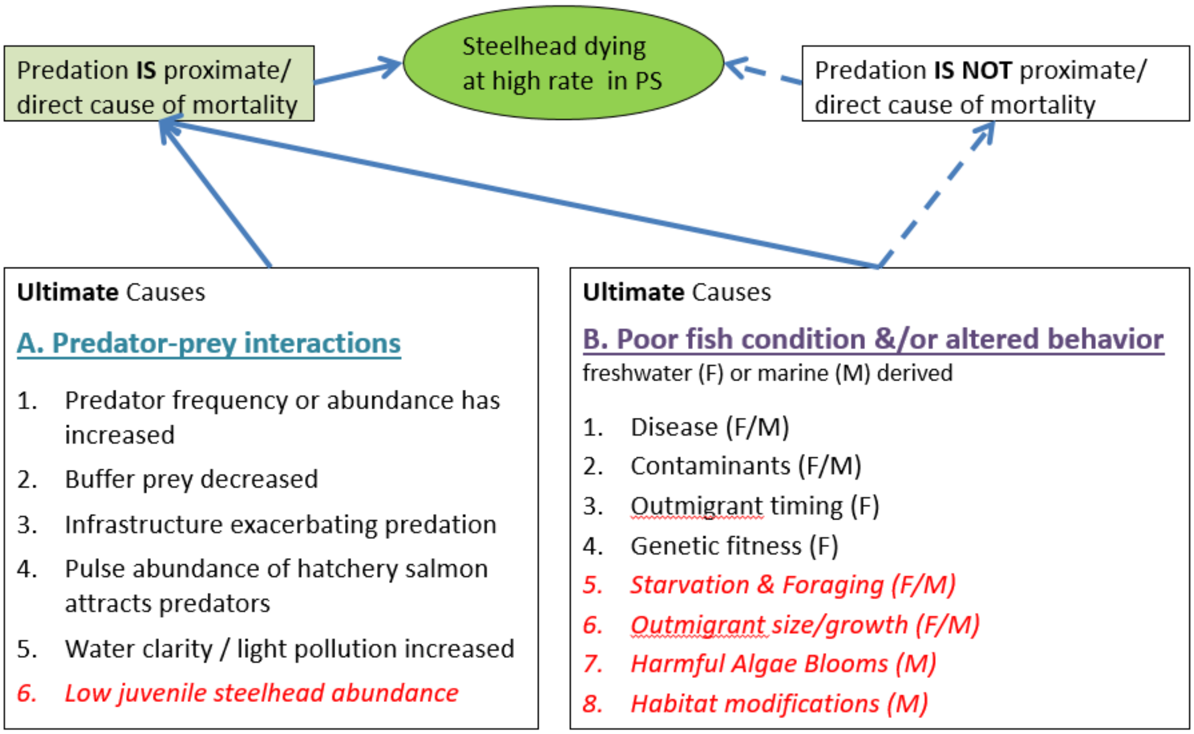

Figure A3-9. The factors affecting Puget Sound steelhead early marine mortality. Factors are roughly ranked based upon existing evidence. Those in red have been found to be less likely to contribute to early marine mortality (Puget Sound Steelhead Marine Survival Workgroup 2018).

[23] A proximate cause is an event which is closest to, or immediately responsible for causing, some observed result. This exists in contrast to a higher-level ultimate cause (or distal cause) which is usually thought of as the "real" reason something occurred.

[24] A contributing cause is defined here as one that compounds impacts.

Table A3-4. The factors considered more likely to affect mortality are described based upon best assumptions regarding how they lead to early marine mortality, the amount of scientific evidence suggesting a factor is impacting early marine mortality, and what we know about spatially about the factor is operating. Overall, less is known about impacts to steelhead early marine mortality in the North Cascades and Strait of Juan de Fuca major population groups. Most recent research of the Puget Sound Steelhead Marine Survival Workgroup has focused on South/Central Puget Sound and on Hood Canal.

Factors Assessment	A. Predator-prey Interactions				B. Poor fish condition &/or altered behavior		
	Predation, notably harbor seal	Lack of buffer prey	Human infrastructure	Pulse abundance of hatchery fish	Disease, notably N. salmincola	Contaminants, notably flame retardants	Genetic fitness
Mortality type (Proximate, Ultimate, Contributing)	P, U	U	C	C	C	C	C
Weight of evidence that impact is occurring	High	Med	Med	Low	High	Med	Med
Major Population Groups affected | Yes (Y), No (N), Unknown (?)							
South/Central Puget Sound*	Y	Y	?	?	Y	(Nisqually)	Y
Hood Canal & Strait of Juan de Fuca*	(Hood Canal)	?	(Hood Canal)	?	(Skokomish)	N	?
North Cascades	?	?	?	?	N	Y	?

The following briefly describes the evidence supporting focus on the specific factors highlighted in both Figure A6-2 and Table A6-4. Details are provided in the Workgroup's reports[25] and affiliated publications. Those factors with enough support to test, and, if successful, implement management actions are described in detail in Section III.

Proximate cause of early marine mortality

Predation is the most likely *proximate* source of mortality for juvenile steelhead in the Puget Sound lower river[26] and marine environments. Steelhead migrate rapidly through Puget Sound, traveling from their natal rivers to the Pacific Ocean within 6 to 18 days, depending upon distance between river of origin and the ocean (Moore et al. 2015). Further, steelhead survive at high rates in the lower river (64%-95%) relative to survival in the early marine environments (Moore et al. 2015). Short residence times, coupled with the high freshwater and low Puget Sound survival probabilities observed in this study, suggest a source of mortality that acts quickly on a large number of juvenile steelhead outmigrants in the Puget Sound marine environment (Moore et al. 2015). Predation fits this pattern well. Further, steelhead tend to migrate near the surface (Moore, unpublished data 2018), which may make them susceptible to some bird and marine mammal predation.

Other sources of proximate mortality considered include contaminants, harmful algae blooms, or disease. Contaminants in outmigrating Puget Sound steelhead are at levels of

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[25] Puget Sound Steelhead Marine Survival Workgroup 2018. Puget Sound Steelhead Marine Survival Workgroup 2014.

[26] The primary method for assessing Puget Sound steelhead early marine mortality is with acoustic telemetry. Outmigrating juvenile steelhead are released several kilometers upstream, so a freshwater segment is included.

concern (Chen et al. 2018), but are lower than mortality thresholds for the populations assessed (See contaminants section for details). Disease was broadly assessed by fish health experts in 2013 (Puget Sound Steelhead Marine Survival Workgroup 2014). Although the characteristics of other pathogens may align with the observed behavior and mortality patterns of juvenile steelhead in Puget Sound, *Nanopheytus salmincola* was the strongest candidate and considered the highest priority to investigate. Subsequently, very high prevalence and parasite loads of *N. salmincola* have been reported in steelhead migrating out of the Nisqually and Green Rivers, above mortality thresholds for juvenile trout in laboratory experiments (Chen et al. 2018; Baldwin et al. 1967). However, the laboratory fish were smaller and the rate of infection in the laboratory setting may have been much higher. While *N. salmincola* can lead to direct mortality, based upon the steelhead early marine mortality patterns (Moore et al. 2015; Moore et al. 2017; Berejikian et al. 2016) the parasite is more likely compromising the steelhead smolts' ability to swim (Butler and Millemann 1971) as they enter and migrate through Puget Sound, increasing their susceptibility to predation. See the disease section, below for more details.

The fish health experts categorized harmful algae blooms as having moderate potential for explaining steelhead early marine mortality. While the impact of harmful algae blooms cannot be ruled out, acoustic telemetry and smolt-to-adult return (SAR) data indicate that mortality has not been highly variable on an inter-annual basis and occurs throughout Puget Sound, suggesting that mortality is not caused by factors with high spatial and temporal variability in the environment such as harmful algae blooms (Puget Sound Steelhead Marine Survival Workgroup 2014).

Ultimate causes of early marine mortality

Determining the *ultimate* cause(s) of high predation rates is important for prioritizing recovery actions. Changes in predator abundance and/or distribution can directly lead to increased predation rates. Extrinsic factors such as poor fish health, altered fish behavior, or changing environmental conditions may also lead to increased predation rates (Hostetter et al. 2012). Finally, various inherent characteristics of steelhead smolts may make them more or less susceptible to predation than other fish species. Steelhead migrate in the top meter of the water column (Moore unpublished data 2018) and are relatively large at outmigration compared to other fish in the upper 30m of the water column, which may them more susceptible to predation. Conversely, the low abundance of steelhead relative to the other prey available to predators in Puget Sound, and the fact that steelhead are not a schooling species may make them less susceptible. These inherent characteristics cannot be affected through management but should be accounted for when assessing problems and developing management solutions.

A reciprocal transplant study was performed that took advantage of contrasting conditions in geographically proximate river systems, the Nisqually and Green Rivers (Moore et al. 2017). Steelhead smolts were cross-planted from one river to another, and their survival rates were compared to those planted into their natal rivers. <u>This was done to determine whether the ultimate cause of high early marine mortality rates could be due to population-specific effects like freshwater rearing conditions or hatchery introgression, or due to effects within the South and Central Puget Sound marine environment.</u> Similar survival probabilities were observed among smolts released into each river, regardless of origin, despite clear differences in freshwater habitat and hatchery influence on each population, rendering population-specific effects unlikely to substantially influence early marine survival. Instead, the location of release and distance traveled through Puget Sound influenced survival, suggesting effects in the marine environment are more likely to be the ultimate cause of high early marine mortality rates.

Ultimate factors in the marine environment

Within the marine environment, a substantial increase in the abundance of harbor seals between the early 1980s and late 1990s strongly correlates (with a Pearson Correlation Coefficient of -0.55) with the decline in steelhead marine survival (Sobocinski et al. in prep). Further, there is indirect evidence that harbor seals eat outmigrating steelhead both in river estuaries and the main basin of Puget Sound via acoustic telemetry studies and direct evidence of seal predation of steelhead in South Puget Sound via seal diet analyses (Berejikian et al. 2016; Berejikian unpublished data; Puget Sound Steelhead Marine Survival Workgroup 2018). Harbor porpoise have also increased in abundance, and other predators may contribute to steelhead mortality (Pearson et al. 2015). See the predation section, below, for details.

Declines in the abundance of alternative prey that steelhead predators would otherwise target during the steelhead outmigration period are likely contributing to higher steelhead predation rates. This includes but may not be limited to Pacific herring (Siple and Francis 2015; Stick and Lindquist 2009), Pacific hake (NMFS 2009), Pacific cod (NMFS 2011), rockfish (NMFS 2008a) walleye pollock (EoPS 2013), and hatchery-released Chinook (Sobocinski et al. in prep). See the buffer prey section, below, for details. Specific mechanisms that may drive buffer prey abundance or distribution are not fully explored in this document. However, possible linkages exist between coastal anthropogenic activities (e.g. development, pollution, climate) and the abundance of forage fish in pelagic waters (Rice et al. 2012; Greene et al. 2015). Early marine survival rates correlate with Puget Sound sea surface temperature and PDO, which may suggest a climate influence on buffer prey abundance (pers. comm. Berejikian 2018).

Puget Sound salinity is strongly negatively correlated with steelhead marine survival, with a Pearson Correlation Coefficient of -0.68 (Sobocinski et al. in prep). However, the potential linkage between steelhead marine survival and salinity is unclear and requires further evaluation.

Human infrastructure can exacerbate predation. In Puget Sound, the Hood Canal floating bridge is obstructing the migration of juvenile steelhead and appears to be facilitating high levels of predation-based mortality (Hood Canal Bridge Assessment Team 2016; Moore et al. 2010; Moore et al. 2013). Light from overwater structures can also facilitate predation on steelhead migration routes, as can artificial pinniped haul outs or seabird roosts (Yurk and Trites 2000; Farrer and Gutierrez 2010; Scordino 2010; Kahler et al. 2000). See the human infrastructure section, below.

The release timing of hatchery fish has become more consolidated throughout Puget Sound (Nelson et al. in prep). Pulse abundances of hatchery fish entering the marine environment may affect predator behavior and make steelhead more vulnerable to predation (Sobocinski et al. in prep; Nelson et al. in prep). See the pulse abundance sections, below, for details.

Other marine-derived factors that may exacerbate predation-based mortality rates include increasing water clarity (Puget Sound Steelhead Marine Survival Workgroup 2014) and light pollution (Puget Sound Steelhead Marine Survival Workgroup 2018). Turbidity and light may affect predators that use both vision and tactile senses (e.g., harbor seals); however, these predators may be able to compensate for a reduction in one modality through the other (Weiffen et al. 2006). For example, according to Henkel and Harvey (2008), the distribution of harbor seals in Monterey Bay, California was not influenced by water clarity. The plan does not include strategies to address light pollution or turbidity.

Starvation in the marine environment, and with that competition for food, is not likely. Telemetry suggest steelhead are migrating quickly through Puget Sound and not foraging (or lethargic, if starving) in both low and high early marine mortality years (Moore et al. unpublished data). Diet and migration rate comparisons with other regions where marine survival rates are higher than Puget Sound reinforce this notion (Daly et al. 2014 and Puget Sound Steelhead Marine Survival Workgroup 2018). Questions remain regarding what triggers marine phase feeding and when. Without knowing, itis difficult to conclude that steelhead are not interested in foraging in the offshore of Puget Sound. For example, continued rapid migration through Puget Sound could be induced by a lack of food in a particular area and could lead to increased exposure to predation.

Finally, while the brief residency of steelhead in Puget Sound suggests a minimal role of nearshore structural habitat for refuge (eelgrass, kelp forests) these habitats may be important for 'buffer prey' and reduced presence of these habitats may affect predator foraging behavior (Puget Sound Steelhead Marine Survival Workgroup 2014).

Ultimate factors in freshwater

Because the steelhead smolts in the Moore et al 2017 reciprocal transplant study were released at river kilometer 19 in both systems, factors affecting their health or behavior in the lower river—if immediate and at a high rate—could still explain why the location of release and not the origin of each population influenced survival. The amount of N. salmincola infecting juvenile steelhead increases as the fish migrate downstream through the lower river and estuary in both the Green and Nisqually watersheds (Chen et al. 2018). N. salmincola can quickly burrow into the steelhead's muscle tissue and reduce their swimming performance (Butler and Millemann 1971), increasing their susceptibility to predation in Puget Sound. N. salmincola is addressed in the disease section, below.

While the reciprocal transplant study suggests otherwise, other freshwater factors may still contribute to increased early marine mortality rates. Upstream in the Nisqually watershed, steelhead are being exposed to polybrominated diphenyl ethers (PBDE), a flame retardant, at levels that can increase disease susceptibility or alter thyroid hormone production (Chen et al. in prep and O'Neill, unpublished data). A genome-wide association study (GWAS) found a strong relationship between the Omy05 genotype, higher early marine mortality, and higher N. salmincola loads for the Green and Nisqually steelhead populations. This genotype may be associated with the influence of residency vs anadromy. In some cases, the circadian clock and immune system may also influence parasite loads and survival. However, the power of these findings is currently limited (see genetic fitness section, below).

If steelhead smolts are starving, their lower lipid levels can exacerbate the effects of contaminants (Lassiter and Hallam 1990) and disease. Whole body lipid content was assessed and found to be 1.5% or less in wild Puget Sound steelhead populations in 2014 (Skagit, Nisqually, Green, Snohomish, Tahuya). Low lipid levels are not inconsistent with the natural decline in whole body lipid content toward depletion during the smolt outmigrant life-stage (Sheridan et al. 1983, Stefansson et al. 2003). Therefore, low lipid levels not always a sign of starvation. However, levels below 1% were observed in some Puget Sound steelhead (Skagit, Nisqually, Green), and this may be cause for concern as 1% has been documented as a threshold for the onset of high over-winter mortality in rainbow trout (Biro et al. 2003). If low lipid levels contributed significantly to early marine mortality across Puget Sound, one could assume that hatchery steelhead, which are fed until release and have higher lipid levels during out migration, would survive at higher rates compared to wild fish from the same river. In most cases where the early marine mortality of hatchery and wild steelhead from the same river have been tracked, wild fish survived better (Moore et al. 2015).

Juvenile steelhead outmigration timing may affect mortality rates in years with lower early marine survival overall. Puget Sound steelhead telemetry data indicated, in years with lower early marine survival (2006-2011 and 2014), higher early marine mortality occurs during the first half of May when compared to late April or late May/early June (Moore et al. 2015).

Other factors were reviewed by the Puget Sound Steelhead Workgroup and were considered less likely to contribute to early marine mortality. The importance of steelhead growth in freshwater and, thusly, size at outmigration is assessed through size-selective mortality in the marine environment. Size-selective mortality (bigger is better) may be occurring while steelhead from Puget Sound are in the open ocean (Ward 2000; Thompson and Beauchamp 2014). However, there is no evidence of it regulating survival while juvenile steelhead are migrating through Puget Sound (Puget Sound Steelhead Marine Survival Workgroup 2014 and Moore et al. 2015). This is based upon telemetry data that only exclude the lowest 10% of the outmigrant size range, and based upon assessments of marine survival time series. The telemetry data, which suggest rapid entry into the marine environment, are also not consistent with physiological issues such as stunting and parr reversion (Puget Sound Steelhead Marine Survival Workgroup 2014).

Impacts and proposed management strategies

This section describes the factors with greatest likely influence on steelhead early marine mortality, and the management strategies to address them. Each factor leads with a hypothesis that best describes the impact, followed by the evidence supporting the hypothesis. A suite of management strategies that constitute a response to a specific factor follow. Here, a **strategy** is defined as a group of actions that work together to reduce threats, capitalize on opportunities, restore natural systems, or improve our knowledge.

While some site-specific **actions**, or tasks within each strategy, are included below, additional actions may be detailed in the forthcoming recovery implementation plan. These will include specifics regarding improving regulations, on-the-ground habitat restoration/acquisition, implementing or improving on best management practices, outreach, amending statutes or laws, and directed research.

Predation

Hypothesis: Increased predator presence, abundance, or targeting of juvenile steelhead in the Puget Sound marine environment during the steelhead outmigration period has increased steelhead early marine mortality.

Evidence: The list of most likely potential bird and marine mammal predators of outmigrating juvenile steelhead includes harbor seals, harbor porpoises, double-crested cormorants, Caspian terns, and Brandt's cormorants (Pearson et al 2015). These fish-eating species have demonstrated relatively stable or increasing population trends in recent years (over the same period as the decline in Puget Sound steelhead marine survival) and, with the exception of harbor porpoise, there is evidence that diet includes juvenile salmon and steelhead. Piscine predators were assessed in a very limited fashion by the Puget Sound Steelhead Marine Survival Workgroup in 2014. Most of the potential piscine predators (resident Chinook/coho, dogfish, six-gill or salmon shark, Sebastes spp., lingcod, and other larger gadids) are assumed to be more active deeper in the water column than where steelhead outmigrate (Puget Sound Steelhead Marine Survival Workgroup 2014). Abundance data to relate to steelhead smolt-to-adult survival rates are also lacking for many of these species in Puget Sound.

Double-breasted cormorants may be of lower concern because a large portion of the population migrates to the Columbia River by early/mid May for breeding season, which is before the peak of the juvenile steelhead outmigration period. However, it is possible that immature birds (one and two- year olds) may linger in the Sound longer than adults because they do not fully populate the Columbia River breeding colonies until mid-June (Pearson et al. 2015). Anecdotally, the presence of Caspian tern nesting has been variable in Puget Sound in recent years; however, their arrival and nesting, in May, coincides with the juvenile steelhead outmigration period (Pearson et al. 2015).

Harbor porpoise sightings the harbor porpoise population increased at a rate of 8-9% per year between 1995 and 2015 (Evenson et al. 2016, Jefferson et al. 2016). The increase in harbor porpoise sightings was greatest from the late 1990s onward (Pearson et al. 2015), after the period during which Puget Sound steelhead marine survival declined significantly (Kendall et al. 2017). However, the harbor porpoise data over the period of steelhead decline are coarse (Pearson et al. 2015). Porpoises find their prey using echolocation allowing them to exploit a resource like juvenile steelhead that tend to move individually or in small groups. However, no salmon or steelhead have been present in diets of Salish Sea harbor porpoise, despite reasonable sample sizes for April and May, the period of juvenile steelhead outmigration (Walker et al. 1998; Nichol et al. 2013, as referenced in Pearson et al. 2015).

California sea lions are present in Puget Sound during the steelhead outmigration period, although most depart by late May to return to their rookeries in California and Mexico (Pearson et al. 2015). Recent dive data from sea lions in South Puget Sound during the steelhead outmigration period suggest that sea lions are mainly foraging deep in the water column, at lower depths than where juvenile steelhead outmigrate.[27] Sea lions may impact adult steelhead returns in some areas; however, impacts to adult returns are not covered in this section.

The abundance *of harbor seals* increased substantially in Puget Sound and the greater Salish Sea over the period of steelhead decline. From 1983 to 1996, the annual rate of increase for the inland Washington stock was 6%, before the population reportedly became stable (Jeffries et al. 1997; Jeffries et al. 2003, as referenced in Pearson et al. 2015). However, in recent years, the seal population may have declined (pers. comm. Pearson, Washington Department of Fish and Wildlife 2018). Correlative analyses illustrate an inverse relationship between seal abundance and Puget Sound steelhead marine survival, with a Pearson Correlation Coefficient of -0.55 (Puget Sound Steelhead Marine Survival Workgroup 2018 and Sobocinski et al. in prep). The relative abundance and distribution of harbor seals during the April-June steelhead outmigration period has not been fully established.

Direct and indirect evidence of harbor seal predation on steelhead exist through seal diet (Puget Sound Steelhead Marine Survival Workgroup 2018) and acoustic telemetry studies (Berejikian et al 2016 and Puget Sound Steelhead Marine Survival Workgroup 2018), respectively. Evidence of predation by harbor seals inferred from steelhead acoustic telemetry transmitters deposited near seal haul outs suggests harbor seals eat outmigrating steelhead both in river estuaries and throughout the main basin of Puget Sound. While there were only two years of intensive study (2014 and 2016), low steelhead survival through Puget Sound (6%) in 2014 was associated with more evidence of seal-caused mortality in Puget Sound, while high smolt survival (38%) in 2016 was associated with less evidence of predation (Puget Sound Steelhead Marine Survival Workgroup 2018). In 2016, seal diet data were also collected via feces taken from haul out sites in South Puget Sound. During outmigration from April to June, steelhead DNA was identified in 3 scats, a very small percentage of the total scats collected (Puget Sound Steelhead Marine Survival Workgroup 2018). Additional scat samples have been collected in 2017 and 2018. Anchovy presence/absence data and steelhead early marine mortality trend data suggest lower steelhead mortality in 2016 may have been associated with increased availability of alternative prey. However, seal diet and prey biomass data are needed over time to more directly assess whether this is occurring (see buffer prey section).

The diet and telemetry studies are improving our understanding of the relative intensity, spatial distribution, temporal distribution, and inter-annual variation of mortality. These studies have yet to result in a formal estimate of the overall predation rate by seals on migrating juvenile steelhead; however, both diet and telemetry data will be assessed to do so. Establishing a predation rate is inherently difficult because the relative number of steelhead available as prey compared to other prey types is small (Berejikian et al 2016). Thus, even a very small percentage of the seal diet consisting of steelhead could have a substantial impact, given the total number of seals.

Prey specialization is often referenced as something to consider when assessing management options for predators. Predator populations with specialists could result in more direct management actions if those specialists can be identified. Evidence suggests harbor seals are

[27] pers. comm. S. Jeffries, Washington Department of Fish and Wildlife, June 2015.

serial diet specialists as individuals and generalists as a population. Individual seal diets often consist of a few items, dominated proportionally by one species (Lance et al. 2012), and seals have high foraging site fidelity at least for specific time periods until switching to another foraging area (Peterson et al. 2012; Wilson et al. 2014; Bromaghin et al. 2013). However, when assessing harbor seal populations as a whole, diet analyses confirm a wide range of prey are being eaten, suggesting harbor seals are generalists as a group and eating proportionately what is available to them (Bromaghin et al. 2013).

Several studies show pinnipeds specializing in consuming fish at bottlenecks, obstruction points, and lighted areas. The most notable study of juvenile salmon predation by harbor seals was on the Puntledge River where individual seals swimming under a lighted bridge were observed preying on chum fry nightly, repeatedly identified from their markings (Olesiuk 1996).

Although there is evidence of individual harbor seal specialization, and specifically on juvenile salmon, that does not mean that the majority of juvenile salmonids consumed by seals are taken by specialists. Many more scats contain low portions of juvenile salmon compared to few with high proportions, indicating that the seal population (as a whole) consumes juvenile salmon as part of their pelagic foraging strategy. Juvenile salmon tend to co-occur in scats with other forage fishes such as herring, and thus the main driver of seal impact on juvenile salmon is a large number of seals eating small portions of juvenile salmon that now comprise a significant percentage of the available forage fish (Thomas, Allegue & Trites 2015; Nelson et al. in prep). Recent research does, however, suggest that male seals more often forage in the pelagic environment and have a more diverse diet as individuals, compared to females which target the benthic environment and are more specialized on certain prey species (Voelker 2018).

Thus, evidence of prey specialization should be assessed on a case-by-case basis when considering management options. In cases where there are physical salmonid migration bottlenecks or obstructions, specialists may be identifiable. However, where predation appears more widespread, mitigation strategies focused on the predator population as a whole are more likely to be impactful.

Strategies and actions related directly to predation:

Implement regional actions to allow for testing the effectiveness of marine mammal management in support of steelhead recovery.

Continue monitoring to determine whether marine mammal populations of concern are at optimum sustainable population sizes, enabling discussions of returning management responsibilities to Washington State.

Identify “problem areas or animals” and experiment with non-lethal action (see Strategy 2).

If warranted, work with Washington’s congressional delegation to change requirements in the MMPA to allow for site-specific actions on marine mammals in Puget Sound.

Specify the regulatory options in the Marine Mammal Protection Act (MMPA) for controlling the numbers, distribution or both of marine mammals.

Track progress in the Columbia River pinniped management approach and learn from results.

Determine the feasibility and effectiveness of actions that reduce predator numbers, including wildlife contraception, relocation, and culling.

Assess and test the effectiveness of specific actions to alter harbor seal behavior at locations associated with high steelhead mortality. Thoroughly assess whether steelhead early marine mortality declines, whether predator distribution will be adequately altered, and evaluate any unexpected consequences. Specific actions to test include:

Identify and remove artificial haul-out sites in key areas while animals are not present. Simultaneously, provide alternative refuges for the harbor seals.

Install barriers at natural haul-out sites to restrict access, either permanently or during the steelhead outmigration window.

Test acoustic deterrents or hazing of animals in mortality hotspots during the short steelhead outmigration window.

Continue predation research and monitoring, with a focus on areas of greatest steelhead early marine mortality.

Monitor steelhead early marine mortality rates, predation (e.g. diets, behavior), and other response variables for reactions to environmental change and before and after testing management strategies to assess effectiveness. Monitor later marine mortality for the same steelhead populations to test whether early marine, predation-based mortality is additive vs compensatory.[28] Use information to help determine whether, when, what, and where management actions should be fully implemented.

Monitor the abundance of harbor seals and their distribution during the juvenile steelhead outmigration period. Continue to assess the trajectory of harbor seal population abundance and consider impacts such as the increasing presence of transient killer whales as a potential natural moderator of harbor seal population size.

Monitor harbor seal diets relative to seal foraging behavior and environmental change. Harbor seals diets can provide information regarding the extent seals are targeting steelhead, the extent to which they may be feeding in areas with steelhead, and what else they are targeting in a given year.

Continue to improve assessments of harbor seal predation rates on juvenile steelhead.

To improve focus on particular predator populations, create predation risk maps that associate potential primary predator foraging areas with mapping of steelhead migration routes and mortality patterns through Puget Sound.

Determine whether harbor porpoises impact juvenile steelhead survival. If found to impact juvenile steelhead survival, consider in the context of regional actions elements.

[28] Additive predation decreases survival in a prey population. Compensatory predation does not affect overall survival of a prey population and merely replaces or compensates for existing sources of mortality.

Determine if Caspian terns, cormorants, or other seabirds are substantially impacting juvenile steelhead survival, regionally or on a site-specific basis, consider testing actions to control their numbers or alter their distribution to reduce predation on steelhead. Be cognizant of whether predator distribution will be adequately altered and of unexpected consequences.

Strategies and actions related to factors that may lead to, exacerbate or ameliorate predation-based mortality:

Address factors that may exacerbate or ameliorate predation-based mortality. Determine which of these factors to address based upon the specific predator, location of high outmigrating juvenile steelhead mortality, and specific steelhead populations affected. Factors include but may not be limited to buffer prey, human infrastructure, disease, contaminants, hatchery fish distribution, and genetic fitness as described in Figure A3-3 and in other sections of this report.

Buffer prey

Hypothesis: The abundance of buffer or alternative prey for predators during the steelhead outmigration window has declined, contributing to increased predation on outmigrating steelhead.

Evidence: Buffer prey include species that occupy similar size ranges and habitats as outmigrating steelhead or prey that do or would otherwise comprise a significant part of a predator of concern's diet during the steelhead outmigration period. This includes but may not be limited to Pacific herring, Pacific hake, Pacific cod, rockfish, and hatchery-released Chinook, all of which have declined in Puget Sound over the past 40 years as described below. Hatchery release strategies are covered in another section below.

Herring and Pacific sand lance (at least historically) comprise(d) the major part of the forage fish assemblage in upper 30 meters of the Puget Sound water column (Hiss 1986). Trends in abundance and current status of pacific sand lance is unknown. Most Puget Sound herring populations have declined since the 1980s (Siple and Francis 2015). This includes the later-spawning Cherry Point stock, which historically represented half of the total Puget Sound herring spawning biomass, and other north Puget Sound and Strait of Juan de Fuca stocks have declined (Siple and Francis 2015; Stick and Lindquist 2009). Further, over the past 40 years catch per unit effort data indicate that historically dominant forage fishes (Pacific herring and surf smelt) have declined in the surface waters of Central and South Puget Sound by up to two orders of magnitude (Greene et al. 2015). Jelly fish-dominated catches increased 3- to 9-fold, and abundance positively tracked human population density across all basins. The strongest predictors of forage fish declines were human population density and commercial harvest. Climate signals offered additional explanatory power for forage fish but not jellyfish catch (Greene et al. 2015). These patterns suggest possible linkages between coastal anthropogenic activities (e.g. development, pollution) and the abundance of forage fish and jellyfish in pelagic waters (Rice et al. 2012; Greene et al. 2015). In general, small pelagic fish abundance decreases and jellyfish abundance increases with decreasing latitude in Puget Sound and this relationship is related to water clarity (Rice et al. 2012).

A correlative assessment of long-term trends found a moderate relationship between herring spawning abundance and steelhead smolt-to-adult / marine survival, with a Pearson Correlation Coefficient of 0.36 (Sobocinski et al. in prep. and Puget Sound Steelhead Marine Survival Workgroup 2018). However, given how dynamic herring populations are, spawner abundance may not be the best metric for assessing their pelagic abundance during the steelhead outmigration period.

It also worth noting the collapse in age structure of Puget Sound herring. Data from the mid 1980s to 2006 show a collapse in age structure for all Puget Sound herring stock (Landis and Bryant 2010; Siple et al. 2017), with fewer fish of older ages being observed. This may represent a significant decline in larger prey available, which may compound the reduction of the buffer effect herring may have historically provided for outmigrating steelhead.

Recently, there have been qualitative signs that other forage fish may be acting as buffer prey. Nisqually River steelhead early marine survival more than doubled in 2016 and remained high in 2017 compared to previous years' studied (Puget Sound Steelhead Marine Survival Workgroup 2018). Numerous sources suggest a significant increase in northern anchovy abundance (qualitative data) in Puget Sound in 2016 (Duguid et al, unpublished data) that may have continued into 2017. Qualitative comparisons suggest a positive relationship between anchovy abundance and Nisqually steelhead early marine survival rates for years available between 2006 and present (Puget Sound Steelhead Marine Survival Workgroup 2018). Further, anchovy were identified in seal diets during the steelhead outmigration period; however, low sample sizes limited any ability to make inferences regarding a buffer prey affect (Puget Sound Steelhead Marine Survival Workgroup 2018). Northern anchovy are energy-rich and school in nearshore areas in spring, summer and fall.[29] This may result in a change in directed effort toward steelhead, and a change in predator distribution, both lowering predation risks to steelhead that predominantly migrate through the deeper open waters of Puget Sound. A similar affect was found off the California Coast. Common murre consumption of out-migrating juvenile Chinook salmon increases (and survival declines) when murre distribution moves inshore, to feed on anchovies, versus offshore, to feed on rockfish (Wells et al. 2017).

Other prey that historically may have comprised a significant portion of harbor seal diets has also declined, including Pacific hake (NMFS 2009), Pacific cod (NMFS 2011), rockfish (NMFS 2008a) and walleye pollock (EoPS 2013). Data were insufficient for to be included in time-series analyses correlating abundance trends with trends in steelhead marine survival (pers. comm. Sobocinski 2018).

Specific mechanisms that may drive buffer prey abundance or distribution are not explored in this document. However, relationships between steelhead smolt-to-adult and early marine survival rates and Puget Sound sea surface temperature and PDO may suggest a climate influence (Sobocinski et. al. in prep; Moore et al. unpublished data).

[29] http://usa.oceana.org/responsible-fishing/northern-anchovy

Strategies and actions:

Support efforts to recover or enhance the abundance of forage fish that are of a size that attracts harbor seals and other predators of concern, and that occupy the top 30m of the water column, at the time of steelhead outmigration, including pacific herring, pacific sand lance, and northern anchovy.

Advocate for, fund and track progress to develop and test herring management strategies, such as increasing egg survival rates, reducing noise at spawning sites at key times, identifying herring predation hotspots, and improving habitat quality (see WDFW Forage Fish Management Plan 1998 and recent update by Salish Sea Pacific Herring Assessment and Management Strategy Team report "Assessment and Management of Herring in the Salish Sea.")

Fund and expedite acquisition, restoration and protection of high priority nearshore habitat for forage fish population spawning and rearing sites in Puget Sound.

Implement site-specific actions, such as removing bulkheads/shoreline hardening at key forage fish sites, adding wrack to beaches, protecting and restoring submerged vegetation including eelgrass and kelp, and removing pilings. Explore beach nourishment options where infrastructure disconnects drift cells.

Support efforts to recover or enhance the abundance of other prey historically important to harbor seals and other predators of concern (e.g. hake, cod, rockfish).

Implement NOAA's rockfish recovery plans for Puget Sound/Georgia Basin.

For other species not covered by recovery plans, work with NOAA, WDFW and advocacy groups to identify and protect key habitats and populations.

Continue research and monitoring to further assess the buffer prey hypothesis.

Assess the effectiveness of the above strategies. In addition to tracking steelhead mortality rates and locations, include response variables such as changes to the abundance and distribution of alternative prey during the steelhead outmigration in areas of high steelhead mortality, and changes to predator distribution, behavior and diet.

Perform mesocosm experiments that test the buffer prey hypothesis in areas of high steelhead early marine mortality.

Support efforts to improve monitoring of forage fish and other prey of historic importance to predator of concern.

Human infrastructure

Hypothesis: Human infrastructure that either affects juvenile steelhead migration behavior, conceals predators, or draw predators to the steelhead migration route exacerbates predation.

Evidence: In the Puget Sound estuarine and marine environment, the Hood Canal floating bridge and artificial bird roosts or seal haulouts can exacerbate predation.

Hood Canal Bridge – Overwater structures are known to exacerbate predation on salmon and steelhead (Yurk and Trites 2000; Celedonia et al. 2009; Blair et al. 2010). Because of its location, all juvenile steelhead migrating out of Hood Canal must pass the Hood Canal Bridge. As a 1.5-mile long floating bridge, its pontoons span 83% the width of Hood Canal and extend 15 feet underwater (Hood Canal Bridge Assessment Team. 2016). Studies show that juvenile steelhead approach the bridge within the top few feet of the water column (Moore et al. unpublished data). Upon reaching the bridge their migration slows, behavior changes, and they succumb to higher mortality in the vicinity of the bridge relative to other areas on their migration route (Moore et al. 2010; Moore et al. 2013; Moore et al. unpublished data). The unique behavior and mortality patterns at the Bridge suggest the bridge is impeding steelhead migration and increasing predation. Current work is being performed to determine whether the floating pontoons simply act as a migration barrier, or if traffic noise, light, an artificial reef effect, or the hydrodynamic changes to the water column facilitate predation. The most likely predators are also being identified (Hood Canal Bridge Assessment Team 2016).

Artificial haulouts and bird roosts – Artificial resting sites for predators may facilitate predation of salmonids, including steelhead. The most referenced impacts are man-made or altered islands in the lower Columbia River, created or enhanced by the deposition of dredge material, that allow cormorants and Caspian terns to colonize in high numbers, exposing outmigrating juvenile steelhead to high rates of predation (Hostetter et al. 2015). In the estuary of the Puntledge River, log booms provide a haulout for harbor seals, acting as a base for foraging for juvenile hatchery salmon in the Puntledge River (Yurk and Trites 2000). A bridge and its lighting are creating cover for seals and facilitating predation there; therefore, it's unknown whether predation would decline if the log booms were removed, or if the seals would simply haul out elsewhere. In Puget Sound, log booms, barges, piers, docks, bulkheads, pilings for salmon net pens and other structures provide haulouts for seals and sea lions or roosts for birds in the vicinity of juvenile salmonids (Farrer and Gutierrez 2010; Scordino 2010; Kahler et al. 2000). While we know birds and pinnipeds use artificial resting sites in Puget Sound, no analysis has been done to determine locations of these sites relative to the steelhead early marine mortality hotspots. Further, we don't know whether removing access to these structures would reduce predation on juvenile steelhead. Predators may rest elsewhere and continue to forage in the same locations.

Strategies and actions:

Address high steelhead mortality at the Hood Canal Bridge through structural modifications or through management approaches to facilitate steelhead passage or alter predator behavior during the steelhead outmigration period.

Fund and complete Hood Canal Bridge Assessment to isolate how bridge is leading to high steelhead mortality.

Develop, test, and implement specific actions/solutions based upon the results. (Depending upon results, actions may include but aren't limited to obstructing predators from accessing the water surrounding the bridge pontoons, changes to lighting, blocking predator access to "pools" in bridge structure, and changing grating.)

Test the effectiveness of removing artificial haul-outs or roosts in areas of high steelhead early marine mortality. Be cognizant of whether predator distribution will be adequately altered and of unexpected consequences.

Continue research to further assess the extent of impact by human infrastructure on steelhead mortality.

Assess the effectiveness of strategies and actions above. In addition to tracking steelhead mortality past the modified infrastructure, include response variables such as changes to steelhead migration patterns or time taken to pass infrastructure, and changes to predator distribution, behavior and diet during the steelhead outmigration period.

Early marine mortality and hatchery salmon releases: predator attractant or buffer prey?

Hypothesis: Pulse abundances of outmigrating hatchery fish that occur in concert with juvenile wild steelhead outmigration attract predators and increase predation rates on the wild steelhead.

Hypothesis: The abundance of buffer or alternative prey for predators during the steelhead outmigration window has declined, contributing to increased predation on outmigrating steelhead.

Evidence: The number of hatchery Chinook and coho released into Puget Sound has varied greatly over time and has declined in recent years. This could affect predation. A correlative assessment suggests hatchery Chinook release numbers in Puget Sound correlates moderately with steelhead smolt-to-adult survival rates, with a Pearson Correlation Coefficient of 0.46 (Puget Sound Steelhead Marine Survival Workgroup 2018; Sobocinski et al. in prep). Empirical studies suggest the size of outmigrating Chinook and coho is critical in determining whether they will attract harbor seals, a predator of concern, during the steelhead outmigration period. Harbor seals targeted yearling coho over subyearling Chinook migrating from Big Qualicum Hatchery through the estuary and into the Strait of Georgia (Allegue 2018). In another study, harbor seal predation on juvenile Chinook appeared to increase in June and July, as the Chinook grew larger in the Strait of Georgia marine environment (Thomas et al. 2017).

As the number of hatchery Chinook released into Puget Sound annually has declined Chinook subyearling release dates have also become much more consolidated since the 1980s (Nelson et al. unpublished data; Puget Sound Steelhead Marine Survival Workgroup 2018). Correlative trend analyses indicate the CV (coefficient of variation) of hatchery subyearling Chinook release date had a positive, although weak, relationship with steelhead smolt-to-adult/marine survival, with a Pearson Correlation Coefficient of 0.21 (Sobocinski et al. in prep). Also, a meta-analysis of Puget Sound steelhead telemetry data indicated, in years with lower early marine survival (2006-2011 and 2014), higher early marine mortality occurs during the first half of May when compared to late April or late May/early June (Moore et al. 2015; Moore et al. 2017). Predators may not be responding to the steelhead outmigrants until the peak of the steelhead outmigration period. Alternatively, predators may be responding to periods when large volumes of hatchery fish are entering the Puget Sound marine environment.[30]

While a high abundance of highly distributed prey could buffer predation impacts to steelhead, declines in the number of hatchery fish released that are also becoming much more consolidated could alter the behavior of predators. A pulse of fish could attract predators to specific places, at specific times, making steelhead more vulnerable to predation there. A predator response to hatchery releases is well documented in Alaska (Chenoweth et al. 2017). Fish released from hatcheries may not immediately enter the Puget Sound marine environment; therefore, release data is not the best indicator for marine entry timing. Ongoing work is focused on whether there is any alignment between hatchery Chinook entry timing into the Puget Sound marine environment and within-year early marine mortality patterns of steelhead. Coho, yearling Chinook and steelhead are also released from hatcheries during the steelhead outmigration period; however, their release numbers are substantially lower than subyearling Chinook.

Strategies and actions:

Determine the effectiveness of distributing the marine entry timing of hatchery Chinook (and possibly other species, such as coho), in particular in areas where hatchery Chinook (and coho) are of a size that attracts predators, in places that overlaps with high steelhead early marine mortality. Assess the hatchery management, harvest and wild fish recovery implications to Chinook and coho of any action considered.

Test and, if successful, implement different release strategies that attempt to increase distribution of marine entry timing.

Test and, if successful, implement other manipulations to hatchery fish (photoperiod, water temperatures, feeding) that improve ability to increase distribution of marine entry timing.

Assess whether increasing the abundance of similar-sized wild or hatchery out-migrating juvenile Chinook and coho buffers predation and lowers steelhead smolt mortality. Consider that hatchery-based efforts may have a negative ramification in the context of potential pulse-abundance impacts (see above). Assess the hatchery management, harvest and recovery implications to Chinook and coho of any action considered.

Continue research to further assess the pulse abundance and buffer prey hypotheses for hatchery fish impacts on steelhead early marine mortality and survival.

Determine whether pulse abundances of hatchery fish are affecting predator behavior and increasing predation on Puget Sound steelhead.

Consider mesocosm experiments that test the pulse abundance hypothesis in areas of high steelhead early marine mortality.

Assess the effectiveness of strategies and actions above. In addition to tracking steelhead mortality rates and locations, include response variables such as changes to hatchery fish

[30] This hypothesis is being tested by the Puget Sound Steelhead Marine Survival Workgroup in 2018-2019.

marine entry timing relative to steelhead outmigration timing, and changes to predator distribution, behavior and diet during the steelhead outmigration period.

Disease

Broad hypothesis: Disease is reducing juvenile steelhead outmigrant swimming performance and survival.

Evidence: There is limited support for disease as a broad, categorical factor affecting steelhead early marine mortality. In 2013, fish health experts reviewed juvenile steelhead migration behavior and mortality patterns relative to pathogens that could affect steelhead early marine mortality. Although the characteristics of other pathogens may align with the observed behavior and mortality patterns of juvenile steelhead in Puget Sound, based on current knowledge *Nanopheytus salmincola* was the strongest candidate and considered the highest priority to investigate. Other pathogens considered moderate or low priority are described in their technical report.[31]

Specific hypothesis: Infections of the parasite *Nanophyetus salmincola* is reducing steelhead juvenile swimming performance in some South and Central Puget Sound and southern Hood Canal rivers, increasing their susceptibility to predation. At high intensities, *N. salmincola* infection may also lead to direct mortality.

Evidence: A study compared the prevalence and intensity of *N. salmincola infections* in five steelhead populations throughout Puget Sound in 2014 (Skagit, Snohomish, Green, Nisqually) and Hood Canal (Tahuya). The prevalence and parasite loads of *N. salmincola* were significantly higher in outmigrating steelhead smolts from central and south Puget Sound watersheds (Green and Nisqually) than in those from north Puget Sound (Skagit and Snohomish), where infections were rarely detected (Chen et al. 2018). *N. salmincola* was not found in in the Tahuya watershed (pers. comm. M. Chen 2018). *N. salmincola* has been documented in the Skokomish watershed (pers. comm. P. Hershberger 2014); however, steelhead were not sampled there as part of this study. The Green and Nisqually Rivers had very high prevalence and parasite loads, above reported thresholds for negative health effects. Further, a substantial portion of fish from these rivers with *N. salmincola* also exhibited gill (Green 28%, Nisqually 42%) and heart (Green 45%, Nisqually 69%) inflammation not found in the other three rivers (Chen et al. in press). While other diseases were found (e.g. Sanguinicola), none other than *N. salmincola* were significantly associated with tissue damage (Chen et al. 2018). A downstream progression of *N. salmincola* prevalence and intensity in steelhead, and high prevalence and intensity of *N. salmincola* in steelhead captured in the estuaries, suggests that new infections of *N. salmincola* are occurring as juvenile steelhead move downstream to Puget Sound during their migration (Chen et al. 2018). The presence of new infections occurring in the lower river/estuaries of the Green and Nisqually, and heart and gill inflammation found in the steelhead, may be killing the steelhead outright (Jacobson et al. 2008). Alternatively, and more likely based upon the mortality patterns seen (Moore et al. 2015; Moore et al. 2017; Berejikian et al. 2016, *N. salmincola* may be compromising the steelhead smolts' ability to swim (Butler and

[31] Appendix 2 of Puget Sound Steelhead Work Plan. Puget Sound Steelhead Marine Survival Workgroup 2014.

Millemann 1971) as they enter and migrate through Puget Sound, increasing their susceptibility to predation.

As there is little to no *N. salmincola* found in steelhead in rivers north of Lake Washington, the presence of this parasite does not explain the early marine mortality rates experienced by steelhead in Northern Puget Sound, or the similarities in low smolt-to-adult survival rates from the 1990s through 2012 common across Puget Sound steelhead populations as illustrated in Kendall et al. 2017.

Studies to determine the extent to which *N. salmonica* infections contribute to steelhead early marine mortality and to refine methods for isolating *N. salmincola* hotspots in rivers are ongoing (Puget Sound Steelhead Marine Survival Workgroup 2018).

Strategies and actions:

Implement actions to address *N. salmincola* in watersheds where the parasite is prevalent and at high enough intensities to influence the health and survival of outmigrating juvenile steelhead.

> Remove any *N. salmincola*-burdened salmonid carcasses from nutrient enhancement efforts in watersheds with the parasite. Alternatively, determine whether treatment such as freezing carcasses prior to use for nutrient enhancement kills the parasite.
>
> Filter or treat hatchery water supplies in rivers where *N. salmincola* is present, including Soos Creek Hatchery on the Green River, to attempt to break down the *N. salmincola* life cycle in watersheds.
>
> If hatchery water supplies cannot be treated and *N. salmincola* continues to affect salmon or steelhead while in the hatchery, consider reducing or eliminating upstream passage of these hatchery fish, when they return as adults, in areas where juvenile steelhead rear or above hatchery intakes to attempt to break down the *N. salmincola* life cycle in watersheds.
>
> Isolate *N. salmincola* hotspots and associated *juga* snail colonies (intermediate host) and take direct actions to reduce the abundance *juga* snails.

Continue research to further our understanding of *N. salmincola* impacts and approaches for mediating the impacts.

> Determine whether changing ecological characteristics of watersheds are leading to increased abundance of the intermediate host, the *juga* snail, or changes to *N. salmincola* shedding events. Include characteristics such as water temperature, flows, vegetation (broadleaf vs conifer), amount of sun exposure, substrate, and riverbed gradient. Structure habitat restoration efforts to obstruct the productivity of the *juga* snail, or that reduce the opportunity for *N. salmincola* shedding events.
>
> Determine the degree to which *N. salmincola* is contributing to juvenile steelhead marine mortality.

Assess the effectiveness of strategies and actions above. In addition to tracking steelhead mortality rates and locations, include response variables such as reduced parasite loads in steelhead smolts and lowered abundance of the intermediate host, juga snail.

If other disease is found to be prevalent and at high enough intensities to influence the health and survival of outmigrating juvenile steelhead in populations critical for recovery, take actions to reduce it.

Contaminants

Hypothesis: Exposure to contaminants in rivers and the marine environment impairs juvenile steelhead, increasing their susceptibility to disease and predation during their migration out of their natal rivers and through Puget Sound.

Evidence: Steelhead from the Skagit, Green and Nisqually Rivers were analyzed for persistent organic pollutants (POPs) in 2014, including polychlorinated biphenyls (PCBs), polybrominated diphenylethers (PBDEs) flame retardants, and organochlorine pesticides [dichloro-diphenyl-trichloroethanes (DDTs), chlordanes, hexachlorocyclohexanes (HCHs), hexachlorobenzene (HCB), aldrin, dieldrin, mirex, and endosulfans. The results show that PCBs and PBDEs accumulate in some populations of Puget Sound steelhead during freshwater residence, and, concomitant with lipid loss, reach levels during smolt outmigration that may affect their health (Chen et al. 2018). PCB and PBDE levels did exceed potentially harmful levels in up to 17-25% and 50%, respectively, of samples from steelhead recovered in the North/Whidbey Basin, Central and South Puget Sound offshore marine habitats. However, PCB concentrations were low within the Skagit, Green and Nisqually Rivers and their associated estuaries. The increase in harmful PCB concentrations offshore is primarily due to lower fish lipid content as migration proceeded. In contrast, 33% of the steelhead collected in the in-river trap and the estuary of the Nisqually River had PBDE levels that could increase disease susceptibility or alter thyroid hormone production. Nisqually steelhead were again analyzed in 2015 and similar results were found (pers. comm. O'Neill, Washington Department of Fish and Wildlife 2018). Ongoing work suggests exposure to PBDEs is occurring upriver in the Nisqually basin near Eatonville.

The profile of contaminant concentrations in the Skagit, Nisqually and Green watersheds do not explain high early marine mortality rates experienced throughout Puget Sound (Moore et al. 2015) or the low smolt-to-adult survival rates from the 1990s through 2012 common across Puget Sound steelhead populations (Kendall et al. 2017). The higher levels of PBDEs may help explain the greater on average early marine mortality experienced by the Nisqually River versus elsewhere (Moore et al. 2015). However, a study assessing the early marine mortality of steelhead cross-planted in the Nisqually and Green Rivers, where both populations survived their migration through Puget Sound at equal rates (Moore et al. 2017), suggests otherwise.[32]

Regardless, due to the persistent levels seen and their known to impact salmonid health, the source of these contaminants should be pursued so that it can be addressed. Sources of PBDEs to the Puget Sound include input from waste water treatment plants, followed by stormwater and then atmospheric deposition (Osterberg and Pelletier 2015) but the relative importance of these sources in the upper Nisqually watershed are unknown.

[32] See explanation in Section II., "Identifying and prioritizing sources of mortality to address".

Strategies and actions:

Implement actions to identify and reduce/or eliminate contaminants impacting steelhead smolt condition.

Identify the source of flame retardants (PBDEs) affecting Nisqually River steelhead and take actions to reduce or eliminate the quantity entering the river.

Assess other watersheds where contaminants may be of concern (e.g. Snohomish and Puyallup). If warranted, consider assessments for other contaminants such as trace metals, polycyclic aromatic hydrocarbons (PAHs), and contaminants of emerging concern (CECs).

If other contaminants are affecting a large portion of a steelhead population and have accumulated to concentrations sufficient to impair steelhead health and survival, identify the contaminant sources and implement solutions to reduce or eliminate their loads.

Genetic fitness

Hypothesis: Smolts in some populations with particular genetic fingerprints may be predisposed to higher early marine mortality and higher *N. salmincola* loads. This may be associated with the influence of residency vs anadromy. In some cases, the circadian clock and immune system may also influence *N. salmincola* loads and survival.

Evidence: Two rounds of genome-wide association studies (GWAS) were performed to test the hypothesis that there is a genomic association with (1) survival of outmigrating steelhead smolts as they transit from through Puget Sound to the Pacific Ocean, or (2) *Nanophyetus salmincola* infestation in steelhead smolts captured in the freshwater, estuary, or offshore areas (Studies 10 and 11). These studies were performed by analyzing DNA samples taken prior to release of acoustic-tagged steelhead in past years. The pilot year (study 10) included tagged fish from multiple watersheds, then was paired down to the Nisqually, Green and Skokomish Rivers after removing sample sets that may confound the results. The results suggested that survival may be influenced by differences in morphological features that may affect swimming performance (axial and fin development) and in the capacity for a fish to respond to pathogens or parasites). The many rivers and therefore lineages and collection years, and the few individuals that were categorized as survived, created small samples sizes and limited statistical power. In study 11, the sample design was improved by limiting analyses to two rivers (Green and Nisqually) and two years (Green + Nisqually = 2014 and Nisqually = 2015) with higher sample sizes. An additional data set characterizing *N. salmincola* loads in 2014 was also included. From both the survival and *N. salmincola* data sets, there is a genomic association with both steelhead smolt survival and *N. salmincola parasite loads*, but the association is statistically weak. The strongest association is with Omy05 genotypes, known elsewhere to be related to residency (A allele) vs anadromy (R allele). If the Omy05 genotypes here are associated with migration life histories, it is possible that the Omy05 A allele is maintained in the anadromous steelhead population by resident rainbow trout, and the presence of that A allele may reduce the individual's probability of survival or will result in a higher *N. salmincola* count, which directly or indirectly may reduce survival. That the Omy05 association is seen in both the Green and Nisqually population provides a basis for consistency with the outcomes of the reciprocal transplant study (study 4). Other components of the genome are more difficult to discern and appear population specific (e.g. loci associated with the circadian clock and a locus associated with the immune system in the Nisqually River). While this work lacked sufficient statistical power, steelhead early marine survival does appear to be associated with a smolt's genome.

Strategies and actions:

More work is needed to understand the importance of the genome compared to environmental factors and how the genome interacts with environmental factors. In particular, further assessing the relationship between the genome, *N. salmincola parasite* loads and early marine mortality could be promising.

If the Omy05 genotype continues to correlate with early marine mortality, and the Omy05 genotype is confirmed as an indicator of relative contribution of residency versus anadromy, consider the various factors that influence this (naturally occurring, freshwater barriers fragmenting habitat and steelhead/rainbow populations, hatchery influence, etc.).

Other considerations

This section was added to capture additional research and monitoring considerations for addressing Puget Sound steelhead early marine mortality.

Strategies and actions:

Implement long-term monitoring protocol to continue to assess steelhead early marine mortality rates and distribution, and compare to freshwater and later ocean mortality.

- Select index streams for each major population group, taking into consideration where monitoring has or continues to occur.
- Fund maintenance of Puget Sound acoustic telemetry array to track migration patterns, survival rates, and locations of mortality.
- Continue to assess later marine mortality for the same steelhead populations to test whether early marine mortality is additive vs compensatory. Perform this monitoring in the context of tracking responses to environmental change and in the context of the other research considerations for specific factors affecting the early marine mortality of steelhead.

Consider additional research to further assess juvenile steelhead outmigrant lipid levels, steelhead outmigrant size, steelhead prey availability, and the onset of foraging during outmigration on juvenile steelhead early marine survival (or later marine survival). The apparent, immediate mortality and lack of size-dependent mortality demonstrated by the acoustic telemetry data; the data supporting limited foraging during outmigration; and our understanding of natural declines in smolt lipid levels suggest these are not significant contributors to early marine mortality. However, uncertainties compel a greater understanding of the issue.

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Appendix 4. Detailed List of Strategies and Actions

Fish Barriers at Road Crossings (Including Culverts)

Strategy 1: Maintain and increase support for the Fish Barrier Removal Board (FBRB) and related programs.

Table A4-1. Proposed actions to maintain and increase support for the Fish Barrier Removal Board and related programs.

#	Actions for Strategy 1	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
1.a	Seek continued financial support to FBRB.	Various agencies and organizations continuously advocate for maintaining funding for the FBRB.	Continued funding support to the FBRB.	NOAA, WDFW, LLTK, others	DPS	none
1.b	Continue implementation of the Road Maintenance and Abandonment Program, Family Forest Fish Passage Program.	Monitor compliance (those who asked for 2021 extension).	Continued support to private landowners who can improve fish passage.	DNR, WDFW, Washington State Legislature	DdPS	RMAPs are getting finalized by 2016 (except for extensions until 2021).
1.c	Continue to work with and support Snohomish County in their fish barrier repair/replacement pilot program (and potentially others as program are created).	Work with Snohomish County	Faster fish passage construction projects.	WDFW, FBRB, NMFS, tribes, and local governments	DIP	Related to the Puget Sound Federal Task Force Action Plan. Refer to the pilot program in the Snohomish basin, which expedites fish passage project repairs using collaborative decision-making

#	Actions for Strategy 1	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
						process among federal, state, private, tribal, and local partners.
1.d	Develop a monitoring program for RMAP-repaired structures and report results over life of Forests and Fish Habitat Conservation Plan.	Repaired barriers sometimes revert to barriers when installed incorrectly or are undersized. Effectiveness monitoring identifies these issues. No program currently exists to validate if these repairs are being done or if they are successful in passing steelhead.	A science-based assessment of the effectiveness of the RMAP program and faster repairs of barriers that failed.	WDFW, DNR, tribes, NOAA (as administrator of the HCP?)	DPS	Based on results of failed structures, action could be taken to repair or replace those structures.
1.e	Repair fish passage barriers (w/in 6 years?) after results of monitoring have determined that they no longer continue to pass fish.	DNR requires repairs of barriers (post-RMAP) when they are aware of them, but there is no timeline for repairs.	Faster repairs of reformed barriers.	DNR, forest landowners	DPS	

Strategy 2: Highlight the gap in fish passage removal programs.

Table A4-2. Proposed actions to highlight the gap in fish passage programs.

#	Actions for Strategy 2	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
2.a	Ensure that recovery entities continue to seek resources to be put towards programmatic gaps in fish barrier removal programs.	Write a letter to the legislature to ensure adequate funding.	More solutions to existing gaps in fish barrier removal programs.	Regional salmon recovery groups	DPS	none
2.b	NMFS to work with BNSF to consider steelhead needs in their work that affects fish passage.	Align industry/business (BNSF) actions to be steelhead-friendly.	Reduce work that directly harms fish passage.	NMFS	DPS	Seek cost-share opportunities with the FBRB. Related to the Puget Sound Federal Task Force Action Plan.
2.c	Work with businesses that might increase fish barrier construction.	Develop training program for construction workers and engineers.	Reduce the number of new fish passage barriers being installed and leverage future partnerships with funding programs (such as FBRB).	NMFS, WDFW		Related to the Puget Sound Federal Task Force Action Plan.
2.d	Provide education and technical assistance at the City/County level for fish barrier removal.	Could also include guidance for critical areas ordinances (being updated late 2016).	Reduce the number of new fish passage barriers being installed.	WDFW; WA Commerce; Salmon Recovery Council, Association of Washington Cities, Washington State Association of Counties, FBRB	DIP, DPS	Some extension of current networking efforts with the Washington County Engineers program might be useful.

#	Actions for Strategy 2	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
2.e	Leverage existing programs (Floodplains by Design, FEMA BiOp, fish farm flood programs).	These programs often have barriers included within larger projects. Partnering with other programs (e.g., FBRB) may stretch limited resources.	May stretch limited funding to remove more barriers.	FBRB	DPS	Recovery Team needs to tee this issue up for the FBRB.
2.f	Supplement FBRB plan with federal actions identified in the federal MOU and workplan.	Channel federal funds to repair fish passage barriers on federal lands, and improve funding partnerships through federal grant mechanisms (e.g., FRIMA, Federal Highways, USFS, etc.).	Increased barrier repairs on federal lands and increased partnerships to stretch limited state funding on non-federal barrier repairs.	NOAA, Federal Highways, USFS, USFWS, BPA	DPS	Related to the Puget Sound Federal Task Force Action Plan
2.g	Encourage Cities and Counties to use taxing authority to repair or replace barriers.	Cities and Counties currently focus more funding priorities on road repairs and not on fish passage problems per se.	More repaired or replaced structures in City/County ownership.	WDFW on behalf of FBRB; WA Commerce; Salmon Recovery Council, Association of Washington Cities, Washington State Association of Counties	DPS-wide, at every DIP level	Related to 2.d.
2.h	Monitor fish abundance response in repaired/replaced structures through validation monitoring.	Funding entities (e.g., legislature) need greater assurances that limited public funding is working to	Greater outreach and communication tools, which in turn continue to support needed funding	WDFW; tribes; SRFB; NMFS	DIP, DPS	Related to Intensively Monitored Watershed approach. Pull out for separate

#	Actions for Strategy 2	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
		improve fish abundances.	for culvert repairs.			monitoring plan.

Strategy 3: Provide funding and resources for fish barrier removal.

Table A4-3. Proposed actions to provide funding and resources for fish barrier removal.

#	Actions for Strategy 3	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
3.a	Increase and diversify funding/resources.	Limited federal funding for barrier repairs leaves many federal barriers in place as others are being repaired.	Increased funding and resources for fish barrier removals.	FBRB, WDFW; NMFS; Cities; Counties; SRC; ECB; Puget Sound Regional Council (or other FHWA-based groups)	DPS	There are federal funding programs that are currently unfunded (or underfunded), e.g., FRIMA, USFS, etc. Related to the Puget Sound Federal Task Force Action Plan
3.b	Maintain existing funding/resources.		Maintain the existing level of fish barriers removals.	WDFW; NMFS; Cities; Counties; SRC; ECB	DPS	Related to the Puget Sound Federal Task Force Action Plan

Strategy 4: Education, social science, and social marketing.

Table A4-4. Proposed actions to provide education, social science, and social marketing.

#	Actions for Strategy 4	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
4.a	When telling the story of fish passage barrier correction, message it so landowners get energized instead of overwhelmed.	Create story-telling videos for shows and fairs. Develop landowner	People around the Sound are encouraged to repair or remove their fish barrier.	WDFW, FBRB, local governments, watershed groups	DIPS & DPS	Clear and immediate results.

#	Actions for Strategy 4	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
		leave-behind 2 pagers with information about barriers and available programs.				
4.b	Educate about the need for culvert correction to adapt/be resilient to climate change.	Showcase tools and presentations at conferences. Develop 2-pager handouts for sportsman shows for lay audiences.	Climate change impacts are widely shared in how they will affect barriers.	WDFW, FBRB, watershed groups	DIPS & DPS	Need to identify audiences e.g., aquatic scientists, landowners, land managers.
4.c	Educate to the general public about steelhead and steelhead restoration.	Develop videos and handouts for sportsman shows. Attend recreational fishing advocacy groups and provide presentations	Improved “image” of the on-the-ground work.	FBRB, WDFW, tribes, recovery groups, Lead Entities, City/County Public Works departments.	DIP and DPS	WDFW could partner with forest/timber industry.
4.d	Explore investment opportunities with potential new funding partners (e.g., private foundations).	Private and non-profit companies have expressed an interest in funding fish passage projects	Enhanced partnership opportunities for steelhead passage	WDFW, FBRB, PSP, LLK	DIP, MPG, and DPS	none

Strategy 5: Program alignment to ensure consistency (between state agencies, cities, counties, etc.).

Table A4-5. Proposed actions to provide program alignment to ensure consistency.

#	Actions for Strategy 5	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
5.a	Share expertise, improvements in technology, etc., to keep everyone up to date on best practices.	Present at cross-trade forums such as forestry sciences groups, County engineer and public Works groups, etc.	Best practices are more widely shared and understood.	FBRB, WDFW, Washington State Association of Counties, Association of Washington Cities, Washington Forest Protection Association, Washington Association of General Contractors	DIPS & DPS	We need to reach audiences who may not have historically been on the same page.
5.b	Create a "roster of experts".	The roster will include experts who have been trained/certified in culvert correction and will be available to local groups for their own barrier removals/corrections.	Correct information for how to repair or replace a barrier is available to local groups.	WDFW	DPS	There is no currently developed or recognized certification process but it will be important.
5.c	A mechanism and tools need to be developed and shared to ensure that local watershed groups provide steelhead-specific information, including new barrier inventories and newly repaired barriers, to	WDFW maintains the statewide database on stream crossings and their barrier status. New inventories are not always shared with WDFW. Also, when barriers are repaired, there are no current mechanisms to inform WDFW of the status change to avoid a barrier status when the barrier had been repaired.	Reduce duplicate efforts to gather information.	Watershed groups, WDFW, FBRB	DIPs & DPS	none

#	Actions for Strategy 5	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
	WDFW and others					

Strategy 6: Dis-incentivize new fish passage barriers.

Table A4-6. Proposed actions to dis-incentivize new fish passage barriers.

#	Actions for Strategy 6	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
6.a	Enforce and support regulation to prevent new fish passage barriers.	Enforce and support regulation	Fewer new problems; isolate the problem in existing infrastructure.	Federal enforcement of federal processes (NOAA, USFWS, EPA, USCOE, FERC). WDFW (for HPA-related work). Local governments.	DPS	RCW 77.57 currently prohibits barriers. Efforts to implement better enforcement should be encouraged WDFW is focusing attention on positive and collaborative approaches by educating public about RCW 77.57.
6.b	Evaluate effectiveness of newly installed culverts.	Evaluate effectiveness	Fewer fish passage barriers installed.	WDFW and others interested.	DPS and potentially DIP if watersheds are interested.	For separate monitoring plan.
6.c	Seek federal permit process improvements to expedite stream simulation designs (or better). Consider state-funding for dedicated CORPs' staff to expedite permits for barrier repair (other restoration projects for steelhead?).	Corps and Engineers permit process is very lengthy and can delay repairs for months.	Barriers can be corrected faster.	NOAA, USFWS, Corps', FBRB, WDFW, GSRO	DPS	Good progress recently from services in developing a programmatic permit. Corps' is limited in number of staff and in their review process.

Strategy 7: Increase data and information.

Table A4-7. Proposed actions to increase data and information.

#	Actions for Strategy 7	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
7.a	Incorporate steelhead-specific information to the FBRB's work (separate program, incorporate information into existing programs, etc.).	Provide steelhead life cycle modelling outcomes and density dependent basin needs to WDFW.	More connection between steelhead needs and barrier removals.	Recovery Team, WDFW/FBRB	DPS & DIPs	Steelhead modeling experts meet with WDFW FBRB tech team to reflect on current and alternative tools to benefit steelhead with barrier removals.
7.b	Map DIPs to HUC-10s.	FBRB based its selection of priority watersheds on federal HUC scales whereas the recovery team has selected DIPs. Educate which HUC-10s are in each DIP.	Increased understanding among different groups implementing barrier repairs.	Recovery Team (to include in the Plan or supplemental webpage)	For each DIP	none
7.c	When inventorying culverts, focus on already prioritized areas.	Stream crossing culverts can change from passable to barriers over time if they are undersized or improperly designed. By inventorying just those streams and reaches where repairs	Less waste in inventory effort.	WDFW, watershed groups	DIPs & DPS	Re-enforce culvert inventory efforts which focus on prioritized FBRB streams and discourage inventories on streams which are not priorities in the

#	Actions for Strategy 7	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
		are a priority, the information stays fresh.				immediate future.
7.d	Build for future climate change impacts (storm events, higher/lower flows, etc.).	Addressing future climate change impacts	More awareness of climate change impacts and what is needed to accommodate those in the future.	WDFW/FBRB	DIPs & DPS	none
7.e	Improve understanding of climate effects on culverts. Examine current climate change tools in the design of culverts.	Current climate models suggest that streams may widen with increased BFW flows in some areas. Increased BFW may require larger culverts in replacement designs to handle increased flows.	Fewer culverts may fail in time as climate-induced stream flows increase beyond the capacity of current culvert designs.	WDFW, FBRB, NOAA	DIPS & DPS	Need to educate more watershed groups on this new topic to improve network of information sharing.
7.f	Ask watershed-level salmon recovery groups to canvas their jurisdiction annually and report corrected barriers to WDFW.	Gaining better information	Better, more up-to-date information on where barriers are and have been corrected.	Watershed groups (lead entities, LIOs, NGOs, etc.). Local governments. Tribes.	DIP	none
7.h	Convene annual meetings at DIP level to refine the needs for culvert removal/repair	Sharing information and setting priorities	Most up-to-date information on existing culverts.	PSP, local watershed groups, cities and counties	DIP	none

#	Actions for Strategy 7	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
	in priority basins.					
7.i	Align the Habitat Work Schedule (HWS) with the WDFW fish passage database (FPDSI).	HWS can be useful in sharing newly corrected barrier data with FPDSI. FPDSI can be useful in helping local watershed groups get information about barrier status through HWS.	Less time wasted searching for current information, more accurate and up to date information on culvert status.	GSRO & WDFW	DPS	none
7.j	Align permitting databases (e.g., HPA database) with FPDSI.	Aligning databases	Provides current information to permitting biologists and tribes on barrier locations and status when in water work is permitted.	WDFW	DPS	none

Strategy 8: Barrier corrections should recognize needs of beavers.

Table A4-8. Proposed actions to recognize needs of beavers when correcting barriers.

#	Actions for Strategy 8	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
8.a	Incorporate beaver needs into barrier removal programs and guidelines	Beavers take advantage of narrow stream crossings and block access to steelhead and other salmonids.	Better plan for all species, acknowledge differing needs.	WDFW	DPS	none

#	Actions for Strategy 8	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
		Design guidelines will help practitioners develop more durable passage remedies. Relocation of beavers (if allowed under state law) will provide restoration of steelhead habitat in other areas				

Dams

Strategy 1: Identify opportunities and priorities for dam removal in watersheds were steelhead migration has been blocked.

Table A4-9. Proposed actions to identify opportunities and priorities for dam removal in watersheds where steelhead migration has been blocked.

#	Actions for Strategy 1	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
1.a	Provide education and technical assistance at the City/County level for non-FERC / non-Federal dams	Could also include guidance for critical areas ordinances (being updated late 2016).	Reduce the number of new fish passage barriers being installed.	WDFW; WA Commerce; Salmon Recovery Council, Association of Washington Cities, Washington State Association of Counties, FBRB	DIP, DPS	Some extension of current networking efforts with the Washington County Engineers program might be useful.
1.b	Follow and participate in work of the ongoing dam	Prioritizing dam removal projects	Improved steelhead distribution	Dam removal prioritization project by American	DIS, DPS	Brand new team (spring 2017); started by

#	Actions for Strategy 1	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
	removal prioritization team (Washington-wide, but includes Puget Sound).			Rivers and NOAA		American Rivers/NOAA.

Strategy 2: Provide funding and resources for dam removal.

Table A4-10. Proposed actions to provide funding and resources for dam removal.

#	Actions for Strategy 2	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
2.a	Provide input to federal legislators for federal authorization and funding for dams identified as a high priority for removal	Communicate with authorities to fund dam removal	Removal of federal owned or licensed dams that are blocking steelhead migration.	NOAA; WDFW; PSP; NGOs; WRIA groups	DIP, DPS	none
2.b	Provide support to state and local governments for funding the removal of non-federal public and private dams	Provide support for government funding	Removal of non-federal dams that are blocking or impeding steelhead migration	NOAA; WDFW; PSP; NGOs; WRIA groups	DIP, DPS	none
2.c	Provide support for use of federal and state salmon and steelhead restoration funds for removing high priority municipal and private dams	Provide support for use of restoration funds	Removal of municipal and private dams that are blocking or impeding steelhead migration	NOAA; WDFW; PSP; NGOs; WRIA groups	DPS, DIP	none

Strategy 3: Remove high priority dams that block or impair steelhead migration into historic spawning and rearing areas.

Table A4-11. Proposed actions to remove high priority dams that block or impair steelhead migration into historic spawning and rearing areas.

#	Actions for Strategy 3	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
3.a	Removal Middle Fork Nooksack Diversion Dam	This is project has been submitted for	At least 15 miles of steelhead spawning and rearing habitat above dam	City of Bellingham; Nooksack Tribe; Nooksack Watershed Lead Entity; Puget Sound Partnership	DIP (Nooksack)	Also benefits SRKW

Strategy 4: Construct or improve fish passage facilities at dams, locks, and water diversions where steelhead migration is blocked or impaired. Reduce passage injuries and mortalities at these facilities.

Table A4-12. Proposed actions to construct or improve fish passage facilities at dams, locks, and water diversions that impair steelhead migration.

#	Actions for Strategy 4	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
4.a	Exercise Federal Power Act Section 10(j) authority for mandatory fish passage at during FERC licensing and relicensing of dams	Section 10(j) fish passage prescriptions can be included as part of licensing conditions for non-federal hydro dams	Improved upstream and downstream passage of steelhead at hydroelectric dams if fish passage requirements are met. Reduced passage injuries and mortalities at existing facilities.	NMFS; USFWS; federal land management agencies at certain projects	DPS	Address tribal rights and water rights
4.b	For non-FERC dams, provide authority to get regulatory mechanisms	Authority to address regulations	Increase fish passage through low-head dams	NMFS, WDFW, Ecology, PSP	DPS	Ecology dam safety programs?

#	Actions for Strategy 4	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
	to remove them or provide durable fish passage.					
4.c	Improve Ballard Locks and dam for upstream and downstream passage	Aging facilities are decreasing productivity of out-migrating smolts and returning adult steelhead	Improved survival rates of adult and juvenile steelhead in Lake Washington system.	Corps', WDFW, NOAA, PSP, Ecology	Lake Washington / Cedar River (DIP)	Primary passage and predation issue for this population of both steelhead (nearly extirpated) and Chinook.
4.d	Improve downstream fish passage facility at Howard Hanson dam.	Completion of major downstream juvenile fish passage facility on hold due to lack of federal authorization and funding	Restore steelhead runs to upper Green River drainage. Substantially increase steelhead spawning and rearing area in WRIA 9. Possibility of introducing / restoring summer steelhead population.	USACE; US Congress, NOAA	Green River (DIP)	Green River watershed above HHD has excellent steelhead habitat
4.e	Improve steelhead passage at Buckley Diversion Dam and Mud Mountain Dam fish passage facilities	Currently under construction	Improved adult passage and productivity	ACOE; NOAA, tribes, WDFW	White River (DIP)	Buckley trap and haul improvements primarily improve Chinook but are expected to benefit steelhead as well.
4.f	Monitor steelhead use above Electron Dam	New fish passage was created, but unclear if fish	Improve fish passage and productivity	Puyallup Tribe; PSE	DIP (Puyallup)	Details from Annual Salmon, Steelhead, and Bull Trout Report (2015-

#	Actions for Strategy 4	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
		are utilizing new habitat				2016), Puyallup Tribe pg16 (Ask Russ if helpful to include in regional plan)
4.g	Evaluate and improve juvenile steelhead migration passage potential through two Baker River reservoirs and fish passage facilities at dams	Fish passage facilities were constructed by PSE during Baker River relicensing process	Improved downstream passage can improve production and abundance	Upper Skagit Indian Tribe; Swinomish Tribe; PSE; NOAA; WDFW	Baker River (extirpated DIP)	Steelhead are presently not being passed upstream due to concerns over residualization of juvenile steelhead, but smolts are being produced from resident life-history forms.

Strategy 5: Education, social science, and social marketing.

Table A4-13. Proposed actions to provide education, social science, and social marketing.

#	Actions for Strategy 5	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
5.a	Educate and involve agencies, tribes, and NGOs on the FERC relicensing process. Involvement can be as "interveners" (high level of effort) and/or as reviewers/ commenters on the EIS part of relicensing.	Greater involvement and technical support in FERC relicensing process.	Increased consideration for steelhead recovery in FERC relicensing process	Federal stakeholders; Tribes; NGOs; FERC; Dam Owners	DPS, DIP	Technical support by NWFSC staff may be needed by NOAA regulatory staff
5.b	Educate public on NEPA review process for proposed construction of water diversion structures and dams, and pending relicensing of hydroelectric dams.	Greater involvement and support	Increased consideration for steelhead recovery in NEPA process required for hydroelectric dam relicensing	Federal stakeholders, tribes, etc.	DPS	none

Strategy 6: Dis-incentivize new dams, locks, and water diversion structures.

Table A4-14. Proposed actions to dis-incentivize new dams, locks, and water diversion structures.

#	Actions for Strategy 6	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
6.a	Reinforce regulations to prevent new anadromous fish passage barriers, including dams	Regulation to prevent new fish passage barriers	Fewer new problems; isolate the problem in existing infrastructure.	Federal enforcement? NOAA?	DPS	RCW 77.57 currently prohibits anadromous fish barriers, but has thus far been unenforced. WDFW is focusing attention on positive and collaborative approaches.
6.b	For new dams, include Federal Power Act Section 10(j) conditions for mandatory fish passage authority, and Section 18 fish passage prescriptions.	Section 10(j) fish passage prescriptions can be included as part of licensing conditions for non-federal hydro dams	Improved upstream and downstream passage of steelhead at hydroelectric dams if fish passage requirements are met. Reduced passage injuries and mortalities at existing facilities.	NMFS; USFWS; federal land management agencies at certain projects	DPS	Address tribal rights and water rights
6.c	Use the Wild & Scenic Rivers Act and Wilderness Designations to protect important steelhead habitat from future dam development.	Wild & Scenic River and Wilderness designations will prevent development of new dams and small hydro projects	Increased protection of steelhead migration and habitat use in specific drainages	USFS; NOAA; NGOs	DIP	Recent examples: Upper Skykomish Wilderness Designation, and Sauk River Wild & Scenic designation.

Strategy 7: Improve instream flows downstream of hydroelectric dams and water storage reservoirs.

Table A4-15. Proposed actions to improve instream flows downstream of hydroelectric dams and water storage reservoirs.

#	Actions for Strategy 5	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
7.a	Revise minimum instream flow requirements downstream of hydroelectric dams and water storage reservoirs to improve flows for steelhead spawning, incubation, and juvenile rearing	Instream flow requirements are implemented by WDFW and WDOE downstream of hydroelectric dams and water storage facilities	Improved survival and habitat conditions for all freshwater life stages of steelhead	WDFW; WDOE; NMFS; Tribes; dam owners	DIP	none
7.b	Reduce impacts of peak flows on steelhead egg and juvenile survival downstream of dams through improved reservoir operations	Impacts of natural peak flow events on steelhead can be moderated by fish management measures at storage reservoirs	Improved freshwater productivity of steelhead in rivers downstream of dams	WDFW; WDOE; NMFS; tribes; dam owners	DIP	none
7.c	Reduce impacts of flow ramping below hydroelectric dams by implementing site specific flow ramping criteria	Many dams vary flow releases during day in response to changes in electricity demand.	Reduction of steelhead egg and fry stranding mortality caused by daily flow fluctuations downstream of dams	WDFW; WDOE; NMFS; tribes; dam owners	DIP	none

Strategy 8: Improve habitat conditions downstream of hydroelectric dams and water storage reservoirs.

Table A4-16. Proposed actions to improve habitat conditions downstream of dams and water storage reservoirs.

#	Actions for Strategy 8	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
8.a	Evaluate impacts of dams and reservoir operations on downstream habitat conditions	Habitat impact analysis is typically conducted as part of FERC licensing and relicensing process. Also conducted as part of ESA Section 7 consultations; HCPs, and NEPA environmental review process.	Major impacts of dams on steelhead habitat conditions identified and prioritized for potential mitigation actions.	WDFS; NMFS; tribes; dam owners; NGOs	DPS, DIP	none
8.b	Restore geomorphological conditions downstream of dams through restoration and mitigations actions	Improved habitat conditions for steelhead in tailwater areas downstream of dams.	Mimicking natural hydrologic regimes will improve redd success and juvenile access to floodplain habitats.	WDFS; NMFS; tribes; dam owners; NGOs	DIP	Trinity River restoration in northern California provides classic example of efforts to restore natural geomorphic channel patterns and processes below dams for steelhead
8.c	Restore gravel recruitment, or introduce gravels (gravel seeding programs), in river channels below dams which are "gravel starved".	Large hydroelectric and storage dams cut off gravel inputs from upper watershed	Improved access to coarse sediment for spawning and improved reproductive success of redds	WDFS; NMFS; tribes; dam owners; NGOs	DIP	ACOE gravel seeding program in Green River below Howard Hansen Dam is good example

#	Actions for Strategy 8	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
8.d	Restore large wood jams downstream of dams and water storage reservoirs	Large hydroelectric and storage dams cut off wood inputs from upper watershed. Placement of large wood in channel, and engineered log jams can be used to improve habitat conditions for steelhead.	Increased gravel retention for steelhead spawning. Improved habitat cover for juvenile rearing and adult steelhead holding. Restoration of natural channel patterns and migration processes.	WDFS; NMFS; tribes; dam owners; NGOs	DIP	none

Strategy 9: Improve temperature and water quality conditions downstream of hydroelectric dams and water storage reservoirs.

Table A4-17. Proposed actions to improve temperature and water quality conditions downstream of dams and water storage reservoirs.

#	Actions for Strategy 9	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
9.a	Hydroelectric dams and reservoirs must meet state water quality standards for temperature, dissolved oxygen, and other WQ requirements to meet fish uses (including steelhead spawning and rearing)	Hydroelectric and water storage dams are issued a CWA 401 certification for water quality compliance by WDOE. Water temperatures of release waters can be improved for steelhead.	Improved temperature and water quality conditions in rivers and streams downstream of dams	WDOE; NMFS; tribes; dam owners	DIP	Instream flow studies are typically required by WDOE as part of 401 certification process for major dams. Water quality conditions are closely linked to flow regimes. 303(d) listings may trigger the TMDL process.

Floodplain Impairments

Strategy 1: Protect intact floodplains using effective land use regulations and enforcement.

Table A4-18. Proposed actions to protect intact floodplains using effective land use regulations and enforcement.

#	Actions for Strategy 1	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
1. a	Integrate NOAA's riparian buffer tables into land use planning and regulations to improve habitat and water quality for steelhead.	Improves habitat through regulation	Improved habitat, flows, and water quality in steelhead streams	Ecology, Local government, WDFW, NOAA, EPA	DIP	none
1. b	Increase coordination between local governments and groups pursuing Basin-wide land protection to identify opportunities for sharing information and collaborating on regulatory updates	Improves habitat through coordination	Increased coordination will lead to more effective regulations to protect floodplain habitat for steelhead by showcasing lessons learned and benefits gained among jurisdictions	Local government, Commerce,	DPS, MPG, DIP	Information sharing collaboration protect
1. c	Fund and assess the effectiveness of existing land use regulations (GMA/SMA) to protect floodplains and riparian habitats	Monitoring compliance with and effectiveness of existing land use laws is poorly implemented due to funding constraints.	An improved understanding of where land use laws work and do not work will increase the effectiveness of those laws and the protection of steelhead habitat processes	Local Government, state agencies (esp. Commerce)	MPG/DPS – mostly a county scale	GMA Funding monitoring
1. d	Incentivize Agriculture programs to retain compatible land use while improving	Seek partnership with the Ag community to increase riparian habitats in floodplains while increasing	A healthy partnership with the Ag community and increased protection and	Conservation Districts, WDFW, Ecology, local governments, tribes	DPS/ MPG / DIP	none

#	Actions for Strategy 1	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
	steelhead habitat in productive floodplains and riparian habitats.	productive quality of farms and increasing the quantity of suitability farmland acreage.	restoration of steelhead habitat			
1.e	Identify and prioritize critical area recharge areas to improve low flows and moderate flash flows	Helps regulate temperature and water quantity	Identifies important protection and acquisition opportunities and secure stream flows for steelhead rearing and spawning areas	Ecology, WDFW, local governments, tribes	DIP	GMA protect
1.f	Increase the public education and awareness of land use regulations for steelhead.	Local government leaders often face land rights advocates with little support from habitat-knowledgeable publics.	Increased public discussion on the value of increasing steelhead habitat	State agencies, tribes, federal agencies, local government leaders, local salmon recovery entities	MPG/DPS/DIP	Education GMA
1.g	Ensure that funding is provided to appropriately implement and enforce regulations.	Enforcement of existing laws is among the most straight forward and agreed upon actions, but it is too often under-funded	Less land use activities are conducted that impair floodplains and riparian areas/functions, and increases mitigation activities where impairment does occur.	Local governments, tribes, state (DNR, Ecology, WDFW, and federal agencies (Corps', NOAA)	MPG/DPS/DIP	Funding enforcement
1.h	Limit the exceptions, exemptions, and variances that can result in decreased function of hydrologically sensitive areas	Variances are often provided to landowners that weaken riparian and wetland protection ordinances. This action would reduce variances to	Better protected riparian and floodplain habitat. More consistent and predictable monitoring/Adaptive	Local governments, tribes, agencies.	MPG/DPS	Protect-GMA

#	Actions for Strategy 1	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
	such as shorelines, wetlands, forest cover, riparian zones, aquifer recharge areas, and hyporheic areas.	those with demonstrable need.	management and implications			
1.i	Develop and implement standardized mitigation criteria to off-set impacts to floodplain development where development is unavoidable.	Integrate mitigation tables from different entities to increase consistency and effectiveness of mitigation requirements from floodplain impacts	Adequate and consistently implemented mitigation measures for unavoidable impacts will help ensure a no-net-loss of productive steelhead habitat.	WDFW, Ecology, DNR, local governments, Commerce	DPS	Regulation mitigation
1.j	Institute/implement flexible development tools, such as land swaps, transferable development rights, environmental mitigation banking/reserve programs, and in-lieu fee mitigation to shift development to areas which are less environmentally sensitive and/or to mitigate impacts by restoring areas with highest ecological functions.	Coordinate with mitigation bank and mitigation reserve programs to ensure their work considers/compliments salmon habitat benefits.	Increased opportunity to increase protection for productive stream reaches, and restore unproductive reaches.	Land Trusts, DNR, Commerce, local governments, conservation commission	DIP	none
1.k	For development proposals on steep slopes and		Increased protection of streams from	Commerce, Ecology, and local	DPS/DIP	none

#	Actions for Strategy 1	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
	other environmentally critical areas, CAO regulations should require assessment and recommendations from a qualified geotechnical professional, to protect sediment sources, vegetative cover and appropriately mitigate any impacts		land use-induced landslides and erosion.	governments		
1.l	Coordinate with Regional Transportation Councils and agencies to incorporate steelhead and salmon protection and recovery into long-range planning efforts.	The Puget Sound Regional Council "Transportation 2040" plan contains goals that are mutually conflicting, and none of the goals contain steelhead recovery elements. Likewise, the State Department of Transportation long range plan, "Transportation 2017-2040", lacks planning for salmon and steelhead recovery.	Early planning avoids impacts to steelhead rather than mitigates for impacts as they occur during implementation.	Puget Sound Partnership, WDFW, Ecology, NOAA, WSDOT, Federal Highways, local governments and regional transportation councils.	MPG and DPS	none

Strategy 2: Identify and protect floodplains and freshwater wetlands for steelhead through funding and implementing farm-fish-flood integrated planning programs at the local level.

Table A4-19. Proposed actions to identify and protect floodplains and freshwater wetlands for steelhead through funding and implementing farm-fish-flood programs at local level.

#	Actions for Strategy 2	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
2.a	Increase funding and use of Floodplain by Design to plan, protect and restore floodplains.	Protects and restores floodplains	Increased partnership with landowners, especially Ag land uses, to promote habitat protection and restoration opportunities	Ecology, Restoration community	DPS	none
2.b	Support engagement in and funding for local processes and implementation of locally developed plans such as King County's Snoqualmie Farm, Fish, and Flood and watershed development district; Snohomish Sustainable Lands Strategy; Puyallup Floodplains for the Future Project.	These plans bring local stakeholders to the table to identify and negotiate goals and site-specific actions for reach-based or watershed-level planning	Agreed upon floodplain and estuary habitat for working lands and habitat protection.	Counties, local stakeholders, Ecology, WDFW, Commerce	DIP	none
2.c	Use the High Resolution Change Detection Approach (developed by WDFW) to determine where land change is happening, the type of conversion taking place, identify hotspots where	Gains information to improve protection and identify hotspots	Better information expected to improve regulation implementation and ease of compliance and monitoring, which would in turn improve protection of	WDFW, NOAA	DIP, reach scale	none

#	Actions for Strategy 2	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
	change happening at a higher rate than average.		ecologically important areas.			
2.d	Use NOAA's riparian buffer tables to standardize protocols and priorities for permanent riparian buffer easements and fund these priorities	Applied to high priority locations, provides permanent protection to riparian and floodplain habitats	Improved habitat functions in riparian and instream processes.	Protocols and priorities = PS SRC, Science team Funding = state and federal agencies	DPS/MPG/DIP	Protect – funding easements
2.e	Develop a tax benefit program for landowners willing to retain adequate existing riparian buffers (e.g., Public Benefit Rating System)	Ecosystem benefits are obtained with improved riparian buffers. A reward (benefit) program would pay landowners who provide a buffer	Increased landowner participation in leaving riparian vegetation on shorelines	Commerce. Local governments, WDFW, Ecology	DPS	Incentive protect
2.f	In rural areas, counties should utilize conservation easements, current use taxation (e.g., Public Benefit Rating System and Timberland Program), Transfer of Development Rights program, and Native Growth Protection Area programs	Increased funding and outreach to interested landowners in protecting high priority stream reaches.	Increased protection of rural stream corridors and riparian areas through acquisition and easements will lead to increased spawning and rearing success for steelhead.	Local governments, conservation commission, conservation districts, land trusts, WDFW, Ecology	DIP, MPG, DPS	none
2.g	Provide technical assistance for	Conservation Districts find	Increased interactions	Conservation District,	DIP, MPG	none

#	Actions for Strategy 2	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
	small forest landowners and develop farm plans with farmers through increased funding for Conservation Districts.	routine success in working with rural landowners to jointly protect farmland and stream corridors but funding for these programs is lacking and unreliable.	between steelhead conservation interests and farm land interests will increase protection for steelhead habitats, especially in smaller streams.	County governments, land trusts, Conservation Commission.		

Strategy 3: Reduce levee impacts through setbacks and improved vegetation management.

Table A4-20. Proposed actions to reduce levee impacts through setbacks and improved vegetation management.

#	Actions for Strategy 3	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
3.a	Integrate floodplain planning guidance on the National Flood Insurance Program, Clean Water Act (404), levee standards, SMA, and GMA	Providing consistent guidance	Less ambiguity with inconsistent guidance from multiple sources	FEMA, Ecology, local governments	DIP	none
3.b	Analyze floodplain data for projected population growth, flood risk, and hydrological and geomorphological benefits to steelhead.	Creates an analysis of ecologically important lands in floodplains juxtaposed with lands at high risk for development	Reach-scale planning to prioritize protection strategies for steelhead	Local governments, WDFW, Ecology, PSP, Commerce	DIP	None
3.c	Update climate change projections to strengthen the identification of	Updating climate change projections	Planners have access to improved flood risk info. Increases the opportunity for flood-risk and steelhead	FEMA, NOAA, Ecology, local governments, WDFW	DPS/MPG/DIP	none

#	Actions for Strategy 3	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
	areas at high risk for flooding.		habitat restoration/protection partnerships			
3.d	Educate policymakers on flood and flood risk tolerance projections	Informs decision makers on the real costs of developing floodplains	Regulatory staff at the local level are supported in flood-risk decision making, increasing floodplain protection for steelhead.	WDFW, Ecology, Lead Entities, PSP,	DPS/DIP	none
3.e	Develop and showcase examples of mutual benefit projects that help alleviate flooding and benefit steelhead	e.g., Fisher Slough, etc	Gain greater acceptance that mutual benefit projects are possible and increase confidence and trust in restoration projects	Ecology, PSP, WDFW, NOAA, local governments, restoration entities (e.g., Nature Conservancy)	DIP	none
3.f	Develop and implement regional variance models to existing Corps' vegetation requirements on levees	Using SWIFD or alternative Corps' process, safely increase vegetation on levees	Improved shade and structure for instream steelhead habitat	Corps', WDFW, Ecology, NOAA, tribes, local governments	DIP/ MPG / DPS	none
3.g	Incorporate Reasonable and Prudent measures from the FEMA Biological Opinion into local government planning and Critical Area Ordinances.	Actions from the FEMA BiOp are not being implemented However, protection measures in the BiOp remain germane to local, state, and federal government protection strategies in floodplains.	Adoption of BiOp protection measures in both regulatory and voluntary programs will increase protection of steelhead spawning and rearing habitat.	Local governments with outreach from NOAA and WDFW and Ecology.	MPG, DIP and DPS	none

Strategy 4: Reduce bank armoring and other habitat stressors in steelhead river systems.

Table A4-21. Proposed actions to reduce bank armoring and other habitat stressors.

#	Actions for Strategy 4	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
4.a	Increase the use of 'demonstration of need' for new hard armor permits.	Limiting bank armoring projects to those locations where soft armor approaches are demonstrably infeasible	A reduction of new armoring in steelhead streams	WDFW, Corps', tribes, NOAA, local governments, DNR	DIP	none
4.b	Incentivize soft bank protection where needed, including the use of streamlined permit processes where wood is mostly used	Increase bank armoring	Fewer armoring on riverine banks and where it does occur, soft approaches will promote healthy habitat.	WDFW, Corps', local governments, NOAA, Ecology, DNR	DPS/DIP	none
4.c	Fully mitigate the installation of unavoidable bank armoring in steelhead streams to off-set the loss of steelhead habitat	Reduces loss of habitat	Decreased loss of steelhead habitat	WDFW, tribes, Ecology, DNR, NOAA, Corps'	DPS, DIP	none
4.d	Develop civil penalties and enforce un-permitted bank armoring and the removal of large wood from streams and riparian areas.	Increase compliance with streambank regulations	Increased landowner participation in leaving riparian vegetation on shorelines	Commerce. Local governments, WDFW, Ecology, Corps'	DPS, MPG, DIP	none
4.e	Incentivize and promote the removal of invasive vegetation and promote the plantings of native and beneficial species	Promotes removal of invasive vegetation	Reduce competition between native and non-native riparian vegetation, increasing stream complexity	Conservation districts, RFEGs, local governments, county weed boards	DIP	Invasive veg

#	Actions for Strategy 4	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
			and increasing steelhead VSP metrics.			
4.f	Provide expertise/technical assistance to property owners (e.g., templates for riparian planting plan, assistance with designing habitat restoration, identifying potential grant funding for implementation)	Many landowners would "do" the right thing for steelhead and watershed health, but are unaware of what to do or how to do it.	Increase voluntary efforts to increase "backyard" stream restoration efforts (ground-up approach).	Conservation districts, RFEGs, WDFW, Ecology, Region, Counties,	DIP	none
4.g	Actively remove hard bank protection from streams and replace with soft approaches where necessary or opportunistic	Increased technological advances in soft protection strategies combined with increased outreach by restoration groups has led to increased opportunities to convert hard armoring into more beneficial techniques.	Restored stream banks will provide increased productive habitats for spawning and rearing.	Regional fish enhancement groups, conservation districts, WDFW, Ecology, local governments, Corps'	DIP	none

Residential/commercial/industrial development

Strategy 1: Reduce impediments to infill and redevelopment in Urban Growth Areas (UGAs).

Table A4-22. Proposed actions to reduce impediments to infill and redevelopment.

#	Actions for Strategy 1	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
1.a	Increase incentives for developers to infill or	To simplify permitting process and increase	Increased attractiveness of infill/redevelopment for developers;	Local government, Commerce,	DIP	LU/LC IS

#	Actions for Strategy 1	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
	redevelop property	incentives for infill, permit costs should be reduced, processed faster, and the process should be predictable. Tax incentives, municipality-provided infrastructure, and a reassessment of overly stringent zoning.	(reduced development on currently undeveloped land).	WDFW, Ecology		
1. b	Increase resources for Department of Ecology voluntary cleanup program to expedite permitting for redevelopmen t on contaminated sites.	Incentives for redeveloping within the UGA of local communities could be enhanced if cleanup programs created more opportunity at contaminated sites within those areas.	More opportunity/willingne ss for infill to reduce conversion pressure on rural or ecologically sensitive lands.	Ecology, Commerce, local governments	DIP	This is an issue of interest to the Ecosystem Coordinati on Board (ECB).
1.c	Coordinate with Regional Transportatio n Councils and agencies to incorporate steelhead and salmon protection and recovery into long-range planning efforts.	The Puget Sound Regional Council "Transportatio n 2040" plan contains goals that are mutually conflicting, and none of the goals contain steelhead recovery elements. Likewise, the State	Early planning avoids impacts to steelhead rather than mitigates for impacts as they occur during implementation.	Puget Sound Partnership, WDFW, Ecology, NOAA, WSDOT, Federal Highways, local governments and regional transportatio n councils.	MPG and DPS	none

#	Actions for Strategy 1	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
		Department of Transportation long range plan, "Transportation 2017-2040", lacks planning for salmon and steelhead recovery.				

Strategy 2: Improve local implementation and enforcement of Growth Management Act existing regulations that protect streams and wetlands from residential/commercial/ industrial development.

Table A4-23. Proposed actions to improve local implementation and enforcement of Growth Management Action regulations.

#	Actions for Strategy 2	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
2.a	Minimize increases of current Urban Growth Area (UGA) boundaries and continue to absorb the majority of growth inside the UGA	Helps protect habitat by enforcing GMA.	Directing growth to UGAs helps preserve ecologically important lands in more priority landscapes with less infrastructure.	Local governments, Commerce	DIP	none
2.b	Encourage cluster developments in rural areas in areas where important habitat can be protected or linked, in order to preserve contiguous habitat and provide important ecological services for steelhead.	This strategy aims to minimize potentially harmful impacts of residential, commercial, and industrial development outside of UGAs	More steelhead habitat protected outside of UGAs	Local governments	DIP	none

#	Actions for Strategy 2	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
2.c	Strictly apply, and improve compliance with, critical areas ordinance (CAO) protections for aquatic buffers, wetlands and forest cover. Limit or eliminate variances	Increased protection of riparian buffers by limiting allowable uses that impact habitat functions that support steelhead.	Less negative impact to steelhead habitat, especially in riparian and wetland landscapes.	Local governments, Commerce, WDFW, Ecology	DIPs & MPGs	none
2.d	For development proposals on steep slopes and other environmentally critical areas, CAO regulations should require assessment and recommendations from a qualified geotechnical professional, to protect sediment sources, vegetative cover and appropriately mitigate any impacts to steelhead habitats.	Prior to an automatic or default variance or exemption for development on steep slopes, local governments should require a geotechnical assessment that determines that a variance is necessary for safety or structural loss.	Improved natural conditions for steelhead along banks of streams, rivers, and deltas.	Commerce, local governments, WDFW, Ecology	DIPs	none
2.e	Determine the lands at risk of conversion by aligning UGAs with steelhead habitat data and watershed characterization data to identify solutions to risks, then implement protective regulations.	Identifies habitat areas at risk of conversion	With a greater understanding of habitat at risk of conversion, more precise and effective habitat protection strategies can be devised.	Local governments, Commerce, WDFW, Ecology, tribes	DIPs	none
2.f	Assess accuracy of historic buildout scenarios	Alternative Futures provides an	Assessing the accuracy of projections can	Local governments, Commerce,	DIPs	Would be beneficial for this task to

#	Actions for Strategy 2	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
	(Alternative Futures) to determine where habitat protection efforts are most crucial, then implement protective regulations.	opportunity to protect the most important habitat that is projected to be developed into the future.	highlight places where habitat is being lost more quickly than expected, and should be bolstered.	WDFW, Ecology, tribes		feed into plan development, rather than being part of the plan itself.
2.g	Advance other, systemic ways of improving local implementation of GMA such as restoring state funding that supports county-level GMA planning	Improves local implementing of GMA	With state funding restored, counties can update local CAOs and SMPs in a timely and effective manner	State legislators and their constituents		Solicitation for Near-Term Actions (2018)
2.h	Use the High Resolution Change Detection Approach (developed by WDFW) to determine where land change is happening, the type of conversion taking place, identify hotspots where change happening at a higher rate than average.	Improves understanding of habitats at risk of conversion	Better information expected to improve regulation implementation and ease of compliance and monitoring, which would in turn improve protection of habitat important to steelhead.	WDFW, NOAA	DIP, reach-scale	LD/LC IS Would be beneficial for this task to feed into plan development, rather than being part of the plan itself.
2.i	Assess the degree to which exemptions and variances are occurring and the resulting extent of degradation to riparian and wetland habitats.	There are no statewide statistics and few if any local statistics on the number or magnitude of variances to local land use regulations	Knowing the number of variances and when and how they occur can elucidate remedies to their degradation	Local governments, Commerce, NGOs (e.g., Futurewise), WDFW, Ecology	DIPs	none

Strategy 3: Incentivize protection of priority habitat areas beyond those covered via regulations.

Table A4-24. Proposed actions to incentivize protection of priority habitat areas.

#	Actions for Strategy 3	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
3.a	Provide technical assistance for developing and maintaining small forest and rural landowner plans	Financial and technical assistance can aid small forest landowners and keep them in the business of farming and growing trees, which is more beneficial than converting to urbanizing land uses.	Maintaining small forest landowners in developing landscapes helps protect steelhead habitat from conversion to urbanizing landscapes.	Conservation District, local governments, DNR	DIPs	none
3.b	Provide assistance to property owners in steelhead restoration (e.g., templates for riparian planting plan, assistance with designing habitat restoration, identifying potential grant funding for implementation)	Many landowners want to help salmon and steelhead habitat, but are unsure how.	Maintaining small forest landowners in developing landscapes helps protect steelhead habitat from conversion to urbanizing landscapes.	Conservation District, local governments, DNR	DIPs	none
3.c	Develop and implement protective flexible development tools, such as transferable development rights, environmental mitigation banking/reserve programs, and in-lieu fee mitigation to shift development to	Coordinate with mitigation bank and mitigation reserve programs to ensure their work considers/compliments salmon and steelhead habitat benefits.	Improved steelhead habitat protection by providing landowners and managers with a suite of tools.	Local governments, WDFW, Ecology, tribes	DIPs & MPG	none

#	Actions for Strategy 3	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
	areas which are less environmentally sensitive and/or to mitigate impacts by restoring areas with highest ecological functions for steelhead.					
3.d	Develop and implement restorative tools such as conservation easements, current use taxation (e.g., Public Benefit Rating System and Timberland Program), Transfer of Development Rights program, and Native Growth Protection Area programs		Improved steelhead habitat restoration by providing landowners and managers with a suite of tools.	Local governments, WDFW, Ecology, tribes	DIPs & MPG	none

Strategy 4: Ensure and improve effectiveness of mitigation to offset impacts of development.

Table A4-25. Proposed actions to ensure and improve effectiveness of mitigation to offset impacts of development.

#	Actions for Strategy 4	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
4.a	Support on-site, in-kind mitigation when it is ecologically feasible and likely to succeed long-term.	Provides support for on-site, in-kind mitigation	Degradation to steelhead habitat from unavoidable activities can be remedied by mitigating for impacts as close as possible to	Local government, WDFW, Ecology, tribes	DIP	none

#	Actions for Strategy 4	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
			the type and location as the original impact.			
4.b	If mitigation on or adjacent to the development site is impractical or will not result in meaningful ecological benefit, consider off-site mitigation options, such as a mitigation bank or in-lieu fee mitigation (e.g., County or WSDOT Mitigation Reserves Program), which would perform mitigation in areas prioritized for restoring ecological function of habitat that supports steelhead.	To the extent possible, mitigation should occur within the same basin in which the impact originally occurred.	Degradation to steelhead habitat from unavoidable activities can be remedied by mitigating for impacts within the watershed of the original impact.	Local government, WDFW, Ecology, tribes	DIP	none

Timber Harvest

Strategy 1: Develop and perform an independent and comprehensive review of forest practices rule compliance and effectiveness.

Table A4-26. Proposed action to develop and perform an independent and comprehensive review of forest practices rule compliance and effectiveness.

#	Actions for Strategy 1	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
1.a	Develop and implement an independent compliance monitoring review of the	Current compliance monitoring efforts are biased and do not inform	Unbiased understanding of whether rules are being implemented and followed	Forest Practices Board, DNR, WDFW, Ecology, NWIFC,	DPS	Services have previously provided letters to

#	Actions for Strategy 1	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
	Forests and Fish rules for key activities (including riparian buffers, road associated sediment management, fish passage, and stream typing).	decision makers of the progress in implementing the rules negotiated in the Forests and Fish HCP.		CMER, forest landowners		this effect to DNR.
1.b	Develop and implement effectiveness studies where compliance is understood to fully implement the adaptive management program as identified in the L1 and L2 schedules and as identified in Master FFR priority research efforts.	Almost all research priorities identified in the Forests and Fish report (1998) have yet to be completed. These research priorities were essential to the parties in identifying and remedying key uncertainties in the protection of fish, including steelhead.	Improved understanding of what works and does not work in the protection of steelhead under the Forests and Fish rules.	Forest Practices Board, CMER, DNR, WDFW, Ecology, NWIFC, forest landowners	DPS	Re-enforce culvert inventory efforts which focus on prioritized FBRB streams and discourage inventories on streams which are not priorities in the immediate future.
1.c	Implement strategic outcomes of the Subcommittee on Adaptive Management Program Improvements	The Forest Practices Board requested and received a report to improve the adaptive management program (CMER and Policy committees). The actions contained in the report and	Quality monitoring and research programs that advance the stated goals of the program will be conducted, and management actions will be more adaptive where results indicate that change is needed.	Forest Practices Board, CMER, Forest and Fish Policy committee, DNR, WDFW, Ecology, NWIFC, forest landowners	DPS	none

#	Actions for Strategy 1	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
		other actions should help resolve the gridlock that remains in the administration of the adaptive management program				

Strategy 2: Collaborate on water temperature monitoring and modeling.

Table A4-27. Proposed actions to collaborate on water temperature monitoring and modeling.

#	Actions for Strategy 2	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
2.a	Improve understanding of water temperature dynamics in forest headwater riverscapes by identifying novel water monitoring and modeling efforts/networks.	Recent studies have demonstrated that headwater stream buffers (Type N) may be inadequate to protect downstream stream reaches from elevated temperature increases. Questions remain on the size of buffers that are needed to adequately protect steelhead habitat from these upstream sources.	Better understanding of adequate buffers (and adaptive management to implement changes where needed) will reduce elevated temperature regimes and improve rearing capacity of steelhead habitat	Ecology, EPA, CMER, Forest Practices Board, DNR, NWIFC, WDFW, NOAA, USFWS, forest landowners	DPS	Innovative approaches to stream temperature modeling are being conducted by Dan Isaak (USFS RMRS) and Christian Torgensen (USGS FRESC), among others
2.b	Coordinate, integrate and expand existing	Ecology's structure for housing	Expanded data collection networks will	Ecology, EPA, CMER, DNR, NWIFC,	DPS	none

#	Actions for Strategy 2	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
	water temperature monitoring efforts.	temperature data should continue to be used as the clearinghouse for temperature data. Networks that expand data collection in headwater streams should increase to support improved modeling approaches (see above).	improve modeling efforts, which should lead to more conclusive buffer needs in headwater streams to protect steelhead.	WDFW, NOAA, USFWS, tribes, forest landowners		
2.c	Coordinate with Ecology to test assumptions about adequacy of forest practice rules to meet Clean Water Act criteria, specifically for temperature.	Where needed, forested buffers may need to be changed to protect steelhead and remain in compliance with the Clean Water Act.	Stream buffers in Type N streams are appropriately sized to protect steelhead habitat, economic stability for landowners, and Clean Water Act provisions.	Ecology, EPA, CMER, DNR, NWIFC, WDFW, NOAA, USFWS, tribes, forest landowners	DPS	none

Strategy 3: Prioritize forest riparian restoration with Clean Water Act 303d listings.

Table A4-28. Proposed actions to prioritize forest restoration with Clean Water Act listings.

#	Actions for Strategy 3	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
3.a	Identify and compare 303d listings with steelhead streams and the Type N streams	Using GIS, juxtapose steelhead streams with 303d-listed	A common understanding of where steelhead habitat is impaired by	WDFW, Ecology, NWIFC	DPS	none

#	Actions for Strategy 3	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
	above them, and make these data available.	streams for analysis	water quality (temperature)			
3.b	Using vegetation Change Detection tools* prioritize revegetation efforts using existing temperature models.	Change detection tools will inform restoration groups of where land cover is in need of aggressive restoration in order to reduce stream temperature and improve rearing capacity for steelhead	Specific locations in forested landscapes of watersheds will be identified where restoration is needed to reduce stream temperature and increase steelhead capacity	NOAA NWFSC, WDFW, Ecology, NWIFC, PSP	DPS & DIP	Consider PSP as the clearinghouse for these data once developed. *Recent change detection tools have been developed by Tim Beechie (NOAA NWFSC) and Ken Pierce (WDFW Science)
3.c	Identify a list of the most impaired streams in each DIP and seek restoration agreements with landowners	With data available from the juxtaposition of steelhead and temperature impairment, and the availability of land cover data showing poor quality riparian areas, identify the most impaired streams in need of riparian restoration	Local entities will have the most current information of where steelhead are impaired by stream temperature	Restoration groups, Lead Entities, forest landowners	DIP	WDFW, PSP, tribes, and Ecology would be useful in providing assistance to local groups

Strategy 4: Explore potential funding and financial incentives for discussions with timber companies.

Table A4-29. Proposed actions to explore potential funding and financial incentives for timber companies.

#	Actions for Strategy 4	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
4.a	Collaborate with timber companies to explore longer rotation harvest practices to benefit steelhead while maintaining timber company's bottom line	Engage forest industry in developing alternative approaches and developing incentives to increasing steelhead habitat or increasing the rate in which functional habitat can be achieved.	More rapid expression of functional stream habitat, improved relationships with landowners, opportunity to develop novel approaches in collaborative framework	Forest and Fish policy committee, WFPA, forest landowners, Ecology, WDFW, NOAA, USFWS, tribes, NWIFC, DNR	DPS	none
4.b	Explore successes and failures of Pacific Northwest Community Forest ventures and their ability to maintain or increase functional stream habitats.	Develop a review of recent community forest projects and evaluate their business and resource protection successes	Where successful, these forests could improve stream habitats for steelhead	Conservation organizations, NGOs, Land Trusts, USFWS, DNR	DPS & DIP	none
4.c	Develop, fund, and implement volunteer incentives related to harvest rotation cycles where benefits to steelhead may be realized more effectively and quickly than traditional rules and approaches allow	Alternate plans, Riparian Reserve Programs, land swaps, and watershed plan implementations are all underutilized approaches to improve steelhead habitat while providing landowners with certainty and continued business success.	Increased buffer widths in key habitats, increased wood in streams through restoration, reduced fine sediment	WDFW, Ecology, tribes, NRCS, CDs,	DPS & DIP	Programs developed at DPS scale, and implemented at DIP scale

Strategy 5: Improve accuracy of water type classifications to ensure steelhead habitats (per WAC 222-16-010).

Table A4-30. Proposed actions to improve accuracy of water type classifications.

#	Actions for Strategy 5	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
5.a	Develop methodologies for accurately delineating steelhead habitat that is less harmful to steelhead than electrofishing.	Most land use regulations depend on understanding the upstream extent of fish. Electroshocking is an effective tool, but is known to harm or kill fish.	Fewer fish harmed in making routine land use determinations	WDFW, tribes, NGOs, NOAA, local gov'ts, timber industry	DPS, DIP	none
5.b	Use LiDAR to improve watercourse delineation Require use of consistent hydrography (National Hydrography Dataset (NHD)) across resource mgmt. agencies. Transfer F/N breaks to NHD, then use NHD henceforth - DoE pilot study in the Skagit	NHD is a national standard for mapping water courses and provides a useful modelling platform. Alternative platforms have more data on fish use, but are less useful for developing predictive tools (e.g., steelhead use).	A universal predictive tool to delineate steelhead habitat availability	Ecology, WDFW, WDNR, tribes, USFWS, NOAA	DPS	Ecology leads Washington's efforts on NHD, WDNR leads the older data platform
5.c	Require training and certification of water type surveyors and reviewers.	The use of assessment tools (e.g., electroshocking), and the interpretation of predictive models require training to be consistent and protective of steelhead and their habitat.	Fewer fish harmed	WDFW, Ecology, tribes, NOAA	DPS	Some electroshocking training exists, but it is not required or consistently used.

#	Actions for Strategy 5	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
5.d	Require water type modification process for all ground-truthed mapping confirmations or modifications.	Acceptance of some water typing determinations by regulatory agencies occurs without acceptable tools and without adequate training to assess habitat.	Fewer land use decisions are made which inappropriately categorize steelhead habitat as "non-fish habitat"	WDFW, WDNR, tribes, local governments, NGOs	DPS, DIP	none
5.e	Improve water type modification process to increase agency review and participation.	Current practices allow a change in stream classification from assumed "fish habitat" to "non-fish habitat" without a review by fish managers.	Increased oversight by qualified state and tribal fish managers will prevent steelhead streams from being reclassified to non-fish streams.	WDFW, tribes, WDNR, NOAA, timber industry, NGOs	DPS	none

Strategy 6: Fish Passage (note: there is some duplication in this strategy with the culverts strategy).

Table A4-31. Proposed actions to improve fish passage through road maintenance and abandonment.

#	Actions for Strategy 6	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
6.a	Assist landowners to ensure that Road Maintenance and Abandonment Plans (RMAPs) are completed to meet the 2021 time extension deadline	Due to the economic recession, some landowners requested and received a time extension to implement their RMAPS, including completing their fish passage	Fish passage barriers, fine sediment delivery sources, and stream-adjacent roads will be corrected on large forest ownerships by 2021.	DNR, WDFW, Ecology, tribes, NWIFC	DPS	none

#	Actions for Strategy 6	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
		barrier corrections. Some collaborative assistance to some landowners may be necessary to meet the deadline				
6.b	After ensuring compliance with stream typing determinations (see compliance monitoring actions and stream typing actions), correct remaining barriers that may have remained uncorrected due to incorrect determinations of steelhead habitat	Ensures that undetected barriers are repaired in a timely way.	Fish passage barriers, fine sediment delivery sources, and stream-adjacent roads will be corrected on large forest ownerships where they were previously undetected due to mis-classified stream typing.	WDFW, Ecology, tribes, NWIFC, DNR	DPS & DIP	none
6.c	Develop and maintain random sampling compliance and repair programs to ensure that new roads do not feature new barriers or that non-barriers do not become barriers.	Because even well-designed stream crossings can become future barriers, a program is needed to ensure that barriers do not increase through time.	Certainty that fish passage restoration successes continue to protect steelhead habitat	Forest landowners, tribes, WDFW, DNR, NWIFC	DPS & DIP	none
6.d	Increase funding to support the Family Forest Fish Passage Program (FFFPP)	Small forest landowners are commonly located in forested	Increased funding would be provided to repair barriers owned by willing	State legislature, DNR, WDFW, Ecology, tribes, CDs, RFEGs	DPS	none

#	Actions for Strategy 6	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
		foothills of Puget Sound where steelhead are common in adjacent streams. The primary program created to repair fish passage barriers on these ownerships is the FFFPP program. There is a list of more than 400 landowners willing to repair their barriers, but the program lacks adequate funding	landowners, most of whom have barriers on steelhead streams.			

Strategy 7: Implement best science practices on other private forest protection needs.

Table A4-32. Proposed actions to implement best science practices on private forest lands.

#	Actions for Strategy 7	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
7.a	Review forest practice regulations for “20-acre exempt” protections (WAC 222-30-023) for steelhead. Develop recommendations for Forest Practices Board consideration and	Very small forest landownerships (<20 acres) are not currently regulated to standards that are protective of steelhead habitat or water quality.	Improved steelhead protection for very small forest ownerships, including riparian habitat, sediment delivery, and fish passage.	Forest and Fish Policy committee, conservation community, WDFW, Ecology, tribes, NWIFC, DNR, NOAA, USFWS	DPS	none

#	Actions for Strategy 7	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
	implement outcomes					
7.b	Ensure DNR is using best available science on steelhead, steelhead habitats and possible threats when processing and approving Class IV special actions permits	Class IV special permits are authorized by DNR when conversion of forest lands to non-forest uses are proposed. DNR and local jurisdictions (via GMA) need to collaborate to ensure that adequate riparian protection provisions are in place to protect steelhead habitat.	Converted land uses do not diminish the quantity or quality of steelhead habitat	DNR, local jurisdictions, Commerce	DPS & DIP	none
7.c	Provide relevant jurisdictions with best available science for managing Class IV general permits	Local jurisdictions may lack the scientific knowledge to adequately protect steelhead habitat	Increased understanding of steelhead habitat needs will increase protection for steelhead	WDFW, tribes, NWIFC, Ecology, Conservation Commission	MPG & DIP	none
7.d	Identify all relevant entities and ensure compliance with conservation measures in HCPs throughout Puget Sound, and ensure they are adequately funded	There are many local, state, and private HCPs throughout Puget Sound. They are variously funded, monitored, or evaluated for protection of steelhead and their habitats.	Increased compliance with conservation measures and increased evaluation of HCP performance as they relate to steelhead.	NOAA, USFWS, WDFW, tribes, Ecology	MPG & DIP	none

Strategy 8: **Manage the Northwest Forest Plan (USFS for federally managed forestlands).**

Table A4-33. Proposed actions to manage the Northwest Forest Plan.

#	Actions for Strategy 8	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
8.a	Fund ongoing USFS forest management planning and activities to manage forests for hydrologic and habitat forming benefits to steelhead	Under the Aquatic Conservation Strategy of the NWFP, land managers must evaluate proposed projects and mgmt. activities for consistency with the objectives of the strategy (which protects habitat-forming processes, water quality, instream flows, and the physical integrity of aquatic systems). Funding has been inadequate to protect and recover steelhead habitat.	Increased restoration actions (including fish passage) accomplished by the USFS	USFS, NOAA, USFWS, WDFW, tribes, Ecology	DPS, MPG, DIP	none
8.b	Increase funding for acquisitions within the USFS district boundaries to secure inholdings and ecologically sensitive areas	Private in-holdings do not commonly adhere to the protection strategies developed by the USFS. Acquiring those properties or leases would enable the Forest	Increased protection of steelhead habitat functions on federal lands	USFS, NOAA, USFWS, WDFW, tribes, Ecology	MPG, DIP	none

#	Actions for Strategy 8	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
		Service to manage those parcels consistent with other strong protections in the Forest Plan.				

Altered Flows

Strategy 1: <u>Identify, protect, and preserve instream flows for steelhead.</u>

Table A4-34. Proposed actions to identify, protect, and preserve instream flows.

#	Actions for Strategy 1	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
1.a	Determine instream flows required for steelhead recovery in Puget Sound streams and rivers.	Biological studies are required to determine instream flows required to recover steelhead in Puget Sound streams and rivers.	Improved understanding of instream flow needs of steelhead. This may result in instream flows for steelhead in watersheds that are not over-appropriated in terms of water rights.	Ecology; WDFW; NOAA; Tribes dam and water diversion operators; counties	DIP	Instream flows are set by WDOE based upon biological studies. Studies that address instream flow needs for steelhead have only been conducted in small number of streams and rivers. Use the Puget Sound Flow Analysis?
1.b	Annually publish actual instream flows relative to recommended flows for steelhead in 1a (above)		A common awareness of instream flow needs for steelhead relative to actual flows	Ecology; WDFW	DIP	Most major streams are gaged by USGS and others
1.c	Develop a tool such as	Identification of DIPs that	Identify DIPs that are most	NOAA; PSP; WRIAs;	DIP	WDOE has designated a

#	Actions for Strategy 1	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
	Instream Atlas for Puget Sound Steelhead DIPs to identify areas where water diversions and withdrawals are impairing steelhead. Identify and prioritize DIPs with inadequate instream flows, or that are likely to be impaired in the future due to population growth.	are currently impaired by inadequate stream flows, and DIPs that are most likely threatened by future human population growth. Identify DIPs where water rights exceed instream flow requirements of steelhead (i.e., over-allocated basins).	impaired by instream flows in Puget Sound under current conditions, and future population growth. This can be used to prioritize instreams flow studies, and development and revision of instream flow rules.	Tribes; Dept. of Ecology; WDFW		number of "Fish Critical" watersheds in Puget Sound for instream flows (see 2011 map). PSP has also completed "dashboard indicator" of hydrological impairment that can be used to identify flow impaired watersheds.
1.d	Establish or revise Instream Flow rules in Puget Sound WRIAs to better protect steelhead	Instream flows are water rights that "protect and preserve" instream resources including steelhead. These rights do not impact senior water right holders, but can be used to prevent issuance of new water right permits. Instream flow rules also can be used to set a "target" for instream flows for flow restoration programs.	Improved long-term flow protections for steelhead DIPs.	Dept of Ecology	DIP	Instream flow rules in most Puget Sound watersheds have were established prior 1990 instream flow rule. Post 2001 instream flow rules have only been established in Upper and Lower Skagit, Stillaguamish, Quilcene, and Dungeness. Instream flow rules are lacking in some watersheds (e.g., Skokomish). The Hirst Decision has had a major effect on Ecology's ability to set

#	Actions for Strategy 1	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
						instream flow rules. No new rules have been set since 2015.
1.e	Identify and protect instream flows required to meet state water quality standards established under authority of Clean Water Act. Encourage Department of Ecology to establish instream flow needs as part of CWA Section 401 certification process and TMDL process in Puget Sound water bodies.	(See Elkhorn decision, 1994, US Supreme Court.) Flows in many streams and rivers have a major influence on water quality conditions, especially temperature and dissolved oxygen.	Protect instream flows for steelhead. Improve water quality conditions for steelhead through increased flows, especially during low-flow periods of the year.	Ecology; WDFW	DIP	Ecology has authority to set instream flows that are needed to meet state water quality criteria. For example, minimum instream flows may be required to meet water temperature standards established for beneficial uses including steelhead spawning and rearing.
1.f	Address instream flows requirements for steelhead under Watershed Planning and Management process established under ESHB 2514 (RCW 90.82). Encourage implementation of minimum flows that will protect and rebuild steelhead populations.	Local governments may choose to include minimum instream flows as component of watershed plan. DOE must use rulemaking to set minimum instream flows.	Establishment of minimum instream flows that will protect steelhead from future water withdrawals.	Local governments; Dept of Ecology; water districts; WRIAs; WDFW, tribes;	DIP	Only a few PS watersheds have completed a Watershed Plan under the 2514 process. Technical support provided by steelhead experts (e.g., NOAA; WDFW; tribes) could help local governments involved in setting minimum instream flows
1.g	Improve habitat-flow	The default hydraulic and	Improved instream flow	WDFW; Ecology	DPS, DIPs	WDFW and Ecology

#	Actions for Strategy 1	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
	models (e.g., 2D flow modeling, bioenergetic models) for determining instream flows for steelhead	habitat models (PHABSIM) used to determine instream flow needs for fish in Washington may underestimate the amount of water needed by steelhead. For example, higher flows may be needed to provide optimal invertebrate food production for juvenile steelhead.	regimes for all freshwater life stages of steelhead			currently requires use of the USGS Physical Habitat Simulation System (PHABSIM) for determining instream flow requirements for fish.

Strategy 2: Maintain, restore, or improve instream flow by protecting tribal, state, and federal water rights by enforcing regulations and improving transparency, efficiency, and accountability.

Table A4-35. Proposed actions to maintain, restore, or improve instream flow by protecting tribal, state, and federal water rights.

#	Actions for Strategy 2	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
2.a	Implement and enforce instream flows for steelhead once established.			Ecology; EPA; WDFW; Tribes; NOAA	DPS	none
2.b	Eliminate illegal surface water diversions by enforcing regulations			Ecology	DIP	none

#	Actions for Strategy 2	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
2.c	Extinguish water rights if they are not used in 5 years.	Enforcement of illegal water withdrawals requires funding	Increased low flow availability for steelhead	Ecology	DPS, DIPs	SBPP
2.d	Protect existing wetlands in aquifer recharge areas.	Wetlands provide flood pulse moderation and store water for availability during low flows	Increase storage for low flow availability and preservation of water quality	Dept of Ecology, Corps', local governments	DIP	SBPP
2.e	Set a limit (number of gallons per day) for domestic water use and stock watering use in over allocated basins.		Secures minimum flows by ensuring that poor low flow conditions do not become worse.	Ecology	DIP	SBPP
2.f	Enforce or implement monitoring requirements for surface and groundwater diversions	Ecology requires water right holders to monitor diversions for compliance purposes		Ecology	DIP	Ecology will enforce water rights when withdrawals exceed water right.

Strategy 3: Develop and implement incentive programs to protect and restore instream flows for steelhead.

Table A4-36. Proposed actions to develop and implement incentive programs to protect and restore instream flows.

#	Actions for Strategy 3	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
3.a	Develop collaborative funding mechanisms among state and federal partners to support willing	Improves funding for instream flow	More water in streams for steelhead	Ecology, Conservation Districts, irrigation districts, NRCS, tribes, WDFW	DPS	none

#	Actions for Strategy 3	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
	irrigation districts and landowners in applying more efficient irrigation systems					
3.b	Support and encourage irrigation districts to upgrade their efficiency and bank the saved rights into the Trust for Water Rights Program.	Trust Water Rights allow water owners to put their water right into the Ecology program to avoid the "use it or lose it scenario"	More water in streams for steelhead	Irrigation districts	DIP implementation, DPS program development	none
3.c	Apply new funding under streamflow restoration law (ESSB 6091) toward restoring instream flows for steelhead, including the acquisition of senior water rights.	This newly signed law provides $300 million in funding for projects that help fish and stream flows in 15 watersheds impacted by the "Hirst Decision".	Restoration of stream flows and habitat for steelhead in many Puget Sound watersheds	Ecology	DPS	none

Strategy 4: Protect uplands to improve hydrological characteristics of watersheds; protect groundwater recharge areas to improve infiltration of precipitation and runoff into aquifers.

Table A4-37. Proposed actions to protect uplands to improve hydrological characteristics of watersheds, protect groundwater recharge, and improve infiltration of precipitation and runoff.

#	Actions for Strategy 4	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
4.a	Where Critical Area Ordinances (CAOs) have not adequately protected recharge	Known as Critical Aquifer Recharge Areas (CARA)	Aquifer recharge – more water, cooler groundwater	Counties, local jurisdictions, Dept. Commerce, Ecology	DIP	SBPP

#	Actions for Strategy 4	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
	areas, acquire transfer of development rights in key areas of hydrologic importance.					
4.b	Determine the adequacy of timber harvest methods and their protection of natural hydrologic regimes.	Questions remain about the adequacy of forest practice implementation and the preservation of hydrologic continuity in stream channels.	Reduced peak flows and restored low flows where influences in forest management are observed and corrected.	DNR, Ecology, WDFW, tribes, EPA	DPS programs; DIPs implementation	SBPP
4.c	Add steelhead-specific recovery goals in the checklist of CAOs to include the protection of aquifer recharge areas and hyporheic areas from development pressures.	To enhance development review by county planners, steelhead needs will be included as a checklist in some CAO reviews and updates	Maintenance of low and high flow regimes that avoid flashy floods and unsuitable summer flows.	Commerce, local governments, Ecology, WDFW	DIP and DPS	Commerce is developing salmon recovery guidance for CAOs (Heather Ballash)
4.d	Develop BMPs for stormwater management and enforce these actions in development strategies, especially to reduce peak flows and enhance base flows.		Protect streams from flashy floods and resulting lower low flows during summer	Ecology with implementation action by cities and counties with review by Ecology.	DPS	Ecology has good BMPs and LID guidance.

#	Actions for Strategy 4	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
4.e	Retrofit stormwater ditch runoff and other opportunities to reduce storm runoff impacts.		Protect streams from flashy floods and resulting lower low flows during summer. Also improves water quality.	Ecology with implementation action by cities and counties with review by Ecology.	DPS	Ecology has good BMPs and LID guidance.
4.f	Implement Low Impact Development for future development, and inside cities and UGAs to protect flows.		flow conditions that mimic naturalized hydrologic regimes	Ecology, Commerce, local governments	DIP	SBPP
4.g	Protect natural hydrologic processes and/or acquire land in floodplains for future levee setbacks.	See floodplain strategies. May be redundant but also a recharge action…	Restore floodplain storage of flood waters and restore low flow protection. Cooler stream temperatures also result.	Trust for Public Lands (TPL); Land Trusts, local governments, DNR, Ecology, FEMA	DIP	SBPP
4.h	Protect forestlands and agriculture lands from conversion (minimize sale of ag land and tree farms to residential developers, which is often more protective of water resources and stream flows).	Use PDR/TDR to purchase development rights in agricultural land; encourage the purchase of development rights in areas currently forested that are zoned rural residential	Reduce the rate of flow changes in steelhead streams	TPL, Land Trusts, local governments, DNR, Ecology	DIP	SBPP

#	Actions for Strategy 4	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
4.i	Evaluate DNR Public Trust lands for hydrologic contributions for steelhead. Avoid putting them in private ownership where impactful, but consider land swaps where beneficial to steelhead and stream flows	DNR may have the opportunity to acquire or trade land parcels where hydrologic benefits could be realized and avoid land swaps where detrimental.	Protected habitat for steelhead where opportunity exists	DNR; land trusts; local governments	DPS, DIP	SBPP. There are several good examples of where this has worked well in Skagit and Teanaway basins.

Strategy 5: Improve instream flow protections and water rights for fish on federal lands.

Table A4-38. Proposed actions to improve instream flow protections and water rights for fish on federal lands.

#	Actions for Strategy 5	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
5.a	Ensure steelhead and instream flow experts are part of evaluating project alternatives in SEPA/NEPA processes.		Ensure that flow impacts are considered for steelhead rearing and spawning.	USFS, BLM, WDFW, Ecology, DNR, local governments	DIP	none
5.b	Participate in EIS review of major water resources developments, including storage reservoirs and water diversions, on federal lands.		Ensure that flow impacts are considered for steelhead rearing and spawning	USFS, BLM, NGOs, agencies, tribes	DIP	none

#	Actions for Strategy 5	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
5.c	Exercise Federal Reserve Water Rights on federal lands and Native American reservations for protecting and restoring instream flows	The federal government may be able to protect or restore flows for fish on federal lands under doctrine of federal reserve water rights	Increased protections of instream flows for steelhead on federal lands and Native American reservations	U.S. Dept. of Justice; Tribes; BIA; USFS; BLM; NOAA	DIP	Federal government has had notable successes in acquiring water rights under state law.
5.d	Establish instream flows to protect critical habitat for steelhead on federal lands	Establish instream flows for steelhead on federal lands that are designated as critical habitat	Improved flows for steelhead on federal lands, and downstream of federal lands	USFS; BLM; NOAA; USFWS	DIP	none

Strategy 6: Through Habitat Conservation Plan (HCP) process, provide long-term protections and conservation measures for steelhead instream flows.

Table A4-39. Proposed actions to improve instream flows through Habitat Conservation Plan process and conservation measures.

#	Actions for Strategy 6	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
6.a	Ensure that instream flows for steelhead are considered in the development, review, and implementation of new HCPs	HCP process provides unique opportunity for establishing instream flow regimes for major water storage and municipal supply projects. HCP's are also completed for	Improved instream flow regimes for steelhead below municipal supply storage reservoirs and diversions. Improved instream flow on private and state lands	NOAA, USFWS, WDFW, Ecology, Tribes	DIP	HCPs have been completed for major municipal water storage and supply projects, including City of Seattle's and City of Tacoma's water supplies (Cedar and Green Rivers, respectively).

#	Actions for Strategy 6	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
		private and state forest lands.	managed for timber harvest.			
6.b	Review and engage in adaptive management plans for existing HCPs, particularly if any instream flow committees.	The adaptive management process may provide an opportunity to improve instream flows.	Improved instream flows for steelhead	Ecology; NOAA; USFWS; NGOs; Tribes	DPS	none

Strategy 7: Restore instream flows for steelhead in over-allocated watersheds.

Table A4-40. Proposed actions to restore instream flows in over-allocated watersheds.

#	Actions for Strategy 7	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
7.a	Acquire water rights in basins where instream flows are insufficient for steelhead due to water withdrawals	Water rights can be donated by senior water rights holders (tax credits?). Water rights can be purchased instream uses (including steelhead).	Increased instream flows for steelhead in flow-impaired water bodies. Improved habitat and water quality conditions for steelhead, especially during natural low-flow periods.	Ecology would need to approve water right transfers. Local government, tribes, WRIA groups, Watershed Planning groups (HB 2514), NGOs (Washington Water Trust; TU's Washington Water Program) ,	DIP	Water rights can be purchased though grant funding, conservation funds, and through water banks.
7.b	Encourage and facilitate water right transfers that result in downstream	Water rights can be transferred from upstream to downstream	Improved instream flows for steelhead in over-	Dept of Ecology; WDFW; NGOs; WRIAs	DPS; DIP	WDFW and Ecology have warned that this action has limited

#	Actions for Strategy 7	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
	conveyance of water in natural river and stream channels	users, providing improved flows in some circumstances.	allocated basins			potential for improving fish flows, especially if this involves out-of-basin transfers.
7.c	Encourage local governments and water districts to develop and implement water reuse and recovery strategies		Improved water quantity and quality in steelhead streams	Dept. of Ecology; local governments; water districts	DIP	State and Federal grants are available for water re-use programs
7.d	Reclaim water at wastewater facilities to replace water diversions for golf courses, irrigation, and other appropriate uses	Wastewater that has undergone tertiary treatment can replace water previously diverted from streams and groundwater.	Improved flows by reducing surface and groundwater withdrawals.	Wastewater utilities	DIP	King County's water re-use program for the Brightwater Project provides good example of reclamation strategy. In some situation, reclaimed water can be used for aquifer recharge.
7.e	Reuse irrigation water, and use agricultural drainage water, to improve instream flows	Irrigation and agricultural drainage water can be used to recharge aquifers, or returned to natural channels	Improved flows	Farmers; Ag. Districts; NRCS; Ecology	DIP	Reused ag. water would need to meet state water quality standards, and comply with TMDL's
7.f	Allocate or purchase reservoir storage to meet	Water storage in reservoirs can be allocated for meeting	Improved instream flows	Ecology, NOAA; reservoir owners /		Consider climate change in this action

#	Actions for Strategy 7	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
	instream flow requirements for steelhead	instream flow needs under HCPs and BiOPs for steelhead, or as condition to 401 WQ permit	downstream of reservoirs	operators; municipal water supplies		
7.g	Develop and market conservation programs that reduce water demand	Municipal water providers and water districts have implemented water conservation programs to reduce water demands	Improved instream flows, especially during base flow conditions	Municipal water provides; water PUD's; water districts	DPS	Most water provides have implemented water conservation programs

Strategy 8: Identify, develop, and fund habitat restoration projects that result in improved streams.

Table A4-41. Proposed actions to identify, develop and fund habitat restoration projects to improve streams.

#	Actions for Strategy 8	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
8.a	Develop and fund habitat restoration projects that result in improved instream flows to streams and rivers	Several types of habitat restoration, including wetland projects, improve "vertical connectivity" to streams, restoring groundwater and hyporheic flows	Improved base flows	Counties, Conservation Districts, Public agencies, special purpose districts, non-profit organizations	DPS	none
8.b	Increase access to beaver management resources, including beaver relocation programs, and hunting and fatal		Beavers enhance stream flows for steelhead and other salmonids.	Counties, Conservation Districts, Public agencies, special purpose districts, non-	DIP	SBPP

#	Actions for Strategy 8	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP	Other Notes
	trapping prohibitions			profit organizations		
8.c	Streamline HPA permits for pond levelers and beaver deceivers.	What is a pond leveler	Incentives to protect beaver ponds will enhance summer base flows and moderate flash flows.	WDFW, ORA, Ecology	DPS	SBPP

Puget Sound Steelhead Hatchery Strategies and Actions

Washington Department of Fish and Wildlife (WDFW) and Puget Sound Indian Tribes manage hatchery programs geographically at the watershed scale. This scale corresponds to one or several distinct population segments. The three general strategies[33] and 17 sub-strategies[34] described below are the foundation for all programs but the specific actions vary by population and location. Hatchery Genetic and Management Plans (HGMP) contain detailed descriptions and justifications for these actions. National Marine Fisheries Service (NMFS) reviews HGMPs and approves hatchery programs when the programs are consistent with the Endangered Species Act. Descriptions of programs already approved or pending approval are available through the National Marine Fisheries Service on its website: http://www.westcoast.fisheries.noaa.gov/hatcheries/salmon_and_steelhead_hatcheries.html

Strategy 1: Develop specific, measurable, achievable, relevant, and timely goals for the harvest and conservation benefits of hatchery programs considering the conservation goals for the natural population and the interactions and status of habitat and harvest.

Table A4-42. Proposed actions to develop specific, measurable, achievable, relevant, and timely goals for the harvest and conservation benefits of hatchery programs considering the conservation goals for the natural population and the interactions and status of habitat and harvest.

#	Actions for Strategy 1	Description	Expected Outcomes	Who Responsible	DPS/ MPG/ DIP (be specific)	Other Notes
1. a.	Identify population viability objectives in terms of abundance and productivity.	Long-term (e.g., recovery goals) and shorter-term numerical objectives provide targets to assess and prioritize the effectiveness of recovery actions and judge progress after they have been implemented.	Populations attaining viability objectives provide for sustainable, recovered DPS.	WDFW; Puget Sound Indian Tribes	DIP	none
1. b.	Identify expected role of population in recovery.	Not all populations need to be highly viable for the DPS to be recovered. Role of each population (and its viability objectives) depends on potential	Mix of population roles provides for a viable, recovered DPS	Recovery Team; WDFW; Puget Sound Indian Tribes	DPS, MPG, DIP	none

[33] Mobrand, L.E., J. Barr, L. Blankenship, D.E. Campton, T.T.P. Evelyn, T.A. Flagg, C.V.W. Mahnken, L.W. Seeb, R.R. Seidel, and W.W. Smoker. 2005. Hatchery reform in Washington State. Fisheries 30:11-23.

[34] Hatchery Scientific Review Group (HSRG). 2015. Annual report to Congress on the science of hatcheries, 2015: A report on the application of up-to-date science in the management of salmon and steelhead hatcheries in the Pacific Northwest. (http://hatcheryreform.us/wp-content/uploads/2016/05/HSRG_Report-to-Congress_2015.pdf).

#	Actions for Strategy 1	Description	Expected Outcomes	Who Responsible	DPS/ MPG/ DIP (be specific)	Other Notes
		biological characteristics (i.e. size, productivity, diversity, connectivity) and feasibility. Likewise, some will be important for conservation and other for harvest.				
1. c.	Identify current phase of recovery and triggers and scientific basis for shifting between different restoration phases.	Stages of recovery are characterized by the different biological (demographic, genetic, evolutionary), economic, and legal/regulatory trade-offs (i.e. risks and benefits) associated with the changing status of populations.	Implementation of recovery actions maximizes the benefits of progressing towards recovery while minimizing the risks at each stage.	WDFW; Puget Sound Indian Tribes	DIP	none
1. d.	Express harvest goals in terms of a population's contribution to specific fisheries.	Numerical objectives for harvest provided by hatcheries assessment of how well hatcheries are meeting harvest objectives (harvest programs) and minimizing risk associated with harvest (conservation programs).	Implementation of hatchery actions maximizes the benefits of harvest while minimizing the risks.	WDFW; Puget Sound Indian Tribes	DIP	none
1. e.	Ensure conservation and harvest goals for individual populations are coordinated and compatible with those for other populations that might be affected.	Because salmon share common geographies during different parts of their life history, management objectives need to be coordinated to avoid actions targeted towards a specific population unintentionally affecting other populations' recovery potential.	All demographically related populations move towards recovery objectives efficiently.	WDFW; Puget Sound Indian Tribes	DPS, MPG, DIP	none

Strategy 2: Ensure that hatchery programs plan and operate in a scientifically defensible manner.

Table A4-43. Proposed actions to ensure that hatchery programs plan and operate in a scientifically defensible manner.

#	Actions for Strategy 2	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP (be specific)	Other Notes
2.a	Identify the purpose of the hatchery program in management plans.	Purpose of hatchery programs may be conservation, harvest, or both.	Hatchery programs achieve conservation or harvest consistent with population goals.	WDFW; Puget Sound Indian Tribes	DIP	none
2.b.	Explicitly state the scientific assumptions under which a program contributes to meeting the stated population goals and hatchery purpose.	Specific assumptions are hypotheses that can be tested through monitoring and research. These can be combined using conceptual, qualitative or quantitative models that describe expected population outcomes of the management of the hatchery environment; brood stock practices; habitat quality, quantity, and connectivity outside of the hatchery; genetic characteristics of the fish; and external sources of mortality (e.g.,harvest, predation, exposure to toxic contaminants, etc.) based on known or hypothesized mechanisms and relationships.	Combination of management actions is the most efficient and fair to reach objectives.	WDFW; Puget Sound Indian Tribes	DIP	none
2.c.	Select an integrated or segregated broodstock management strategy based on population goals and hatchery program purpose.	Segregated strategy is appropriate when the hatchery is producing fish that are not intended to spawn in the wild; integrated strategy is appropriate when hatchery fish are expected to spawn in the wild with natural-origin fish.	Hatchery program contributes to maximizing the benefits to people and the recovery of fish populations while minimizing genetic risks to the fish populations.	WDFW; Puget Sound Indian Tribes	DIP	none
2.d.	Size hatchery programs based on population goals	Program size (number of brood stock and number of juvenile fish released) is one of the key	Appropriate size contributes to maximizing the benefits to	WDFW; Puget Sound Indian Tribes	DIP	none

#	Actions for Strategy 2	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP (be specific)	Other Notes
	and as part of an "All H" strategy.	management actions used to achieve harvest objectives, supplement natural production, and minimize genetic and ecological risk. WDFW and Puget Sound Indian Tribes annually share and review changes in production numbers and fish transfers in the Future Brood Document database.	people, other species, and the recovery of fish populations while minimizing genetic and ecological risks to the fish populations.			
2. e.	Manage harvest, hatchery brood stock, and natural spawning escapement to meet proportions of hatchery fish in the wild appropriate to natural population's biological significance and recovery phase	Proportion of hatchery fish in the wild is a key factor in the levels of genetic and ecological risk to the population. Appropriate proportions depend on the desired and expected pace to recovery, which is a function of demographic, genetic, and evolutionary trade-offs unique to the phase of recovery (see 1.c, above).	Appropriate mixture contributes to maximizing the benefits to people, other species, and the recovery of fish populations while minimizing genetic and ecological risks to the fish populations	WDFW; Puget Sound Indian Tribes, NOAA	DPS, MPG, DIP	none
2. f.	Manage the harvest to achieve full use of hatchery-origin fish	When harvest achieves the full intended use of available hatchery fish, it balances the need to put an appropriate mix of hatchery and wild fish on the spawning grounds, which depends on the phase of recovery, and the desire to maximize harvest. Tools for include management of harvest by time, area, mark, and gear type.	Wild populations are not overharvested; hatchery and wild fish spawning in the wild achieve a mixture that best achieves demographic and biological objectives.	WDFW; Puget Sound Indian Tribes, NOAA	DPS, MPG, DIP	none
2. g.	Ensure all hatchery programs have self-sustaining broodstocks.	Without self-sustaining brood stocks, hatchery programs would need to "mine" declining natural populations or bring in eggs from other populations or programs.	Natural populations are sustained; conditions for local adaption are improved.	WDFW; Puget Sound Indian Tribes, NOAA	DIP	none

#	Actions for Strategy 2	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP (be specific)	Other Notes
		The former increases demographic risk to natural populations and the latter limits local adaptation.				
2. h.	Coordinate hatchery programs to account for the effects of all hatchery programs on each natural population and each hatchery program on all natural populations.	Because salmon share common geographies during different parts of their life history, management actions need to be geographically and temporally coordinated to avoid actions targeted towards a specific population unintentionally affecting other populations' recovery potential.	All demographically related populations move towards recovery objectives efficiently	WDFW; Puget Sound Indian Tribes	DPS, MPG, DIP	none
2. i.	Ensure that facilities are constructed and operated in compliance with environmental laws and regulations, and avoid construction that impedes floodplain function	Hatcheries that operate in compliance in environmental regulations minimize the potential impacts of hatchery operations on water quality (sediment, temperature, chemicals) and barriers to fish migration.	Instream water quality, quantity, and fish migration are preserved.	WDFW; Puget Sound Indian Tribes	DIP	none
2. j.	Maximize survival of hatchery fish consistent with conservation goals.	Facilities and production strategies for incubation, feeding, growth, acclimation, fish transfer, and release strategies are designed to promote survival and minimize ecological interactions after release. The Co-managers' Fish Disease Policy governs egg and fish transfers. Veterinarians and fish pathologists employed by WDFW and the Puget Sound Indian Tribes	Population recovery accelerates; opportunities for harvest increase; straying is reduced by acclimation and imprinting.	WDFW; Puget Sound Indian Tribes	DIP	none

#	Actions for Strategy 2	Description	Expected Outcomes	Who Responsible	DPS/MPG/DIP (be specific)	Other Notes
		monitor fish health at all facilities.				
2. k.	Adopt fish culture practices that avoid disease and parasite risks, including low rearing densities, adequate water supply, and appropriate food and feeding management.	These culture practices produce healthy fish that survive better when they are released and prevent amplification of disease while they are under culture.	Hatchery fish are healthy and able to survive in the wild Released hatchery steelhead are as biologically similar to wild fish as possible	WDFW; USGS; Puget Sound Indian Tribes; NMFS; universities	DPS, MPG, DIP	none
2. l	Volitionally manage hatchery releases	Volitional releases allow fish to migrate when they are physiologically ready, and volitional releases can minimize mass release of hatchery fish that compete with wild steelhead	Better survival and minimize competition between hatchery and wild fish	WDFW; Puget Sound Indian Tribes	DIP	none

Strategy 3: Improve hatchery programs by learning from testing, monitoring, and evaluating results of hatchery programs.

Table A4-44. Proposed actions to improve hatchery programs by learning from testing, monitoring, and evaluating results of hatchery programs.

#	Actions for Strategy 3	Description	Expected Outcomes	Who Responsible	**DPS/ MPG/ DIP** (be specific)	Other Notes
3. a	Regularly review goals and performance of hatchery programs in a transparent, regional, "all-H" context.	Regular review allows managers and NMFS to incorporate new scientific information and to adjust hatchery operations, strategies and objectives. Regular reviews are built into the annual co-management processes and ESA consultations. New information depends on monitoring of key metrics for hatchery production, natural population dynamics, and genetic introgression.	Hatchery programs maximize benefits while minimizing risks and costs.	WDFW; Puget Sound Indian Tribes; National Marine Fisheries Service (NMFS)	DPS, MPG, DIP	none

#	Actions for Strategy 3	Description	Expected Outcomes	Who Responsible	DPS/ MPG/ DIP (be specific)	Other Notes
3. b.	Place a priority on research that develops solutions to potential problems and quantifies factors affecting relative reproductive success and long-term fitness of populations influenced by hatcheries.	Research has documented complex variations in the relative reproductive success of hatchery fish and wild fish, which can affect the rate of population recovery, but causes of the observed patterns and how to manage those is not as well understood.	Research elucidates mechanisms affecting relative reproductive success and tests ways to improve these in hatchery programs	WDFW; USGS; Puget Sound Indian Tribes; NMFS; universities	DPS, MPG, DIP	none
3. c.	Design and operate hatcheries and hatchery programs with the flexibility to respond to changing conditions, including climate change.	Without the ability to change and improve based on new information, hatchery operations would fail to meet expectations and would need to be discontinued. Under climate change scenarios, hatcheries operations face declining hydrographs during spring and summer and flood conditions during fall, which can alter run timing, smolt emigration, and rearing habitat carrying capacity	Hatcheries and hatchery operations improve and adapt to new challenges. Adaptively managed hatchery operations maximize opportunities to enhance wild populations in conservation programs while minimizing risk to wild populations in segregated programs.	WDFW; Puget Sound Indian Tribes	DIP	none
3. d.	Discontinue or modify programs if risks outweigh the benefits.	Hatchery programs that are too expensive biologically and economically given the benefits they produce would be discontinued if they cannot change.	Hatchery programs maximize benefits while minimizing risks and costs.	WDFW; Puget Sound Indian Tribes	DIP	none

Freshwater Habitat Restoration and Acquisition

Habitat type: Tributaries/channel complexity/freshwater shoreline
In most areas of Puget Sound, this is the most critical freshwater habitat type for steelhead. They spend 2-3 years in tributary habitat in Puget Sound watersheds. 60-80% of historic spawning occurred in tributaries. Smaller tributaries are utilized by steelhead than those used by Chinook. For steelhead rearing (and spawning), a tributary reach should have 15-30% instream cover for different sized steelhead – this can include instream cover (incubation and hiding areas) in gravel, cobble and boulders along with large wood, pools and overhanging vegetation. This is what we refer to with the term “instream complexity.” It is also important that the gravel and cobbles are not embedded with sediment to allow for the gaps for refuge of different sized fish.

Table A4-45. Strategies to improve tributary channel complexity and freshwater shoreline.

#	Strategies	Description	Expected Outcomes	Other Notes
Trib 1	Install large woody debris and boulders to increase stream complexity	Stream complexity for steelhead is described above – this may be different than for other species and critical when considering different ages and sizes of fish and how they use the stream.	Abate channel incision by encouraging aggradation Encourages formation of meanders, increasing habitat length, encouraging aggradation that reverses incision, and decreasing bed slope Slow water, reduced water temperature, trap sediments. Refuge/hiding areas for fish reduce competition Increased substrate for prey and organic input for primary productivity Increased number and quality of pools Improves spawning gravel retention Increased rearing habitat Increased sinuosity, increased structural and hydrologic complexity,	For all tributary strategies, see the WDFW 2012 Stream Habitat Restoration Guidelines. Note that the type of system should dictate whether adding boulders is appropriate.

#	Strategies	Description	Expected Outcomes	Other Notes
			increased runs-pools-riffles Lower velocity Improved groundwater recharge Decreased erosion	
Trib 2	Remove riprap and other armoring along tributaries and side channels	Utilize bio-engineered bank stabilization, or additional set-backs, to allow channels to maintain natural structural diversity. May include demonstration projects. Combine with riparian restoration	Increased riparian function, invertebrate communities Improved habitat complexity Increased sinuosity, increased complexity, increased runs-pools-riffles Increased lateral channel migration Improve gravel inputs for spawning Increased rearing habitat	
Trib 3	Reconnect side channels, backwater and off-channel habitat to stream channels	Allow restoration through natural processes or connect historic or potential future side channel and off-channel habitat	Increased rearing habitat Increased extent of riparian area Improved foodweb dynamics Improved groundwater recharge	
Trib 4	Treat headcutting and restore channel gradient by installing instream structures	Instream structures include boulders, large wood, etc in areas undergoing or susceptible to channel erosion	Decreased erosion Reduce and prevent headcutting	Similar to Trib 1 but the location is dictated by treating or preventing headcuts in places that require such

#	Strategies	Description	Expected Outcomes	Other Notes
			Reconnect channel to floodplain Restoring channel gradient	action (different from increasing complexity). Still question of "natural" headcutting – see comments..
Trib 5	Introduce marine derived nutrients to upper watersheds in nutrient-poor systems, including carcass introductions, etc.	Strategy needed in upper watersheds with lack of marine derived nutrients	Increased nutrient levels Improved juvenile growth Increase invertebrate productivity and abundance	This is best done by maximizing the escapement of high density spawners (chum and pink). To maximize nutrients, carcasses should include females with eggs.
Trib 6	Treat landslides and other major erosion through toe stabilization and riparian planting	May include large wood, wood fencing, rip rap, etc to prevent landslides or treat areas with mass wasting	Reduced fine sediment Increased incubation Improved rearing	
Trib 7	Acquire intact tributary habitat (or areas that need purchase prior to restoration)		Maintains current rearing and spawning capacity Maintains current sediment, temperature, nutrient processes	
Trib 8	Remove barriers to restore access	This is covered extensively in dams and culverts tables.		

Habitat type: Riparian areas (mainstem and tributaries)
Steelhead areas should explicitly consider species that increase habitat structure and bank stabilization and alders for nitrogen-fixing qualities and habitat for invertebrates – more complex situation than just "more conifers are better" (pers comm Ed Connor. Where western red cedar isn't appropriate, consider western hemlock and doug fir).

Table A4-46. Strategies to improve riparian areas (mainstem and tributaries).

#	Strategies	Description	Expected Outcomes	Other Notes
Rip 1	Plant riparian areas with native species	-Restore degraded riparian condition.	-Improved egg-to-smolt survival, improved juvenile rearing	For riparian restoration strategies, see the

#	Strategies	Description	Expected Outcomes	Other Notes
		-Reduce loss of vegetation. -Increase shade and overhead cover, terrestrial food sources. -Stabilize unstable or eroding stream banks. -Increased LWD and SWD recruitment	-Restored natural riparian vegetative communities Provide a long-term source of large wood as trees mature and contribute to the channel.	WDFW 2012 Stream Habitat Restoration Guidelines
Rip 2	Acquire intact riparian areas under future threat or degraded riparian areas that need to be purchased before restoration can occur	-Restore natural riparian vegetative communities. -Prevent damage from grazing, logging, development, or other activities that could impact riparian vegetation. Develop grazing strategies that promote riparian recovery.	Restored riparian condition and LWD Maintain unimpaired conditions Maintain or improve threat of high stream temperatures through shading	
Rip 3	Manage riparian areas for improved growth	Improve degraded riparian areas through management and passive restoration; promote survival and growth), develop strategies for stand improve sites with marginal recruitment potential, continue underplanting of unsuitable sites to more suitable stands.	Restoration of riparian native plant communities Improve composition and quantity of wood recruitment to streams Provide for stream shading, and reduce sediment transport to streams	
Rip 4	Install livestock fencing to exclude grazing and bank erosion in riparian areas.	Protect and restore riparian habitat in agricultural areas.	Reduce sediment, pesticide, and E coli input from agriculture lands. Increased riparian revegetation. Maintains recharge functions of stream-adjacent wetlands and floodplains by preventing soil compaction	

Habitat type: Mainstem/floodplains/freshwater shorelines
Note: for steelhead it is often the mainsteam edge and side channels are most important for spawning and rearing, not the fast-moving mainstem river itself. It is important to maintain or restore distinct channel types that are missing – often islanded and side channel areas in Puget Sound watersheds. Complex vegetated channel areas are where most steelhead productivity occurs in mainstem habitats. It is important to restore natural channel pattern (riffle, pool, and sinuosity).

Table A4-47. Strategies to improve mainstem edges, floodplains, and freshwater shorelines.

#	Strategies	Description	Expected Outcomes	Other Notes
Main 1	Breach or setback levees, dikes and other hydromodifications	Remove levees from near mainstem banks and if necessary install new setback levees with as much floodplain available to the river as possible	Increased sinuosity Increased braiding of rivers Reconnected floodplain Improved flow, temperature, riparian areas. Increased spawning and rearing habitat	Breaching typically happens on public lands, whereas setback may be necessary where flood protection is needed for private property or other uses. Setbacks are far more expensive.
Main 2	Plant riparian areas on and along levees	Allows riparian area to develop around levees regardless of their location; may be more important in areas where the levee is close to the channel with less connected floodplain. See riparian for strategies to improve other non-levee riparian areas.	Improved flow, temperature, riparian areas. Increased rearing habitat Improved invertebrate food production for juveniles	None
Main 3	Install large woody debris structures	Where feasibly installed in key areas, LWD can (re)initiate flow into historic or created side channels and wetlands, including river deltas where predation of steelhead smolts is high.	Improved channel complexity Refugia in lower rivers and deltas from marine predators Slowdown flows Create pools Cool water	Large wood in lower rivers is complicated by frequent flooding washing away structures, boaters and swimmers who fear for safety concerns, and tribal fishers who have been outspoken about

#	Strategies	Description	Expected Outcomes	Other Notes
			Reduce sediment	their traditional fishing techniques (wood and nets create conflicts)
Main 4	Acquire key reaches where the natural channel would be a large steelhead producer or could be restored to islanded/braided/forested mainstem	Acquire key reaches to increase steelhead productivity	Maintain current function Purchase so that restoration is possible	none

Habitat type: Freshwater wetlands
Provide enhanced summer low flows, buffer peak flows, and filter water for steelhead. NWFSC working a lot on this and discussing vertical connectivity for hydro function. Maintains and subsidizes base flows and buffers peak flows, also helps with water quality – sediment and pollutants in runoff. Specifically because it is mentioned in NOAA's Listing Factor A when steelhead were listed.

Table A4-48. Strategies to improve freshwater wetlands.

#	Strategies	Description	Expected Outcomes	Other Notes
Wet 1	Restore key wetlands adjacent to priority steelhead areas near mainstem and major tributaries (not as rearing areas but to maintain hydrologic process).	Restore through wetland creation, plantings	Hydrologic reconnection Slowing of water and refuge in high water. Maintain or restore summer base flows Reduce temps	none
Wet 2	Acquire and protect (either through direct purchase or purchase of development rights) wetlands that have a significant influence on hydrology.	Prevent altering and filling of wetlands. Increase the buffer around wetlands by acquiring development rights or properties	Protect and enhance hydrology and water quality.	none
Wet 3	Re-introduce and improve beavers populations following established	Introduction in key areas can increase hydrologic function, build wetlands	Improved hydrologic flow Increased connectivity	Implement the Beaver Restoration Guidebook (Pollock et al. 2015). State

#	Strategies	Description	Expected Outcomes	Other Notes
	guidelines for hydrologic benefits	complexes and improve habitat/channel complexity	Increased channel complexity	law now allows beaver relocation in Western WA.

Habitat type: Upland

While not directly providing habitat for steelhead, management and restoration of uplands is important for water quantity, water quality, sediment and nutrient dynamics.

Table A4-49. Strategies to improve upland areas.

#	Strategies	Description	Expected Outcomes	Other Notes
Up 1	Restore degraded upland processes to minimize unnatural rates of erosion and runoff, and maintain unimpaired natural upland processes.	Restore degraded upland habitat. Reduce altered sediment routing	Restored sediment regimes. Improved hydrological processes	Management activities and protection of upland habitats are covered in other tables (see….)
Up 2	Plant native species in uplands areas	Note: different species than those discussed for riparian zones: focus on soil retention and hydrologic process	Reduce erosion Increase infiltration	none
Up 3	Acquire forested uplands in key locations through fee simple or conservation easement (reforest where necessary)	To protect standing forest for hydrologic benefit, recruitment, sediment control, and carbon sequestration.	Improved hydrological processes Restored sediment regimes Large wood recruitment	Overlap with timber harvest strategy table