ESA Recovery Plan for

Lower Columbia River Coho Salmon, Lower Columbia River Chinook Salmon, Columbia River Chum Salmon, and Lower Columbia River Steelhead

Prepared by the
National Marine Fisheries Service,
Northwest Region

June 2013

Disclaimer

Endangered Species Act (ESA) recovery plans delineate reasonable actions that the best available information indicates are necessary for the conservation and survival of listed species. Plans are published by the National Marine Fisheries Service (NMFS), usually with the assistance of recovery teams, state agencies, local governments, salmon recovery boards, non-governmental organizations, interested citizens of the affected area, contractors, and others. ESA recovery plans do not necessarily represent the views, official positions, or approval of any individuals or agencies involved in the plan formulation, other than NMFS. They represent the official position of NMFS only after they have been signed by the Northwest Regional Administrator. ESA recovery plans are guidance and planning documents only; identification of an action to be implemented by any public or private party does not create a legal obligation beyond existing legal requirements. Nothing in this plan should be construed as a commitment or requirement that any federal agency obligate or pay funds in any one fiscal year in excess of appropriations made by Congress for that fiscal year in contravention of the Anti-Deficiency Act, 31 United States Code (USC) 1341, or any other law or regulation. Approved recovery plans are subject to modification as dictated by new information, changes in species status, and the completion of recovery actions.

With respect to the Lower Columbia River salmon and steelhead recovery plan, where areas of disagreement arose between a management unit plan and the species (i.e., ESU or DPS-level) plan, NMFS worked with the relevant parties to resolve the differences and in a few cases, identified in the species plan, decided not to incorporate the disputed material into the species plan.

Although an ESA recovery plan is not a regulatory document with the force of law, it provides important context for NMFS decisions under ESA section 7(a). The procedures for the section 7 consultation process are described in 50 Code of Federal Regulations (CFR) 402 and are applicable regardless of whether or not the actions are described in a recovery plan.

Acknowledgements

The Lower Columbia River ESA Recovery Plan represents the dedicated effort of numerous people over many years. The National Marine Fisheries Service would like to thank the individuals, organizations, and agencies listed below (alphabetically) for their contributions to this plan. Special thanks go to the members of the Lower Columbia Recovery Plan Steering Committee and the management unit recovery planning organizations for their input, support, and guidance throughout this recovery planning process.

Recovery Plan Authors

Patty Dornbusch – National Marine Fisheries Service, Northwest Region
Ann Sihler – Ann Sihler Writing and Editing

NMFS Contributors and Reviewers

Brian Allee – formerly National Marine Fisheries Service, Northwest Region
Robert Anderson – National Marine Fisheries Service, Northwest Region
Jeff Bash – National Marine Fisheries Service, Northwest Fisheries Science Center
Laurie Beale – NOAA Office of the General Counsel
Nora Berwick - National Marine Fisheries Service, Northwest Region
Craig Busack – National Marine Fisheries Service, Northwest Region
Mark Chilcote – formerly National Marine Fisheries Service, Northwest Region
Tom Cooney – National Marine Fisheries Service, Northwest Fisheries Science Center
David Crouse – National Marine Fisheries Service, Northwest Region
Donna Darm – National Marine Fisheries Service, Northwest Region
Michelle Day – National Marine Fisheries Service, Northwest Region
Peter Dygert– National Marine Fisheries Service, Northwest Region
Elizabeth Gaar – National Marine Fisheries Service, Northwest Region
Ritchie Graves – National Marine Fisheries Service, Northwest Region
Dan Guy – formerly National Marine Fisheries Service, Northwest Region
Rob Jones – National Marine Fisheries Service, Northwest Region
Lynne Krasnow – National Marine Fisheries Service, Northwest Region
Jeff Lockwood - National Marine Fisheries Service, Northwest Region
Paul McElhany – National Marine Fisheries Service, Northwest Fisheries Science Center
Ben Meyer – National Marine Fisheries Service, Northwest Region
Larissa Plants – National Marine Fisheries Service, Office of Protected Resources
Scott Rumsey – National Marine Fisheries Service, Northwest Region
Alix Smith – National Marine Fisheries Service, Northwest Region
Chris Toole – National Marine Fisheries Service, Northwest Region
Rich Turner – National Marine Fisheries Service, Northwest Region
Robert Walton – National Marine Fisheries Service, Northwest Region
Amilee Wilson – National Marine Fisheries Service, Northwest Region

Other Contributors and Reviewers

Ray Beamesderfer – Cramer Fish Sciences

Jeanette Burkhardt – Yakama Nation
Catherine Corbett – Lower Columbia Estuary Partnership
Members of the Columbia Basin Federal Caucus
Pat Frazier – Washington Department of Fish and Wildlife
Kevin Goodson – Oregon Department of Fish and Wildlife
Bernadette Graham Hudson – Lower Columbia Fish Recovery Board
Members of the Lower Columbia River Plan Steering Committee
Rick Mogren – Federal Caucus Program Coordinator
Dan Rawding – Washington Department of Fish and Wildlife
Jeff Rodgers – Oregon Department of Fish and Wildlife
Tom Stahl – Oregon Department of Fish and Wildlife

Lower Columbia Recovery Plan Steering Committee Members

Jim Brick – Oregon Department of Fish and Wildlife
Jeff Breckel – Lower Columbia Fish Recovery Board
Donna Darm – National Marine Fisheries Service, Northwest Region
Patty Dornbusch – National Marine Fisheries Service, Northwest Region
Megan Duffy – Washington Governor's Salmon Recovery Office
Suzanne Knapp – formerly Oregon Governor's Natural Resource Office
Sara Laborde – Washington Department of Fish and Wildlife
Deb Marriott – Lower Columbia Estuary Partnership
Bruce McIntosh – Oregon Department of Fish and Wildlife
Phil Miller – formerly Washington Governor's Salmon Recovery Office
Rick Mogren – facilitator
Guy Norman – Washington Department of Fish and Wildlife
Bill Sharp – Yakama Nation
Tom Stahl – Oregon Department of Fish and Wildlife
Robert Walton – National Marine Fisheries Service, Northwest Region

Lower Columbia Management Unit Organizations

Lower Columbia Fish Recovery Board
Lower Columbia Estuary Partnership
Oregon Lower Columbia Stakeholder Team
Washington Gorge Implementation Team

Member Agencies of the Columbia Basin Federal Caucus

Bonneville Power Administration
National Marine Fisheries Service
U.S. Army Corps of Engineers
U.S. Bureau of Land Management
U.S. Bureau of Indian Affairs
U.S. Bureau of Reclamation
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
U.S. Forest Service
U.S. Geological Survey

Contents

Appendices

Tables

Figures

Acronyms and Abbreviations

AMIP	Adaptive Management Implementation Plan
AMS	Anadromous Salmonid Monitoring Strategy
ASMS	Anadromous Salmonid Monitoring Strategy
BACI	Before and After Control Impact
BiOp	Biological Opinion
BPA	Bonneville Power Administration
C&S	ceremonial and subsistence
C3	Climate Change Collaboration
CATAS	Conservation Assessment Tool for Anadromous Salmonids
CBFWA	Columbia Basin Fish and Wildlife Authority
CFR	Code of Federal Regulations
CREP	Conservation Reserve Enhancement Program
CRT	critical risk threshold
DEIS	Draft Environmental Impact Statement
DPS	distinct population segment
EDT	Ecosystem Diagnosis and Treatment
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
ERME	*Research, Monitoring, and Evaluation for the Federal Columbia River Estuary Program*
ESA	Endangered Species Act
ESU	evolutionarily significant unit
FCRPS	Federal Columbia River Power System
FERC	Federal Energy Regulatory Commission

FR	Federal Register
GHG	greenhouse gas
GIS	geographical information system
GRTS	generalized random tessellation stratified
HGMP	Hatchery and Genetics Management Plan
HSRG	Hatchery Scientific Review Group
IMW	intensively monitored watershed
IP	intrinsic potential
IPCC	Intergovernmental Panel on Climate Change
ISAB	Independent Scientific Advisory Board
ISEMP	Integrated Status and Effectiveness Monitoring Program
ISTM	Integrated Status and Trend Monitoring
IWA	Integrated Watershed Assessment
kcfs	thousand cubic feet per second
LCFRB	Lower Columbia Fish Recovery Board
LCR	Lower Columbia River
MAT	minimum abundance threshold
MOA	Memorandum of Agreement
MPG	major population group
NEPA	National Environmental Protection Act
NFCP	Native Fish Conservation Policy
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPCC	Northwest Power and Conservation Council
NWFSC	Northwest Fisheries Science Center
ODFW	Oregon Department of Fish and Wildlife

OWEB	Oregon Watershed Enhancement Board
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PCE	primary constituent element
PCSRF	Pacific Coastal Salmon Recovery Funds
pHOS	proportion of hatchery-origin spawners
PNAMP	Pacific Northwest Aquatic Monitoring Partnership
PNI	proportion of natural influence
PUD	public utility district
PVA	Population Viability Analysis
QET	quasi-extinction threshold
RCW	Revised Code of Washington
RIST	Recovery Implementation Science Team
RKM	river kilometer
RM	river mile
RME	research, monitoring, and evaluation
RPA	Reasonable and Prudent Alternative
RSW	removable spillway weirs
SRFB	Salmon Recovery Funding Board
SRS	sediment retention structure
TRT	Technical Recovery Team
USC	United States Code
USDA	U.S. Department of Agriculture
USDI	U.S. Department of the Interior
USFWS	U.S. Fish and Wildlife Service
VSP	viable salmonid populations

WAGIT	Washington Gorge Implementation Team
WDFW	Washington Department of Fish and Wildlife
WLC TRT	Willamette-Lower Columbia Technical Recovery Team
WRIA	Water Resource Inventory Area

Glossary

abundance: In the context of salmon recovery, unless otherwise qualified, abundance refers to the number of adult fish returning to spawn, measured over a time series.

adaptive management: Adaptive management in salmon recovery planning is a method of decision making in the face of uncertainty. A plan for monitoring, evaluation, and feedback is incorporated into an overall implementation plan so that the results of actions can become feedback on design and implementation of future actions.

anadromous fish: Species that are hatched in freshwater, migrate to and mature in salt water, and return to freshwater to spawn.

baseline monitoring: In the context of recovery planning, baseline monitoring is done before implementation, in order to establish historical and/or current conditions against which progress (or lack of progress) can be measured.

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.

broad sense recovery goals: Goals defined in the recovery planning process, generally by local recovery planning groups, that go beyond the requirements for delisting, to address, for example, other legislative mandates or social, economic, and ecological values.

compliance monitoring: Monitoring to determine whether a specific performance standard, environmental standard, regulation, or law is met.

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 stratum-wide average viability recommended by the Washington-Lower Columbia Technical Recovery Team (i.e., 2.25 or higher).

delisting criteria: Criteria incorporated into ESA recovery plans that define both biological viability (biological criteria) and alleviation of the causes for decline (threats criteria based on the five listing factors in ESA section 4[a][1]), and that, when met, would result in a determination that a species is no longer threatened or endangered and can be proposed for removal from the federal list of threatened and endangered species. These criteria are a NMFS determination and may include both technical and policy considerations.

distinct population segment (DPS): A listable entity under the ESA that meets tests of discreteness and significance according to USFWS and NMFS policy. A population is considered distinct (and hence a "species" for purposes of conservation under the ESA) if it is discrete from and significant to the remainder of its species based on factors such as physical, behavioral, or genetic characteristics, it occupies an unusual or unique ecological setting, or its loss would represent a significant gap in the species' range.

diversity: All the genetic and phenotypic (life history, behavioral, and morphological) variation within a population. Variations could include anadromy vs. 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.

effectiveness monitoring: Monitoring set up to test cause-and-effect hypotheses about recovery actions: Did the management actions achieve their direct effect or goal? For example, did fencing a riparian area to exclude livestock result in recovery of riparian vegetation?

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.

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.

extinct: No longer in existence. No individuals of this species can be found.

extirpated: Locally extinct. Other populations of this species exist elsewhere. Functionally extirpated populations are those of which there are so few remaining numbers that there are not enough fish or habitat in suitable condition to support a fully functional population.

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.

functionally extirpated: Describes a species that has been extirpated from an area; although a few individuals may occasionally be found, there are not enough fish or habitat in suitable condition to support a fully functional population.

hyporheic zone: Area of saturated gravel and other sediment beneath and beside streams and rivers where groundwater and surface water mix.

implementation monitoring: Monitoring to determine whether an activity was performed and/or completed as planned.

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.

interim regional recovery plan: A recovery plan that is intended to lead to an ESA recovery plan but that is not yet complete. These plans might address only a portion of an ESU or lack other key components of an ESA recovery plan.

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: The expected ratio of natural-origin offspring to parent spawners at levels of abundance below carrying capacity.

kelts: Steelhead that are returning to the ocean after spawning and have the potential to spawn again in subsequent years (unlike most salmon, steelhead do not necessarily die shortly after spawning).

large woody debris (LWD): A general term for wood naturally occurring or artificially placed in streams, including branches, stumps, logs, and logjams. Streams with adequate LWD tend to have greater habitat diversity, a natural meandering shape, and greater resistance to flooding.

legacy effects: Impacts from past activities that continue to affect a stream or watershed in the present day.

limiting factor: Physical, biological, or chemical features (e.g., inadequate spawning habitat, high water temperature, insufficient prey resources) experienced by the fish that result in reductions in viable salmonid population (VSP) parameters (abundance, productivity, spatial structure, and diversity). Key limiting factors are those with the greatest impacts on a population's ability to reach a desired status.

locally developed recovery plan: A plan developed by state, tribal, regional, or local planning entities to address recovery of a species. These plans are being developed by a number of entities throughout the region to address ESA as well as state, tribal, and local mandates and recovery needs.

maintained status: Population status in which the population does not meet the criteria for a viable population but does support ecological functions and preserve options for ESU/DPS recovery.

management unit: A geographic area defined for recovery planning purposes on the basis of state, tribal or local jurisdictional boundaries that encompass all or a portion of the range of a listed species, ESU, or DPS.

metrics: Something that quantifies a characteristic of a situation or process; for example, the number of natural-origin salmon returning to spawn to a specific location is a metric for population abundance.

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.

parr: The stage in anadromous salmonid development between absorption of the yolk sac and transformation to smolt before migration seaward.

persistence probability: The complement of a population's extinction risk (i.e., persistence probability = 1 – extinction risk).

phenotype: Any observable characteristic of an organism, such as its external appearance, development, biochemical or physiological properties, or behavior.

piscivorous: (Adj.) Describes fish that eat other fish.

primary population: A population that is targeted for restoration to high or very high persistence probability.

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 domain: An administrative unit for recovery planning defined by NMFS based on ESU boundaries, ecosystem boundaries, and existing local planning processes. Recovery domains may contain one or more listed ESUs.

recovery goals: Goals incorporated into a locally developed recovery plan, which may include delisting (i.e. no longer considered endangered or threatened), reclassification (e.g., from endangered to threatened), and/or other goals. Broad sense goals are a subset of recovery goals (see glossary entry above).

recovery scenarios: Scenarios that describe a target status for each population within an ESU, generally consistent with TRT recommendations for ESU viability.

recovery strategy: Statements that identify the assumptions and logic – the rationale – for the species' recovery program.

redd: A nest constructed by female salmonids in streambed gravels where eggs are fertilized and deposited.

riparian area: Area with distinctive soils and vegetation between a stream or other body of water and the adjacent upland.

salmonid: Fish of the family *Salmonidae*, including salmon, trout, chars, grayling, and whitefish. In general usage, the term usually refers to salmon, trout, and chars.

smolt: A juvenile salmonid that is undergoing physiological and behavioral changes to adapt from freshwater to saltwater as it migrates toward the ocean.

spatial structure: Characteristics of a fish population's geographic distribution. Current spatial structure depends upon the presence of fish, not merely the potential for fish to occupy an area.

stabilizing population: A population that is targeted for maintenance at its baseline persistence probability, which is likely to be low or very low.

stakeholders: Agencies, groups, or private citizens with an interest in recovery planning, or those who will be affected by recovery planning and actions.

stratum: A group of salmonid populations that are geographically and genetically cohesive. The stratum is a level of organization between demographically independent populations and the ESU or DPS.

Technical Recovery Team (TRT): Teams convened by NMFS to develop technical products related to recovery planning. Planning forums unique to specific states, tribes, or regions may 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.

threat reduction scenario: A specific combination of reductions in threats from various sectors that would lead to a population achieving its target status.

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 NMFS-appointed Technical Recovery Teams to describe a viable salmonid population, based on the biological parameters of abundance, productivity, spatial structure, and diversity. These criteria are used as technical input into the recovery planning process and provide a technical foundation for development of biological delisting criteria.

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 salmonid (genus *Oncorhynchus*) that has a negligible risk of extinction due to threats from demographic variation (random or directional), local environmental variation, and genetic diversity changes (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).

Executive Summary

About This Recovery Plan

This is a plan for the recovery of Lower Columbia River Chinook salmon (*Oncorhynchus tshawytscha*), Lower Columbia River steelhead (*O. mykiss),* Lower Columbia River coho salmon (*O. kisutch*), and Columbia River chum salmon (*O. keta*), all of which spawn and rear in the lower Columbia River or its tributaries in Oregon and Washington. These salmon and steelhead were listed as threatened under the Endangered Species Act of 1973 (ESA) between 1998 and 2005. Each is considered an evolutionarily significant unit (ESU) or, for steelhead, a distinct population segment (DPS). An ESU or DPS is a group of Pacific 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.[1] Under the Endangered Species Act, each ESU or DPS is treated as a species. For convenience this recovery plan frequently uses the term "ESU" to refer to both the salmon ESUs and the steelhead DPS.

The core of the plan is a set of goals and actions for each ESU that, if implemented, would reverse the ESU's decline and lead to recovery of the ESU. Biological recovery for an ESU means that it is naturally self-sustaining and no longer requires the protection of the ESA: enough fish spawn in the wild and return year after year that the ESU is likely to persist in the long run. A recovered ESU is resilient enough that it can survive typical variations in ocean conditions and productivity and has a high likelihood of withstanding catastrophic changes in the environment, such as floods, landslides, and earthquakes.

The ESA requires the National Marine Fisheries Service (NMFS) to develop recovery plans for all listed salmon and steelhead species. NMFS is a branch of the National Oceanic and Atmospheric Administration and is sometimes referred to as NOAA Fisheries. As the federal agency charged with stewardship of the nation's marine resources, NMFS has the responsibility for listing and delisting salmon and steelhead species under the ESA.

Although NMFS is directly responsible for ESA recovery planning for salmon and steelhead, the agency believes that ESA recovery plans for salmon and steelhead should be based on the many state, regional, tribal, local, and private conservation efforts already under way throughout the region, and that local support of recovery plans is essential to success. Accordingly, NMFS based this recovery plan on the information, analyses, and strategies in three locally developed recovery plans, which are referred to as management unit plans.

Each ESU is made up of multiple independent populations, and each management unit plan covers populations in a different portion of the ESU's range:

[1] A DPS is defined based on discreteness in behavioral, physiological, and morphological characteristics, whereas the definition of an ESU emphasizes genetic and reproductive isolation. (For a fuller explanation see, Section 1.4.4 of the recovery plan.)

- *The Oregon Lower Columbia Conservation and Recovery Plan for Salmon and Steelhead* covers the Lower Columbia River salmon and steelhead populations that are within Oregon, including the Willamette River up to Willamette Falls. The Oregon Department of Fish and Wildlife (ODFW) developed this plan in collaboration with NMFS and numerous stakeholders, including governments, agencies, tribes, industry and environmental representatives, and the public (Oregon Department of Fish and Wildlife 2010).

- *ESA Salmon Recovery Plan for the White Salmon River Subbasin* covers Lower Columbia River salmon and steelhead populations in the White Salmon River basin in Washington. NMFS developed this plan in cooperation with stakeholders such as the Yakama Nation, Klickitat County, and Washington Department of Fish and Wildlife (National Marine Fisheries Service 2013).

- *Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan* covers Lower Columbia River salmon and steelhead populations in Southwest Washington, within the planning area of the Lower Columbia Fish Recovery Board (LCFRB). The LCFRB developed this plan using a collaborative process that involved multiple agencies (including NMFS), tribal and other governments, organizations, industry, and the public (Lower Columbia Fish Recovery Board 2010a).

Two other documents, both developed by NMFS, were key in development of this recovery plan: the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) and the *Recovery Plan Module: Mainstem Columbia River Hydropower Projects* (NMFS 2008a). These documents, which address regional-scale issues affecting Lower Columbia River salmon and steelhead, as well as other listed salmon ESUs and steelhead DPSs, provide a consistent set of assumptions and recovery actions that management unit recovery planners incorporated into their management unit plans.

Recovery plans are not regulatory documents. Their implementation is voluntary, except when they incorporate actions required as part of a regulatory process, such as ESA section 7, 10, and 4(d). For this recovery plan, NMFS will rely, to a great extent, on local citizens and organizations, as well as on other federal and state agencies, local jurisdictions, and tribal governments, to voluntarily implement the recovery actions. In some cases, the plan puts forward new recovery efforts that are not part of existing processes. In other cases, the plan recommends coordinating existing programs, both regulatory and non-regulatory, in ways that enhance benefits to Lower Columbia River salmon and steelhead and their ecosystems. Some actions that are integrated into this recovery plan originate in regulatory processes; examples include actions associated with the 2008 Bull Run Water Supply Habitat Conservation Plan (HCP), the 2008 Federal Columbia River Power System Biological Opinion and its 2010 Supplement, Federal Energy Regulatory Commission relicensing agreements (for tributary hydroelectric projects), and the regulation of fisheries that may affect the Lower Columbia River ESUs.

This recovery plan lays out an overall road map for recovery. After the plan is adopted, additional work will be needed in some cases to identify and prioritize[2] site-specific projects, determine costs and time frames, and identify responsible parties, based on strategies and actions in the recovery plan. To address these needs, each entity that developed a management unit plan (i.e., ODFW, NMFS, and LCFRB) also will prepare an "implementation schedule" that spells out the details of implementation for its specific geographical area. Implementation schedules will be updated every 3 to 6 years.

Overall Goal

In general, the goal of this plan is for the Lower Columbia River coho salmon ESU, Lower Columbia River Chinook salmon ESU, Lower Columbia River steelhead DPS, and Columbia River chum salmon ESU to reach the point at which they no longer need the protection of the Endangered Species Act and can be delisted. The delisting decision is made by NMFS, using the best available science. NMFS' delisting criteria are presented later in this summary, after some basic technical information and the population-specific goals are explained.

Technical Foundation

NMFS appointed teams of scientists with expertise in salmonid species to provide scientific support for recovery planners in the Pacific Northwest. These technical recovery teams (TRTs) worked from a common scientific foundation to ensure that recovery plans would be scientifically sound and based on consistent biological principles. All the TRTs based their work on biological principles established by NMFS for salmon recovery planning.

The Willamette-Lower Columbia Technical Recovery Team (WLC TRT) included biologists from NMFS, other federal agencies, states, tribes, academic institutions, and the private sector. The WLC TRT and a subsequent work group consisting of NMFS staff, ODFW staff, and a private consultant produced a set of technical reports that, taken together, present recommended biological criteria and methodologies for determining whether the four Lower Columbia River salmon and steelhead ESUs are viable. A viable ESU is naturally self-sustaining over the long term.

Consistent with principles established by NMFS, the WLC TRT described salmon and steelhead viability in terms of four interrelated parameters:

- **Abundance and productivity.** Abundance refers to the number of adult fish on the spawning grounds. Productivity is the population's growth rate, which indicates whether the population can sustain itself or rebound from low numbers. Productivity can be measured as spawner-to-spawner ratios (i.e., returns per spawner or recruits per spawner), annual population growth rate, or trends in abundance. Abundance and productivity are closely linked, and a population needs both: abundance to maintain genetic health and respond to normal

[2] Some prioritization work already has been done, in that the management unit plans identify high-priority reaches for tributary habitat protection and restoration actions. In addition, the Oregon and White Salmon management unit plans offer some guidance on how actions might be prioritized.

environmental variation, and productivity to bounce back if population numbers drop for some reason.

- **Spatial structure.** Spatial structure refers to both the geographic distribution of individuals in the population and the processes or conditions that generate that distribution. Factors affecting spatial structure include the amount of habitat available, how connected the habitat is, and how much neighboring populations mix with each other. Spatial structure is important because a species that is not geographically spread out is at risk of extinction from a single catastrophic event, such as a landslide.

- **Diversity**. Diversity refers to the variety of life history, behavioral, and physiological traits within and among populations. Some traits are determined completely by genetics, while others, such as appearance, behavior, and life history, vary as a result of a combination of genetic and environmental factors. Diversity is important because it gives populations an edge in surviving (and eventually adapting to) environmental change.

To understand the WLC TRT's biological criteria, it helps to know something about the biological structure of salmon and steelhead species. The Lower Columbia River Chinook salmon, Lower Columbia River coho salmon, Lower Columbia River steelhead, and Columbia River chum salmon ESUs each consist of multiple independent populations that spawn in different watersheds throughout the ESU's range. Additionally, within an ESU, independent populations can be organized into larger groups, known as strata. Stratum designation is based on the combination of ecological zone and life history strategy (indicated by the time of year when adults return to fresh water to spawn). In the lower Columbia region there are three ecological zones—Coast, Cascade, and Gorge. Two ESUs—Chinook and steelhead—display more than one life history strategy. Thus, the strata in this recovery plan include Coast, Cascade, and Gorge coho, Coast fall Chinook, Cascade fall Chinook, Gorge fall Chinook, Cascade spring Chinook, Gorge spring Chinook, etc.

The WLC TRT developed biological criteria and methodologies at three different levels: ESU, stratum, and population. The following are the TRT's key points in defining a viable ESU:

- Every stratum that historically existed should have a high probability of persistence.

- Within each stratum, there should be at least two populations that have at least a 95 percent probability of persisting over a 100-year time frame.

- Within each stratum, the average viability of the populations should be 2.25 or higher, using the WLC TRT's scoring system. Functionally, this is equivalent to about half of the populations in the stratum being viable; a viable population is one whose persistence probability is high or very high.

- Populations targeted for viability should include those within the ESU that historically were the most productive ("core" populations) and that best represent the historical genetic diversity of the ESU ("genetic legacy" populations). In addition, viable populations should be geographically dispersed in a way that protects against the effects of catastrophic events.

- Viable populations should meet specific criteria for abundance, productivity, spatial structure, and diversity.

There are various ways to refer to extinction risk: as viability, persistence probability, extinction risk, or—at the population level—population status. This recovery plan frequently uses the terms "persistence probability" and "population status." Only populations with a persistence probability of 95 percent or higher over a 100-year time frame are considered viable. These populations have a population status of high or very high.

Table ES-1
Population-level Probability of Persistence, Extinction Risk, and Status*

Probability of Persistence	Probability of Extinction	Extinction Risk	Population Status
0 – 40%	60 – 100%	Extinct or at very high risk of extinction (VH)	Very low (VL)
40 – 75%	25 – 60%	Relatively high risk of extinction (H)	Low (L)
75 – 95%	5 – 25%	Moderate risk of extinction (M)	Medium (M)
95 – 99%	1 – 5%	Low/negligible risk of extinction (L)	High (H)
> 99%	< 1%	Very low risk of extinction (VL)	Very high (VH)

+ Probability over a 100-year time frame.
Shading indicates levels at which a population is considered viable.

Population-specific Goals: The Recovery Scenario

The WLC TRT defined viability at the ESU, stratum, and population levels, but it did not specify the target status for each population because (1) there are many different combinations of target statuses that would meet the TRT's viability criteria, and (2) the "best" combination is a function of the biological and ecological conditions on the ground and local community values and interests. Oregon, Washington, and White Salmon management unit planners collaborated to reach agreement on which populations to target for which levels of viability. In making these decisions, management unit planners considered the WLC TRT's viability criteria and the following questions:

- Which populations historically were the most productive?
- Which populations represent important historical genetic diversity?
- Are the populations targeted for viability dispersed in a way that minimizes risk from catastrophic events?
- Which populations can be expected to make significant progress toward recovery because of existing programs, the absence of apparent impediments to recovery, and other management considerations?

- Are there populations that are unlikely to make significant progress toward recovery because of other societal goals, such as maintaining harvest or development opportunities?

The resulting target statuses for each ESU are collectively referred to as the recovery scenario and served as the basis from which to calculate numerical abundance and productivity goals for each population. (Table 3-1 of the recovery plan shows the recovery scenario for each ESU.)

Under the recovery scenario not all populations are targeted for a high degree of improvement, but all of them will need recovery actions—even so-called "stabilizing" populations. These are populations that are expected to remain at or near their current status (usually low or very low) because the feasibility of restoration is low and the uncertainty of success is high. "Primary" populations, on the other hand, are targeted for viability, meaning high or very high persistence probability. "Contributing" populations fall in the middle; they are targeted for some improvement in status so that the stratum-wide average viability is 2.25 or higher.

The recovery scenarios in the management unit plans are largely consistent with the WLC TRT's recommendations at the stratum and ESU level. Exceptions are the Gorge fall Chinook, Gorge spring Chinook, and Gorge chum strata, where the recovery scenarios target only one population to achieve a high probability of persistence, instead of two. As a way of mitigating for this increased risk in the Gorge strata, the recovery scenarios exceed the WLC TRT criteria in the Cascade fall Chinook, Cascade spring Chinook, and Cascade chum strata (i.e., more populations are targeted for viability than are needed to meet the 2.25 average). In addition, management unit recovery planners raised questions about the historical role of the Gorge fall Chinook, spring Chinook, and chum populations: were the populations highly persistent historically, did they function as independent populations within their stratum in the same way that the Coast and Cascade populations did, and should the Gorge stratum be considered a separate stratum from the Cascade stratum? Oregon recovery planners suggested that the Gorge strata's historical status and population structure be reevaluated and that recovery goals be revised if modifications are made; NMFS agrees that the historical role of the Gorge populations and strata merits further examination.

NMFS Delisting Criteria

As described above, the overall goal of this recovery plan is for the four ESUs to reach the point at which they no longer need the protection of the ESA and can be delisted. In order to be delisted, the species must no longer be in danger of extinction or likely to become endangered within the foreseeable future, based on evaluation of the factors that caused the species to be listed in the first place. In accordance with the ESA, this recovery plan incorporates objective, measurable criteria for determining whether an ESU can be delisted.[3] These criteria are of two types: biological viability criteria and threats criteria.

[3] The ESA requires that recovery plans, to the maximum extent practicable, incorporate objective, measurable criteria that, when met, would result in a determination in accordance with the provisions of the

Biological Viability Criteria

NMFS has concluded that the WLC TRT's viability criteria, the recovery scenarios, and the population-level abundance and productivity goals in the management unit plans adequately describe the characteristics of an ESU that no longer needs the protections of the ESA. NMFS endorses the recovery scenarios and population-level goals in the management unit plans as one of multiple possible scenarios consistent with delisting. Therefore, NMFS has developed the following biological viability criteria:

- All strata that historically existed have a high probability of persistence or have a probability of persistence consistent with their historical condition.

- High probability of stratum persistence is defined as:

  A. At least two populations in the stratum have at least a 95 percent probability of persistence over a 100-year time frame (i.e., two populations with a score of 3.0 or higher based on the TRT's scoring system).

  B. Other populations in the stratum have persistence probabilities consistent with a high probability of stratum persistence (i.e., the average of all stratum population scores is 2.25 or higher, based on the TRT's scoring system). (See Section 2.6 of the recovery plan for a brief discussion of the TRT's scoring system.)

  C. Populations targeted for a high probability of persistence are distributed in a way that minimizes risk from catastrophic events, maintains migratory connections among populations, and protects within-stratum diversity.

- Probability of persistence consistent with historical condition refers to the concept that strata that historically were small or had complex population structures may not have met Criteria A through C, above, but could still be considered sufficiently viable if they provide a contribution to overall ESU viability similar to their historical contribution.

Threats Criteria

In addition, for a species to be delisted, the threats that brought it to its threatened or endangered condition must be ameliorated such that they do not keep the ESU from achieving the desired biological status. The ESA identifies five categories of threats (any one or a combination of which may be the basis for the initial listing):

A. Present or threatened destruction, modification, or curtailment of the species' habitat or range
B. Overutilization for commercial, recreational, scientific, or educational purposes
C. Disease or predation

ESA that the species be removed from the Federal List of Endangered and Threatened Wildlife and Plants (50 CFR 17.11 and 17.12).

D. Inadequacy of existing regulatory mechanisms
E. Other natural or human-made factors affecting the species' continued existence

The threats criteria in this recovery plan define the conditions under which the threats can be considered to be addressed or mitigated. Threats criteria for measuring recovery of Lower Columbia River salmon and steelhead ESUs are detailed in Section 3.2.2 of the recovery plan. In general, the threats criteria for the Lower Columbia River ESUs are considered met once the recovery plan actions have been substantially implemented, population-specific threat reduction targets have been met (or threat impacts are otherwise consistent with the desired status of the ESU and its constituent populations), threats have been ameliorated such that the desired status will be maintained, and regulatory mechanisms are being implemented in a way that supports attainment and maintenance of the desired status.

Site-specific Recovery Actions and Cost Estimates

Site-specific recovery actions are discussed in detail in the management unit plans. The Federal Columbia River Power System (FCRPS) Biological Opinion and related recovery plan hydropower module describe site-specific actions related to passage at Bonneville Dam, predation, and flow that affects conditions in the lower Columbia River, estuary, and, potentially, the plume. Site-specific actions for the Columbia River estuary and plume are presented in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead*.

The total estimated cost of recovery actions for the four threatened species in the lower Columbia River over the next 25 years is approximately $2.1 billion, of which about $614 million is expected to be needed in the first 5 years (see Table ES-2). These estimates include expenditures by local, tribal, state, and federal governments, private business, and individuals in implementing capital projects and non-capital work, as well as administrative costs for supervision and coordination. The total estimated cost includes $592 million ($164 in the first 5 years) for actions in the Columbia River estuary that are basinwide in scope and are expected to benefit all 13 listed ESUs and DPSs in the Columbia Basin.

The estimates are based on the best available information at the time the management unit plans were completed and are expected to change as implementation schedules are developed and actions are more clearly scoped and planned. Given that the costs for many actions could not be estimated at the time the management unit plans were completed, it is likely that actual costs will be substantially higher than the estimated costs in Table ES-2.

Table ES-2
Summary of Cost Estimates

Management Unit	5-Year Cost Estimate (millions)	25-Year Cost Estimate (millions)
Washington	$245	$738
Oregon	$189	$758
White Salmon	$16	$16
Columbia River Estuary	$164	$592
TOTAL	$614	$2,104

The remaining sections of this summary focus mostly on the results of the recovery analysis for each ESU. After briefly explaining the overall approach used to complete the ESU recovery analyses, the summary describes general categories of limiting factors that affect multiple ESUs throughout the Lower Columbia region and strategies for addressing those limiting factors at the regional or programmatic level. This is followed by an individual section for each ESU that highlights that ESU's baseline and target status, the factors that are limiting its viability, and the strategy for reducing limiting factors and threats and achieving recovery. The summary concludes with thoughts on the role of research, monitoring, evaluation, and adaptive management and how recovery actions will be coordinated and implemented. Key documents referred to in this summary are listed at the end.

Overall Approach to ESU Recovery Analyses

This recovery plan addresses the needs of each ESU individually, based on analyses in the three management unit plans. Although each recovery planning team used a slightly different process in developing its management unit plan, all of the teams worked from the same TRT recommendations and a consistent set of assumptions about what elements should be included in their plans. Thus, the different recovery planning teams followed the same overall approach in their recovery analyses. In general, the management unit recovery planners did the following:

1. Evaluated the baseline status of their respective populations using techniques based on those recommended by the WLC TRT.[4]

2. Identified limiting factors for each Lower Columbia River salmon and steelhead population.

3. For each population, quantified the estimated baseline impacts of six categories of threats—tributary habitat loss and degradation, estuary habitat loss and degradation, hydropower, harvest, hatcheries, and ecological interactions.

[4] Both Oregon and Washington management unit planners established a baseline period from which to assess population status, limiting factors, and threat impacts. For more discussion, see Sections 5.1 and 5.5.

4. Established a target status for each population, taking into consideration (1) each population's potential for improvement, in view of available habitat and historical production, (2) the degree of improvement needed in each stratum to meet WLC TRT guidelines for a viable ESU, and (3) for some ESUs, the desire to accommodate objectives such as maintaining opportunities to harvest hatchery-origin fish.

5. Calculated the improvements in abundance and productivity and, in some cases, spatial structure and diversity, that each population would need to achieve its target status (i.e., to close the "conservation gap," which is the difference between the baseline and target status for each population).

6. Identified a "threat reduction scenario" for each population, meaning a specific combination of reductions in threats that would lead to the population achieving its target status.

7. Identified and scaled recovery strategies and actions to reduce threats by the targeted amount in each category. Management unit planners identified recovery strategies and actions through workshops and meetings with stakeholders, including representatives of implementing and affected entities.

8. Considered the probable effects of actions, established benchmarks for implementation, and identified critical uncertainties and research, monitoring, and evaluation needs for each species.

9. Developed implementation frameworks that address organizational structures for implementation of the actions, prioritization methods, tracking systems, coordination needs and approaches, and stakeholder involvement.

Given the complexity of the salmonid life cycle and the fact that complete data were not available for every population, some elements of the recovery analyses are subject to significant levels of uncertainty and should be considered working hypotheses that are testable as part of recovery plan implementation. Despite this uncertainty, it is the expert judgment of NMFS and the management unit scientists that, based on the best available information at this time, the results of the management unit plan analyses provide reasonable estimates of the relative magnitude of different threats to each population and the improvements that need to be addressed through recovery actions. Thus, NMFS considers the management plan analyses an adequate basis for designing initial recovery actions. As more and better information is collected, it will be applied to recovery efforts in an adaptive management framework that involves action implementation, monitoring of results, and adjustment of actions as needed.

The management unit plans' recovery analyses indicate that no single factor, threat, or threat category accounts for the declines in the species addressed in this recovery plan. Instead, the status of Lower Columbia River salmon and steelhead and Columbia River chum is the result of the cumulative impact of multiple limiting factors and threats. Thus, recovery will be accomplished through improvements in every general threat category. Even small increments of improvement will play an important role. When the need for improvement for most ESUs is so large, the contribution of no population or threat reduction can be discounted.

Regional Limiting Factors and Strategies

The reasons for a species' decline are generally described in terms of limiting factors and threats. Limiting factors are biological, physical, or chemical conditions and associated ecological processes and interactions that limit a species' viability. Threats are human activities or natural events, such as floodplain development or drought, that cause or contribute to limiting factors. Although the management unit plans analyze limiting factors and threats for each population, it also can be helpful to view limiting factors and threats from a regional, multi-species perspective—to discern large-scale patterns in ecological conditions that are affecting all or most of the listed ESUs. This aids in identifying regional approaches to recovery that can provide high biological benefit while making effective use of limited resources. The sections below describe such regional strategies, which are general approaches that either benefit multiple ESUs or can be tailored to meet the specific needs of each species. However, implementation of the regional strategies alone will not necessarily lead to recovery. The regional strategies are intended to supplement ESU-specific strategies that provide greater specificity and address specific needs at the species, stratum, and population levels.

Tributary Habitat

Tributary habitat degradation from past and/or current land and water use is a limiting factor for all Lower Columbia River salmon and steelhead populations. Widespread development and other land use activities have disrupted watershed processes, reduced water quality, and diminished habitat quantity, quality, and complexity in most lower Columbia River subbasins. Past and/or current land use or water management activities have adversely affected stream and side channel structure, riparian conditions, floodplain function, sediment conditions, and water quality and quantity, as well as the watershed processes that create and maintain properly functioning conditions for salmon and steelhead.

The regional tributary habitat strategy is directed toward habitat protection and restoration to achieve adequate quantities of high-quality, well-functioning salmon and steelhead habitat. This will be accomplished through a combination of (1) site-specific projects that will protect habitat or provide benefits relatively quickly, (2) watershed-based actions that will repair habitat-forming processes and provide benefits over the long term, and (3) landscape-scale programmatic actions that affect a class of activities (such as stormwater management or forest practices) over multiple watersheds. Although many habitat-related actions already have been undertaken, current activities do not reflect the scale of habitat improvements needed. Recovery of the listed species will require concerted efforts to protect remaining areas of favorable habitat and restore habitat quality in significant historical production areas. There is an immediate need to complete prioritization frameworks and get additional targeted, site-specific protection and restoration actions, as well as programmatic approaches, on the ground as soon as possible, especially because the benefits of some habitat actions will take years to accrue. Table ES-3 lists subbasins that will play a key role in recovery because they are targeted to support multiple primary populations, from different ESUs.

Table ES-3
Subbasins Targeted to Support Three or More Primary Populations

Ecozone	Subbasin	Primary Populations
Coast	Elochoman	Fall Chinook, chum, coho
	Clatskanie	Fall Chinook, chum, coho
	Scappoose	Fall Chinook, chum, coho
Cascade	Coweeman	Fall Chinook, winter steelhead, coho
	SF Toutle	Fall Chinook, winter steelhead, coho
	NF Toutle	Fall Chinook, winter steelhead, coho
	Cispus	Spring Chinook, winter steelhead, coho
	Upper Cowlitz	Spring Chinook, winter steelhead, coho
	NF Lewis	Fall Chinook, late-fall Chinook, spring Chinook, chum
	EF Lewis	Fall Chinook, chum, winter steelhead, summer steelhead, coho
	Washougal	Fall Chinook, chum, summer steelhead
	Sandy	Late-fall Chinook, spring Chinook, chum, winter steelhead, coho
Gorge	Lower Gorge tribs	Chum, winter steelhead, coho
	Hood	Fall Chinook, spring Chinook, winter steelhead, summer steelhead, coho

Estuary Habitat

Habitat conditions in the Columbia River estuary and plume are important to the survival of all Columbia River basin salmon and steelhead during critical rearing, migration, and saltwater acclimation periods in their life cycle. Yet the amount and accessibility of in-channel, off-channel, and plume habitat have been reduced as a result of habitat conversion for agricultural, urban, and industrial uses, hydroregulation and flood control, channelization, and higher bankfull elevations, which have been facilitated by diking, dredging, and filling. Sediment conditions and toxic contaminants also have been identified as limiting factors in the estuary, as have high water temperatures in late summer and fall, changes in the food web, and predation.

Estuary habitat strategies focus on providing adequate off-channel and intertidal habitats, such as tidal swamp and marsh; restoring habitat complexity in areas modified by agricultural or rural residential use; decreasing exposure to toxic contaminants; and lowering water temperatures. This will be accomplished over the long term by restoring hydrologic, sediment, and riparian processes that structure habitat in the estuary. An aggressive, strategic approach needs to be developed for implementation of estuary actions.

Hydropower

Bonneville Dam is the only mainstem hydropower facility within the geographic range of Lower Columbia River salmon and steelhead, but flow management at large storage reservoirs in the interior of the Columbia Basin affect habitat in the lower Columbia River mainstem and estuary, and potentially in the plume. In addition, significant tributary hydropower dams are located on the Cowlitz and Lewis rivers in Washington and on the Willamette, Clackamas, and Sandy rivers in Oregon.[5] The impacts of hydropower facility construction and operation on Lower Columbia salmon and steelhead occur both locally (at, above, and immediately below dams) and downstream, in the Columbia River estuary and, potentially, the plume. Impacts include habitat inundation, impaired fish passage, higher water temperatures during the late summer and fall, and alterations in the timing and magnitude of flow that affect downstream habitat conditions and habitat-forming processes.

The regional hydropower strategy focuses on (1) improving passage survival at Bonneville Dam for Lower Columbia River populations that spawn above the dam, (2) addressing impacts in tributaries by implementing actions prescribed in Federal Energy Regulatory Commission agreements regarding operation of individual tributary dams, and (3) implementing mainstem flow management operations designed to benefit spring migrants from the interior of the Columbia Basin; NMFS expects that these flow management operations will also improve survival in the estuary and, potentially, the plume for all Lower Columbia River salmon and steelhead populations. The regional hydropower strategy includes actions identified in the 2008 FCRPS Biological Opinion and its 2010 Supplement that will aid adults and juveniles from the Gorge populations in passing Bonneville Dam. For chum salmon, the strategy involves ensuring adequate flows in the Bonneville Dam tailrace and downstream habitats during chum salmon migration, spawning, incubation, and emergence.

Hatcheries

Hatchery practices such as broodstock collection and spawning protocols can cause genetic changes in hatchery fish. When hatchery-origin fish spawn with natural-origin fish, genetic changes can be transmitted to the naturally produced fish; the larger the proportion of hatchery-origin spawners, the larger the genetic effects to the natural population. These genetic effects can include domestication and loss of diversity within the population. For decades, high proportions of hatchery fish on the spawning grounds have been common among many Lower Columbia River salmon and steelhead populations, including the vast majority of Chinook and coho salmon populations. In addition, hatchery fish infected with pathogens or parasites have the potential to spread these organisms to natural-origin fish. Also, hatchery fish can sometimes prey directly on naturally produced juveniles, particularly chum salmon. Some scientists suspect that closely spaced releases of hatchery fish from Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the Columbia River estuary.

The overall goals of the hatchery recovery strategies for the Lower Columbia ESUs are to (1) reduce hatchery impacts on natural-origin populations as appropriate for each population, (2) ensure that some populations have no in-subbasin hatchery releases and are isolated from stray out-of-subbasin hatchery fish, (3) use hatchery stocks in the short term for reintroduction or supplementation programs to restore naturally spawning populations in some watersheds, and (4) ensure rigorous monitoring and evaluation to

---

[5] Powerdale Dam, on the Hood River, was removed in 2010; Condit Dam, on the White Salmon River, was breached in October 2011 and completely removed in September 2012.

better understand existing population status and the effects of hatchery strategies on natural populations.

Harvest

Lower Columbia River Chinook salmon, steelhead, and coho salmon are caught in commercial, recreational, and tribal fisheries along the West Coast of the United States and Canada as well as in the mainstem Columbia River and its tributaries. These various fisheries focus on different stocks and populations, taking fish to meet commercial, recreational, and tribal harvest allocations. Harvest affects the viability of Lower Columbia River salmon and steelhead populations by causing mortality to naturally produced adult fish, influencing population traits, and reducing nutrients in freshwater ecosystems. Harvest mortality can be either direct or indirect. Direct harvest mortality is associated with fisheries that target specific stocks. Indirect mortality includes mortality of fish harvested incidentally to the targeted species or stock, fish that die after being captured by fishing gear but not landed, and fish that die after being caught and released. Harvest managers have implemented substantial reductions in harvest for Lower Columbia River species since they were listed under the ESA.

The management unit plans include the societal goal of maintaining harvest opportunities created by hatchery fish and have prioritized ESA recovery strategies that allow for continued harvest opportunities while working toward recovery; these strategies have been incorporated into the recovery plan. In addition, as part of their broad sense goals, the management unit plans envision eventual harvest of naturally produced salmon and steelhead from healthy, self-sustaining populations.[6]

Although each species' harvest management requirements are unique, in general the harvest strategy focuses on refining harvest management and reducing impacts to naturally produced fish where needed while maintaining harvest opportunities that target hatchery-produced fish. The recovery plan calls for the use of six general approaches as appropriate and feasible: abundance-based harvest management, weak-stock management, mark-selective harvest, filling information needs, ancillary and precautionary actions, and adaptive management.

Local recovery planners believe that for Lower Columbia River spring Chinook salmon, steelhead, and chum salmon, current harvest impacts are generally consistent with long-term recovery goals, at least in the near term. For these species the recovery plan recommends measures to ensure that harvest does not adversely affect future conservation and recovery. For Lower Columbia fall Chinook and coho salmon, efforts will focus on (1) refinements in harvest management (including abundance-based management) to reduce risk to naturally produced fish, and (2) continued review of overall harvest rates.

Ecological Interactions

Anthropogenic changes to habitat in the lower Columbia River region have altered the

---

[6] Currently, targeted harvest on naturally produced North Fork Lewis late-fall Chinook salmon is occurring when returns are above the escapement goal. The baseline persistence probability of this population, which has remained largely uninfluenced by hatchery production and has not experienced the population bottlenecks common among tule fall Chinook salmon populations, is estimated to be high.

relationships between salmonids and other fish and wildlife species, leaving Lower Columbia River salmon and steelhead more vulnerable to predation by piscivorous fish, birds, and marine mammals (i.e., seals and sea lions) and subject to competition with introduced fish species and possibly hatchery-origin fish for limited food and habitat.

The regional ecological interactions strategy involves reducing predation on all Lower Columbia River salmon and steelhead populations by redistributing Caspian terns and cormorants, increasing the pikeminnow bounty program in the Columbia River mainstem, and reducing marine mammal predation at Bonneville Dam using non-lethal or lethal measures. Managing predation by sea lions at Bonneville Dam is expected to benefit Gorge-stratum populations of Lower Columbia River salmon and steelhead ESUs. To reduce the risk of adverse ecological interactions between hatchery-origin and naturally produced salmon and steelhead, the recovery plan proposes a combination of critical uncertainties research and near-term precautionary measures, such as restoring estuary habitat and managing hatchery releases to prevent large numbers of hatchery-origin fish from accumulating in the estuary.

Climate Change

The warming rate for the Pacific Northwest over the next century is projected to be in the range of 0.1 to 0.6 °C per decade. Although total precipitation changes are predicted to be minor (+ 1 to 2 percent), increasing air temperature will alter snowpack, stream flow timing and volume, and water temperature in the Columbia Basin.

Changes in air temperatures, river temperatures, and river flows in the Pacific Northwest are expected to affect salmon and steelhead distribution, behavior, growth, and survival. The magnitude and timing of the changes are poorly understood, and specific effects are likely to vary among populations. However, likely effects on listed salmon and steelhead in fresh water include winter flooding of redds (i.e., salmon nests), earlier emergence of salmon fry, decreased parr-to-smolt survival, reductions in the quantity and quality of juvenile rearing habitat and possibly overwintering habitat, changes in the timing of smolt migration, and increased adult mortality or reduced spawning success as a result of higher water temperatures.

Possible effects on salmon and steelhead in estuaries include altered growth and disease susceptibility, reduced quality of rearing habitat, and changes in the distribution of salmonid prey and predators, including possible extension of the range of non-native species adapted to warm water.

Climate-related changes in the marine environment are expected to alter primary and secondary productivity, the structure of marine communities, and, in turn, the growth, productivity, survival, and migrations of salmonids, although the degree of impact on listed salmonids currently is poorly understood. A mismatch between earlier smolt migrations (because of earlier peak spring freshwater flows and shorter incubation periods) and altered coastal upwelling may reduce marine survival rates. Ocean warming also may change migration patterns, increasing distances to feeding areas.

In addition, rising atmospheric carbon dioxide concentrations drive changes in seawater chemistry, increasing the acidification of seawater and thus reducing the availability of carbonate for shell-forming invertebrates, including some that are prey items for juvenile salmonids. Ocean acidification has the potential to reduce survival of many marine organisms, including salmon and steelhead. However, because there is currently a paucity of research directly related to the effects of ocean acidification on salmon and steelhead and their prey, potential effects are uncertain.

The regional climate change strategy has two parts: (1) implementation of greenhouse gas reduction strategies, such as through the West Coast Governors' Global Warming Initiative[7] and the Oregon Global Warming Commission's recommendations,[8] and (2) adaptation, to reduce the impacts of climate change on Pacific Northwest salmon and steelhead. Adaptation commonly involves the following:

- Conserving adequate habitat to support healthy fish populations and ecosystem functions in a changing climate
- Managing species and habitats to protect ecosystem functions in a changing climate
- Reducing stresses not caused by climate change
- Supporting adaptive management through integrated observation and monitoring and improved decision support tools

The management unit plans and estuary recovery plan module present specific actions that are responsive to these general strategies. The following documents also are relevant to adaptation:

- *Climate Change Impacts on Columbia River Basin Fish and Wildlife* (Independent Scientific Advisory Board 2007a)
- *Oregon Climate Change Adaptation Framework* (Oregon Department of Land Conservation and Development 2010)
- *Washington State Integrated Climate Change Response Strategy* (interim document) (Washington Department of Ecology 2011)
- *Draft National Fish, Wildlife, and Plants Climate Adaptation Strategy* (U.S. Fish and Wildlife Service et al. 2012)

Human Population Growth

The Oregon and White Salmon management unit plans identify human population growth as a future threat to Lower Columbia River salmon and steelhead, based in part on work done by the Independent Scientific Advisory Board (ISAB), which provides independent scientific advice and recommendations related to the fish and wildlife management responsibilities of the Northwest Power and Conservation Council, Columbia River Basin Indian tribes, and NMFS. Expected population growth rates will vary throughout the lower Columbia region; however, the ISAB expects that human population growth in the Columbia Basin will increase the demand for water, land, and

[7] For the West Coast Governors' Global Warming Initiative, go to http://www.ef.org/westcoastclimate/.
[8] For the Oregon Global Warming Commission's recommendations, see Oregon Department of Energy (2009) or go to http://www.oregon.gov/ENERGY/GBLWRM/GWC/docs/09CommissionReport.pdf.

forests that are key to fish and wildlife populations. This demand for resources will increase threats to and extinction risks for fish and wildlife—including salmon and steelhead—through such mechanisms as loss, degradation, and fragmentation of habitat; increased stormwater runoff; and reduced groundwater recharge and thus base stream flows.

The recovery plan includes actions that will lessen the impacts of human population growth. The focus is on protecting existing high-quality habitat through acquisition and conservation; using land use planning to guide future development away from ecologically sensitive areas, such as wetlands and floodplains; implementing best management practices; protecting and restoring instream flows, runoff processes, and water quality; and educating landowners and others.

Recovery Analysis: Lower Columbia River Coho Salmon

This recovery plan covers all naturally spawned coho salmon (*Oncorhynchus kisutch*) populations in the lower Columbia River and its tributaries, from the mouth of the Columbia upstream to the Hood River (in Oregon) and the White Salmon River (in Washington), including the Willamette River up to Willamette Falls. Twenty-three coho salmon hatchery programs also are part of the ESU.

Historically, the Lower Columbia River coho salmon ESU consisted of a total of 24 independent populations that spawned in almost every accessible stream system in the lower Columbia River basin. Coho salmon typically spawn in small to medium, low-to-moderate elevation streams from valley bottoms to stream headwaters. Coho salmon particularly favor small, rain-driven, lower elevation streams characterized by (1) relatively low flows during late summer and early fall, and (2) increased river flows and decreased water temperatures in winter.

Baseline and Target Status: Coho Salmon

Today, 21 of the 24 Lower Columbia River coho salmon populations are considered to have a very low probability of persisting over the next 100 years, and none is considered viable. All three strata in the ESU fall significantly short of the WLC TRT criteria for viability.

Table ES-4

Baseline and Target Status of LCR Coho Salmon Populations*

Stratum	Population	Contribution to Recovery	Baseline Status	Target Status
Coast	Youngs Bay (OR)	Stabilizing	VL	VL
	Grays/Chinook (WA)	Primary	VL	H
	Big Creek (OR)	Stabilizing	VL	VL
	Elochoman/Skamokawa (WA)	Primary	VL	H
	Clatskanie (OR)	Primary	L	VH
	Mill/Abernathy/Germany (WA)	Contributing	VL	M
	Scappoose (OR)	Primary	M	VH
Cascade	Lower Cowlitz (WA)	Primary	VL	H
	Upper Cowlitz (WA)	Primary	VL	H
	Cispus (WA)	Primary	VL	H

Stratum	Population	Contribution to Recovery	Baseline Status	Target Status
	Tilton (WA)	Stabilizing	VL	VL
	Toutle SF (WA)	Primary	VL	H
	Toutle NF (WA)	Primary	VL	H
	Coweeman (WA)	Primary	VL	H
	Kalama (WA)	Contributing	VL	L
	NF Lewis (WA)	Contributing	VL	L
	EF Lewis (WA)	Primary	VL	H
	Salmon Creek (WA)	Stabilizing	VL	VL
	Clackamas (OR)	Primary	M	VH
	Sandy (OR)	Primary	VL	H
	Washougal (WA)	Contributing	VL	M+
Gorge	Lower Gorge (WA & OR)	Primary	VL	H
	Upper Gorge/White Salmon (WA)	Primary	VL	H
	Upper Gorge/Hood (OR)	Primary	VL	H*

*Status is equivalent to persistence probability. VL = very low, L = low, M = moderate, H = high, VH = very high.

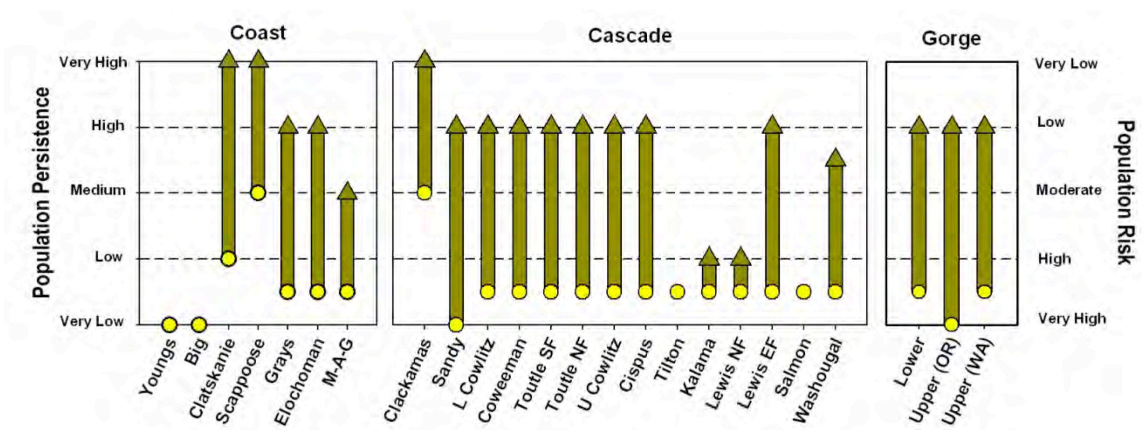

Figure ES-1. *Conservation Gaps for LCR Coho Salmon Populations (i.e., Difference between Baseline and Target Status)*

Prevalent Limiting Factors: Coho Salmon

Lower Columbia River coho salmon's poor status is due to a host of limiting factors that have affected the ESU for decades, or longer. Table ES-5 lists prevalent limiting factors that the management unit plans identified as having the greatest impact during the baseline period.

In addition, tributary hydropower dams are a primary limiting factor for the Upper Cowlitz, North Fork Lewis, Cispus, Tilton, and Upper Gorge/White Salmon populations.

Table ES-5
Prevalent Primary Limiting Factors for Coho Salmon during Baseline Period

Limiting Factor	Populations for Which This Is a Primary Limiting Factor
Degraded riparian conditions along tributaries	Almost all*
Impaired side channel and wetland conditions in tributaries	Almost all
Loss/degradation of floodplain habitat in tributaries	Almost all
Channel structure and form issues[9] in tributaries and the Columbia River estuary	Almost all
Sediment conditions in the estuary	Almost all
Water quantity issues (i.e., altered hydrology) in the estuary	Almost all
Direct mortality from fisheries	Almost all
Reduction in population diversity as a result of stray hatchery fish interbreeding with natural-origin fish	All except Clatskanie, Scappoose, Coweeman, NF Lewis, and Sandy

* "Almost all" means every population except one in each stratum.

Recovery Strategy: Coho Salmon

The ESU recovery strategy for coho salmon involves improvements in all threat categories to increase abundance, productivity, diversity, and spatial structure to the point that the Coast, Cascade, and Gorge strata are restored to a high probability of persistence. The ESU recovery strategy has seven main elements:

1. Protect and improve populations that have a clear record of continuous natural spawning and are likely to retain local adaptation (the Clackamas and Sandy), along with populations where there is documented natural production (the Clatskanie, Scappoose, and Mill/Abernathy/Germany).

2. Fill information gaps regarding the extent of natural production in other populations, and focus additional recovery efforts on populations that have the greatest prospects for improvement.

3. Protect existing high-functioning habitat for all populations.

4. Restore tributary habitat (particularly overwintering habitat) to the point that each subbasin can support coho salmon at the target status for that population. In most subbasins, this will mean having adequate habitat to support a viable population.

5. Reduce hatchery impacts on natural-origin fish so that impacts are consistent with the target status of each population. (The Grays/Chinook, Elochoman/Skamokawa, Mill/Abernathy/Germany, Clatskanie, Clackamas, Washougal, and Gorge-stratum populations are targeted for large reductions in hatchery impacts.)

---

[9] Includes conditions such as channelization, reduced instream habitat complexity, fill and scour, and associated loss of spawning habitat.

6. Refine harvest management so that impacts are consistent with population and overall ESU recovery goals.

7. Reestablish naturally spawning populations above tributary dams on the Cowlitz and North Fork Lewis rivers by improving passage at dams and continuing to reintroduce coho salmon in these mid- to high-elevation habitats.

For most coho salmon populations, loss and degradation of tributary habitat are the single largest threat—and where the greatest gains in viability are expected to be achieved. Notable exceptions are the Clackamas, Upper Cowlitz, and Cispus populations. For the Clackamas population, protection of existing well-functioning habitat and reductions in hatchery impacts will play a key role in achieving the target status. The Upper Cowlitz and Cispus populations are projected to benefit greatly from hatchery reintroduction programs and dam passage improvements designed to restore their access to key historical spawning and rearing habitats. However, significant tributary habitat protection and restoration efforts also will be necessary for these populations. In most cases, population recovery objectives cannot be achieved without substantial improvements in habitat, even when the impacts of other, non-habitat threats are practically eliminated.

Although recent actions have substantially reduced coho salmon harvest levels from baseline conditions, further refinements in harvest management are still needed. Reductions in hatchery impacts are called for in all strata because hatchery impacts remain significant for many populations.

Recovery Analysis: Lower Columbia River Chinook Salmon

This recovery plan covers all naturally spawned Chinook salmon (*Oncorhynchus tshawytscha*) populations in the lower Columbia River and its tributaries, from the mouth of the Columbia upstream to the Hood River (in Oregon) and the White Salmon River (in Washington), including the Willamette River up to Willamette Falls but excluding Clackamas River spring-run Chinook salmon.[10] Chinook salmon from 20 hatchery programs also are part of the ESU.[11]

Historically, the Lower Columbia River Chinook salmon ESU consisted of a total of 32 independent populations: 21 fall populations, two late-fall populations, and nine spring populations. These classifications are based on when adults return to fresh water. Spring and late-fall Chinook salmon are "stream-type" salmon, meaning that they generally rear in the river for a full year before emigrating to the ocean. Returning spring Chinook salmon adults spawn primarily in upstream, higher elevation portions of large subbasins. Fall Chinook display an "ocean-type" life history, meaning that juveniles begin emigrating downstream at 1 to 4 months old and make extensive use of

---

[10] Clackamas River spring Chinook salmon are part of the Upper Willamette River Chinook ESU.

[11] One of these programs—the Elochoman tule fall Chinook salmon program—was discontinued in 2009. In its 2011 5-year review, NMFS recommended that this program be removed from the ESU and that four new fall Chinook salmon programs be added. The new programs are changes in release locations for fish produced at—and previously released from—hatchery programs that are currently part of the ESU.

the Columbia River estuary before entering the ocean. Returning fall Chinook spawn in moderate-sized streams and large river mainstems.

Fall Chinook are commonly referred to as "tule" stock, while late-fall Chinook are referred to as "brights."

Baseline and Target Status: Chinook Salmon

Today, only two of 32 historical populations—the North Fork Lewis and Sandy late-fall populations—are considered viable. Most populations (26 out of 32) have a very low probability of persistence over the next 100 years, and some populations are extirpated or nearly so. Five of the six strata fall significantly short of the WLC TRT criteria for viability. One stratum—Cascade late fall—meets the WLC TRT criteria.

Table ES-6
Baseline and Target Status of LCR Chinook Salmon Populations*

Stratum	Population	Core or Genetic Legacy?**	Contribution to Recovery	Baseline Status	Target Status
Cascade spring	Upper Cowlitz (WA)	C, GL	Primary	VL	H+
	Cispus (WA)	C	Primary	VL	H+
	Tilton (WA)		Stabilizing	VL	VL
	Toutle (WA)		Contributing	VL	M
	Kalama (WA)		Contributing	VL	L
	NF Lewis (WA)	C	Primary	VL	H
	Sandy (OR)	C, GL	Primary	M	H
Gorge spring	White Salmon (WA)	C	Contributing	VL	L+
	Hood (OR)		Primary	VL	VH
Coast fall	Youngs Bay (OR)		Stabilizing	L	L
	Grays/Chinook (WA)		Contributing	VL	M+
	Big Creek (OR)	C	Contributing	VL	L
	Elochoman/Skamokawa (WA)	C	Primary	VL	H
	Clatskanie (OR)		Primary	VL	H
	Mill/Abernathy/Germany (WA)		Primary	VL	H
	Scappoose (OR)		Primary	L	H
Cascade fall	Lower Cowlitz (WA)	C	Contributing	VL	M+
	Upper Cowlitz (WA)		Stabilizing	VL	VL
	Toutle (WA)	C	Primary	VL	H+
	Coweeman (WA)	GL	Primary	L	H+
	Kalama (WA)		Contributing	VL	M
	Lewis (WA)	GL	Primary	VL	H+
	Salmon Creek (WA)		Stabilizing	VL	VL
	Clackamas (OR)	C	Contributing	VL	M
	Sandy (OR)		Contributing	VL	M
	Washougal (WA)		Primary	VL	H+
Gorge fall	Lower Gorge (WA & OR)		Contributing	VL	M
	Upper Gorge (WA & OR)	C	Contributing	VL	M
	White Salmon (WA)	C	Contributing	VL	M
	Hood (OR)		Primary	VL	H

Stratum	Population	Core or Genetic Legacy?**	Contribution to Recovery	Baseline Status	Target Status
Cascade	NF Lewis (WA)	C, GL	Primary	VH	VH
late fall	Sandy (OR)	C, GL	Primary	H	VH

* Status is equivalent to persistence probability. VL = very low, L = low, M = moderate, H = high, VH = very high.

** C = Core populations, meaning those that historically were the most productive. G = Genetic legacy populations, which best represent historical genetic diversity.

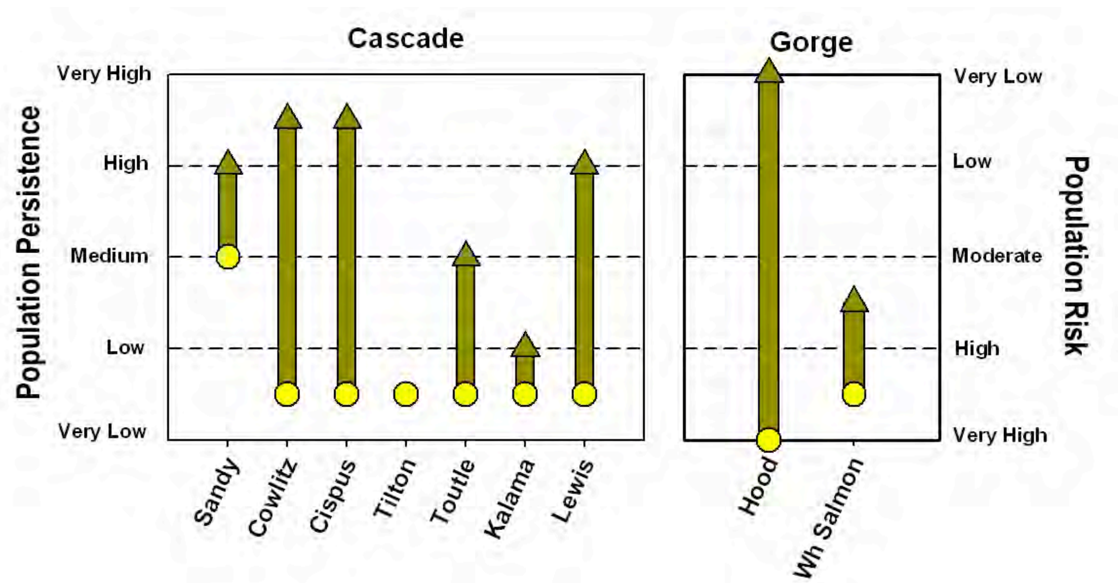

Figure ES-2. *Conservation Gaps for LCR Spring Chinook Salmon Populations (i.e., Difference between Baseline and Target Status)*

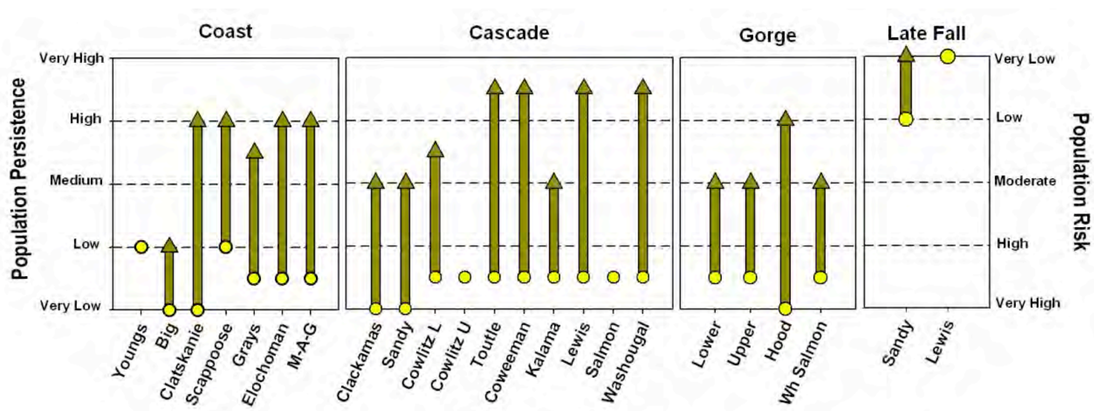

Figure ES-3. *Conservation Gaps for LCR Fall and Late-Fall Chinook Salmon Populations (i.e., Difference between Baseline and Target Status)*

Spring Chinook Recovery Analysis

Prevalent Limiting Factors: Spring Chinook Salmon

Lower Columbia River spring Chinook salmon's poor status is due to a host of limiting factors that have affected the ESU for decades, or longer. Table ES-7 lists prevalent limiting factors that the management unit plans identified as having the greatest impact during the baseline period.

Table ES-7
Prevalent Primary Limiting Factors for Spring Chinook Salmon during Baseline Period

Limiting Factor	Populations for Which This Is a Primary Limiting Factor
Channel structure and form issues[12] in the Columbia River estuary	Almost all*
Sediment conditions in the estuary	Almost all
Water quantity issues (i.e., altered hydrology) in the estuary	Almost all
Reduction in population diversity as a result of stray hatchery fish interbreeding with natural-origin fish	Almost all
Tributary hydropower dams	Upper Cowlitz, Cispus, Tilton, NF Lewis, and White Salmon
Direct mortality from fisheries	Upper Cowlitz, Cispus Tilton, Toutle, Kalama, NF Lewis, and Hood
Degraded riparian conditions in tributaries	All Cascade-stratum populations
Channel structure and form issues in tributaries	All Cascade-stratum populations
Impaired side channel and wetland conditions in tributaries	All Cascade-stratum populations
Loss/degradation of floodplain habitat in tributaries	All Cascade-stratum populations

* "Almost all" means every population except one in each stratum.

Recovery Strategy: Spring Chinook Salmon

The recovery strategy for spring Chinook salmon is aimed at restoring the Cascade spring stratum to a high probability of persistence and improving the persistence probability of the two Gorge spring populations. Although the strategy involves threat reductions in all categories, the most crucial elements are as follows:

1. Protect and improve the Sandy spring Chinook salmon population, which is the best-performing population and the only Lower Columbia River spring Chinook salmon population with appreciable natural production. This will be accomplished by protecting high-quality, well-functioning spawning and rearing

[12] Includes channelization, reduced instream habitat complexity, fill and scour, and associated loss of spawning habitat.

habitat, reducing the proportion of hatchery-origin spawners (pHOS), managing predation, and restoring tributary and estuarine habitat.[13]

2. Reestablish naturally spawning populations above dams on the Cowlitz and North Fork Lewis rivers, in areas that historically were highly productive, by improving adult and juvenile dam passage and developing hatchery reintroduction programs using broodstock from within-subbasin hatchery programs. Reestablishing populations in mid- to upper-elevation habitats is key to recovering the spring component of the Lower Columbia River Chinook salmon ESU.

3. Protect favorable tributary habitat and restore degraded but potentially productive habitat, particularly in the upper subbasins where spring Chinook salmon hold, spawn, and rear. Tributary habitat improvements are crucial for all populations.

4. Reestablish spring Chinook salmon in the White Salmon subbasin (now that Condit Dam has been removed) and in the Hood River subbasin.

Almost every spring Chinook salmon population is greatly affected by the loss and degradation of tributary habitat, and five populations—the Upper Cowlitz, Cispus, Tilton, North Fork Lewis, and White Salmon—have experienced impacts from tributary dams that are comparable to or even greater than those associated with degraded tributary habitat. Accordingly, for most populations, the greatest gains in viability are expected from tributary habitat and dam passage improvements (combined with hatchery reintroduction programs). Exceptions are the Tilton—a stabilizing population that is expected to remain at its baseline status—and the Sandy and Hood populations, for which reductions in hatchery impacts are targeted to provide the greatest benefit.

Although recent actions have substantially reduced harvest of spring Chinook salmon from baseline conditions, ancillary and precautionary actions are needed to ensure that harvest does not adversely affect conservation and recovery in the future. For all but the Tilton population, hatchery-related impacts are targeted to be reduced by half or more, with the largest reductions in the Sandy and Hood populations.

Fall Chinook Recovery Analysis

Prevalent Limiting Factors: Fall Chinook Salmon

Lower Columbia River fall Chinook salmon's poor status is due to a host of limiting factors that have affected the ESU for decades, or longer. Table ES-8 lists prevalent limiting factors that the management unit plans identified as having the greatest impact during the baseline period.

In addition, tributary hydropower dams are a primary limiting factor for the Upper Cowlitz and White Salmon populations, and inundation of historical spawning habitat by Bonneville Reservoir is a primary limiting factor for the Upper Gorge population.

[13] Some reduction in impacts on the Sandy population already have been achieved through removal of Marmot Dam and the Little Sandy River diversion in 2008 and protection of associated instream water rights for fish.

Table ES-8
Prevalent Primary Limiting Factors for Fall Chinook Salmon during Baseline Period

Limiting Factor	Populations for Which This Is a Primary Limiting Factor
Degraded riparian conditions along tributaries	Almost all*
Channel structure and form issues[14] in tributaries and the estuary	Almost all
Impaired side channel and wetland conditions in tributaries	Almost all
Loss/degradation of floodplain habitat in tributaries	Almost all
Loss/degradation of peripheral and transitional habitats[15] in the estuary	Almost all
Sediment conditions in the estuary	Almost all
Water quantity issues (i.e., altered hydrology) in the estuary	Almost all
Direct mortality from fisheries	Almost all
Reduction in population diversity as a result of stray hatchery fish interbreeding with natural-origin fish	Almost all

* "Almost all" means every population except one in each stratum.

Recovery Strategy: Fall Chinook Salmon

The recovery strategy for the tule fall component of the Lower Columbia River Chinook salmon ESU is designed to restore the Coast and Cascade tule strata to a high probability of persistence and to improve the persistence probability of all four Gorge stratum populations. The strategy involves transitioning from decades of management that allowed habitat degradation and emphasized hatchery production of fish for harvest (without adequate regard to effects on natural production) to management that supports a naturally self-sustaining ESU. This transition will be accomplished by addressing all threat categories and sharing the burden of recovery across categories. The most crucial elements are as follows:

1. Protect and improve the Coweeman and Lewis populations, which are currently performing the best, by ensuring that habitat is protected and restored, that the proportion of hatchery-origin spawners (pHOS) is reduced, and that harvest rates allow for gains in productivity to translate into continued progress toward recovery.

2. Fill information gaps regarding the extent of natural production and the extent of hatchery-origin spawners.

[14] Includes conditions such as channelization, reduced instream habitat complexity, fill and scour, and associated loss of spawning habitat.
[15] Peripheral and transitional habitats are sloughs, side channels, wetlands, and similar features that are periodically inundated during high flows.

3. Focus recovery efforts on populations that have the greatest prospects for improvement; determine whether efforts to reestablish populations are needed.

4. Protect existing high-functioning habitat for all populations.

5. Implement aggressive efforts to improve the quality and quantity of both tributary and estuarine habitat.

6. Implement aggressive efforts to reduce the influence of hatchery fish on natural-origin fish.

7. Adjust harvest as needed to ensure appropriate increases in natural-origin abundance.

8. Assess habitat quantity, quality, and distribution.

In the Coast and Cascade strata, much of the gains in fall Chinook salmon viability are targeted to be achieved through reductions in harvest, hatchery, and habitat impacts. This is the case for the Grays/Chinook, Elochoman/Skamokawa, Toutle, East Fork Lewis, Sandy, and Washougal populations. For the Scappoose population, target status is expected to be achieved primarily through reductions in hatchery and harvest impacts. In the Gorge stratum, some threat reductions are also targeted from hydropower actions, as the Upper Gorge, White Salmon, and Hood populations have been affected by dam passage issues at Bonneville, Powerdale, and Condit dams. (Powerdale Dam, on the Hood River, was removed in 2010; Condit Dam was breached in October 2011 and completely removed in September 2012).

Impacts from multiple threat categories will need to be reduced for most populations if they are to achieve their target status. Exceptions are the Youngs Bay, Big Creek, Upper Cowlitz, and Salmon Creek populations. As stabilizing populations, the Youngs Bay, Upper Cowlitz, and Salmon Creek populations are not targeted for reductions in any threat impacts. (However, recovery actions will still be needed for these populations to remain at their baseline status of low [for Youngs Bay] or very low persistence probability.) The Salmon Creek population is not targeted for threat reductions because of the highly urbanized nature of the subbasin and the extent of habitat degradation there. Both the Youngs Bay and Big Creek populations will be used to provide harvest opportunity through terminal fisheries targeting hatchery fish; consequently, the proportion of hatchery-origin spawners (pHOS) and harvest impacts in these populations are expected to remain high.

Late-Fall Chinook Recovery Strategy

Prevalent Limiting Factors: Late-Fall Chinook Salmon

Table ES-9 lists prevalent limiting factors that the management unit plans identified as having the greatest impact on both late-fall Chinook populations during the baseline period.

Table ES-9
Prevalent Primary Limiting Factors for Late-fall Chinook Salmon during Baseline Period

Limiting Factor	Populations for Which This Is a Primary Limiting Factor
Sediment conditions in tributaries and the Columbia River estuary	Both populations
Water quantity issues (i.e., altered hydrology) in the estuary	Both populations
Direct mortality from fisheries	Both populations

In addition, primary limiting factors that affect the Sandy population only are degraded riparian conditions, channel structure and form issues, impaired side channel and wetland conditions, and loss/degradation of floodplain habitat in tributaries, along with reduction in population diversity as a result of stray hatchery fish interbreeding with natural-origin fish.

Recovery Strategy: Late-Fall Chinook Salmon

The recovery strategy for the late-fall component of the Lower Columbia River Chinook salmon ESU is designed to maintain the two healthy populations (North Fork Lewis and Sandy) and raise the persistence probability of the Sandy population from high to very high. Key elements of the strategy are as follows:

1. Implement the regional hatchery strategy. Minimize the impacts of hatchery releases of steelhead, coho, and spring Chinook salmon on late-fall Chinook salmon. Continue the current practice of not releasing hatchery fall Chinook salmon into the North Fork Lewis River.

2. Reduce harvest impacts on the Sandy late-fall population by using the same harvest strategies identified for tule fall Chinook salmon. Continue to manage fisheries to meet the spawning escapement goal for the Lewis River late-fall population and consider reassessing the goal as new data are acquired.

3. Implement actions in the regional tributary and estuary habitat strategy designed to benefit tule fall Chinook salmon. Implement the stratum-level tributary habitat strategies designated for tule fall Chinook.

Improving the persistence of the Sandy population will be accomplished primarily through reductions in harvest and hatchery impacts. As with spring and tule fall Chinook salmon, recent actions have substantially reduced harvest impacts on late-fall Chinook salmon over baseline conditions, but additional reductions in harvest impacts are identified to achieve the target status for the Sandy population. More modest reductions in the tributary and estuarine habitat, hydropower, and predation threat categories are expected to support the gains achieved through reductions in harvest and hatchery impacts.

Recovery Analysis: Columbia River Chum

This recovery plan covers all naturally spawned Columbia River chum salmon (*Oncorhynchus keta*) populations in the lower Columbia River and its tributaries. Chum salmon from three hatchery programs also are part of the ESU.[16]

Historically, the Columbia River chum salmon ESU consisted of 17 independent populations. Of these, 16 were fall-run populations and one was a summer-run population that returned to the Cowlitz River. Columbia River chum display an "ocean-type" life history, meaning that fry emigrate downstream shortly after emerging and rear in the Columbia River estuary before entering the ocean. Although chum salmon are strong swimmers, they rarely pass river blockages and waterfalls that pose no hindrance to other salmon or steelhead; thus, they spawn in low-gradient, low-elevation reaches and side channels. Spawning today is restricted largely to tributary and mainstem areas downstream of Bonneville Dam. Chum salmon need clean gravel for spawning, and spawning sites typically are associated with areas of upwelling water.

Baseline and Target Status: Chum Salmon

Today, 15 of the 17 populations that historically made up this ESU are so depleted that either their baseline probability of persistence is very low or they are extirpated or nearly so; this is the case for all six of the Oregon populations. Currently almost all natural production occurs in just two populations: the Grays/Chinook and the Lower Gorge. All three strata in the ESU fall significantly short of the WLC TRT criteria for viability.

Table ES-10
Baseline and Target Status of Columbia River Chum Salmon Populations*

Stratum	Population	Core or Genetic Legacy?**	Contribution to Recovery	Baseline Status	Target Status
Coast	Youngs Bay (OR)	C	Stabilizing	VL	VL
	Grays/Chinook (WA)	C, GL	Primary	M	VH
	Big Creek (OR)	C	Stabilizing	VL	VL
	Elochoman/Skamakowa (WA)	C	Primary	VL	H
	Clatskanie (OR)		Primary	VL	H
	Mill/Abernathy/Germany (WA)		Primary	VL	H
	Scappoose (OR)		Primary	VL	H
Cascade	Cowlitz - fall (WA)	C	Contributing	VL	M
	Cowlitz - Summer (WA)	C	Contributing	VL	M
	Kalama (WA)		Contributing	VL	M
	Lewis (WA)	C	Primary	VL	H
	Salmon Creek (WA)		Stabilizing	VL	VL
	Clackamas (OR)	C	Contributing	VL	M
	Sandy (OR)		Primary	VL	H
	Washougal (WA)		Primary	VL	H+

[16] In 2010, the Oregon Department of Fish and Wildlife initiated a new chum salmon hatchery program at Big Creek Hatchery to develop chum salmon for reintroduction into Lower Columbia River tributaries in Oregon. NMFS has not yet evaluated this hatchery program for inclusion in the ESU.

Stratum	Population	Core or Genetic Legacy?**	Contribution to Recovery	Baseline Status	Target Status
Gorge	Lower Gorge (WA & OR)	C, GL	Primary	H	VH
	Upper Gorge (WA & OR)		Contributing	VL	M

* Status is equivalent to persistence probability. VL = very low, L = low, M = moderate, H = high, VH = very high.

** C = Core populations, meaning those that historically were the most productive. G = Genetic legacy populations, which best represent historical genetic diversity.

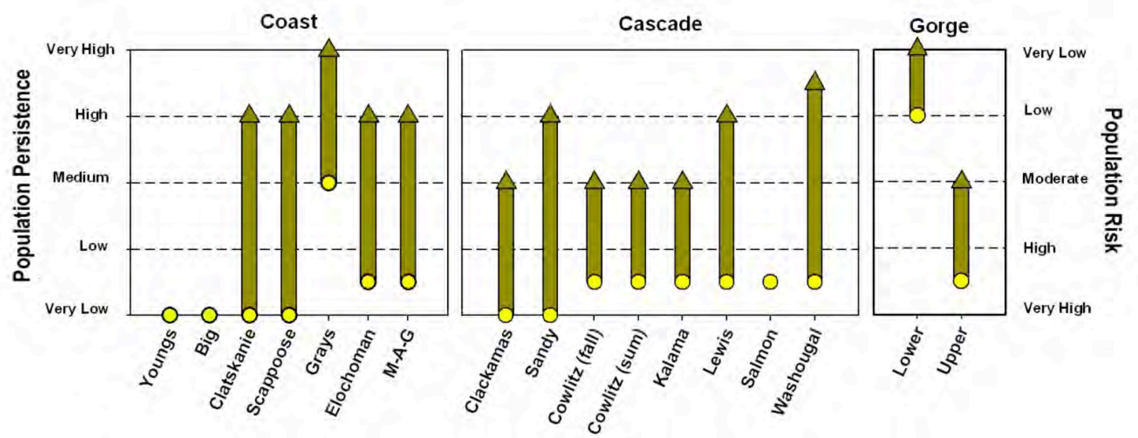

Figure ES-4. *Conservation Gaps for Columbia River Chum Salmon Populations (i.e., Difference between Baseline and Target Status)*

Prevalent Limiting Factors: Chum Salmon

Columbia River chum salmon's poor status is due to a host of limiting factors that have affected the ESU for decades, or longer. Table ES-11 lists prevalent limiting factors that the management unit plans identified as having the greatest impact during the baseline period.

Table ES-11
Prevalent Primary Limiting Factors for Chum Salmon during Baseline Period

Limiting Factor	Populations for Which This Is a Primary Limiting Factor
Channel structure and form issues[17] in the Columbia River estuary	Almost all*
Loss/degradation of peripheral and transitional habitats[18] in the estuary	Almost all
Sediment conditions in the estuary	Almost all
Water quantity issues (i.e., altered hydrology) in the estuary	Almost all

17 Includes conditions such as channelization, reduced instream habitat complexity, fill and scour, and associated loss of spawning habitat.

18 Peripheral and transitional habitats are sloughs, side channels, wetlands, and similar features that are periodically inundated during high flows.

Limiting Factor	Populations for Which This Is a Primary Limiting Factor
Degraded riparian conditions in tributaries	Almost all Washington** populations
Channel structure and form issues in tributaries	Almost all Washington populations
Impaired side channel and wetland conditions in tributaries	Almost all Washington populations
Loss/degradation of floodplain habitat in tributaries	Almost all Washington populations

* "Almost all" means every population except one in each stratum.
** Tributary habitat factors in this table are for Washington populations only because of differences in how Oregon and Washington recovery planners categorized limiting factors occurring in areas of tidal influence in the lower reaches of tributaries; see Table 8-3 of the recovery plan.

In addition, passage issues at Bonneville Dam and inundation of historical spawning habitat by Bonneville Reservoir are identified as primary limiting factors for the Upper Gorge population.

Recovery Strategy: Chum Salmon

The ESU recovery strategy for Columbia River chum salmon focuses on improving tributary and estuarine habitat conditions, reducing or mitigating hydropower impacts, and reestablishing chum salmon populations where they may have been extirpated. The goal of the strategy is to increase the abundance, productivity, diversity, and spatial structure of chum salmon populations such that the Coast and Cascade chum salmon strata are restored to a high probability of persistence and the persistence probability of the two Gorge populations improves. The ESU recovery strategy has the following main elements:

1. Protect and improve the Grays/Chinook and Lower Gorge populations, which together produce the majority of Columbia River chum salmon and are the only populations in the ESU not currently at very high risk of extinction.

2. Identify, protect, and restore chum salmon spawning habitat in lower mainstem and off-channel areas of large rivers and streams that are fed by upwelling from intergravel flows or springs. Restore hydrologic, riparian, and sediment processes (e.g., large woody debris recruitment) that support the accumulation of spawning gravel and reduce inputs of fine sediment.

3. Restore off-channel and side-channel habitats (alcoves, wetlands, floodplains, etc.) in the Columbia River estuary, where chum salmon fry rely on peripheral and transitional habitats for extended estuarine rearing.

4. Use hatchery reintroduction as appropriate in reestablishing chum salmon populations and continue using supplementation to enhance the abundance of the Grays/Chinook and Lower Gorge populations.

Restoring tributary spawning and estuary rearing habitat is essential in the recovery of Columbia River chum salmon. Although the recovery strategy includes other components, no other factor can effectively bring about recovery.

Most of the gains in the viability of Washington chum salmon populations are targeted to be achieved by improving tributary and estuarine habitat. Because potentially manageable harvest, hatchery, and predation impacts on chum salmon already are relatively low, there is little opportunity to further reduce threats in these sectors. Hydropower actions are projected to benefit the Upper Gorge population, which is affected by Bonneville Dam and its reservoir.

Oregon recovery planners developed a chum salmon recovery strategy that involves identifying specific habitat needs and proceeding with reintroduction, initially in the Coast stratum.

Recovery Analysis: Lower Columbia River Steelhead

This recovery plan addresses steelhead in the Cascade and Gorge ecozones only, excluding the White Salmon population and populations in the Coast ecozone. This is because the White Salmon population is part of the Middle Columbia steelhead DPS (and thus is addressed in a separate recovery plan), and the Coast populations are part of the Southwest Washington DPS, which is not listed under the ESA. Also excluded is the resident, freshwater form of *Oncorhynchus mykiss*, which usually is called "rainbow" or "redband" trout. In contrast, steelhead are the anadromous form of *O. mykiss*, meaning that they spend a portion of their life cycle in the ocean but return to fresh water to breed. Thus, this recovery plan covers all naturally spawned anadromous *O. mykiss* populations in streams and tributaries to the Columbia River between and including the Cowlitz and Wind rivers in Washington and, in Oregon, between and including (1) the Willamette River up to Willamette Falls, and (2) the Hood River in Oregon. Steelhead from eight hatchery programs also are part of the DPS.[19]

Historically, the Lower Columbia River steelhead DPS consisted of 23 independent populations: 17 winter-run populations and six summer-run populations. Winter and summer steelhead differ in spawning timing, degree of sexual maturity when returning to fresh water, and other characteristics. Both winter steelhead and summer steelhead spawn in a wide range of conditions, from large streams and rivers to small streams and side channels. Within the same watershed, winter and summer steelhead generally spawn in geographically distinct areas. Summer steelhead can often reach headwater areas above waterfalls that are impassable to winter steelhead during the high-velocity flows common during the winter-run migration. Steelhead are iteroparous, meaning they can spawn more than once.

Baseline and Target Status: Steelhead

Today, 16 of the 23 Lower Columbia River steelhead populations have a low or very low probability of persisting over the next 100 years, and six populations have a moderate

[19] The release of Cowlitz Hatchery winter steelhead into the Tilton River was discontinued in 2007, the Hood River winter steelhead program was discontinued in 2009, and the release of hatchery winter steelhead into the Upper Cowlitz and Cispus rivers was discontinued in 2010. In its 2011 5-year review, NMFS recommended removing these programs from the DPS and adding a Lewis River winter steelhead program that was initiated in 2009.

probability of persistence. Only the summer-run Wind population is considered viable. All four strata in the DPS fall short of the WLC TRT criteria for viability.

Table ES-12
Baseline and Target Status of LCR Steelhead Populations*

Stratum	Population	Core or Genetic Legacy?**	Contribution to Recovery	Baseline Status	Target Status
Cascade summer	Kalama (WA)	C	Primary	M	H
	NF Lewis (WA)		Stabilizing	VL	VL
	EF Lewis (WA)		Primary	VL	H
	Washougal (WA)	C	Primary	M	H
Gorge summer	Wind (WA)	C	Primary	H	VH
	Hood (OR)		Primary	VL	H
Cascade winter	Lower Cowlitz (WA)		Contributing	L	M
	Upper Cowlitz (WA)	C, GL	Primary	VL	H
	Cispus (WA	C, GL	Primary	VL	H
	Tilton (WA)		Contributing	VL	L
	SF Toutle (WA)		Primary	M	H+
	NF Toutle (WA)	C	Primary	VL	H
	Coweeman (WA)		Primary	L	H
	Kalama (WA)		Primary	L	H+
	NF Lewis (WA)	C	Contributing	VL	M
	EF Lewis (WA)		Primary	M	H
	Salmon Creek (WA)		Stabilizing	VL	VL
	Washougal (WA)		Contributing	L	M
	Clackamas (OR)	C	Primary	M	H
	Sandy (OR)	C	Primary	L	VH
Gorge winter	L. Gorge (OR & WA)		Primary	L	H
	U. Gorge (OR & WA)		Stabilizing	L	L
	Hood (OR)	C, GL	Primary	M	H

* Status is equivalent to persistence probability. VL = very low, L = low, M = moderate, H = high, VH = very high.

** C = Core populations, meaning those that historically were the most productive. G = Genetic legacy populations, which best represent historical genetic diversity.

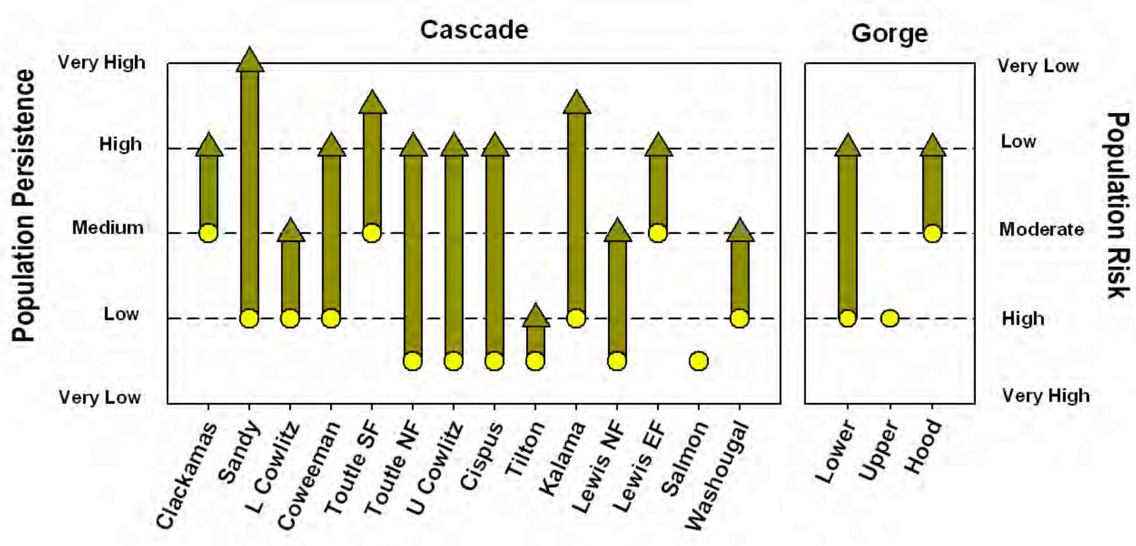

Figure ES-5. *Conservation Gaps for LCR Winter Steelhead Populations (i.e., Difference between Baseline and Target Status)*

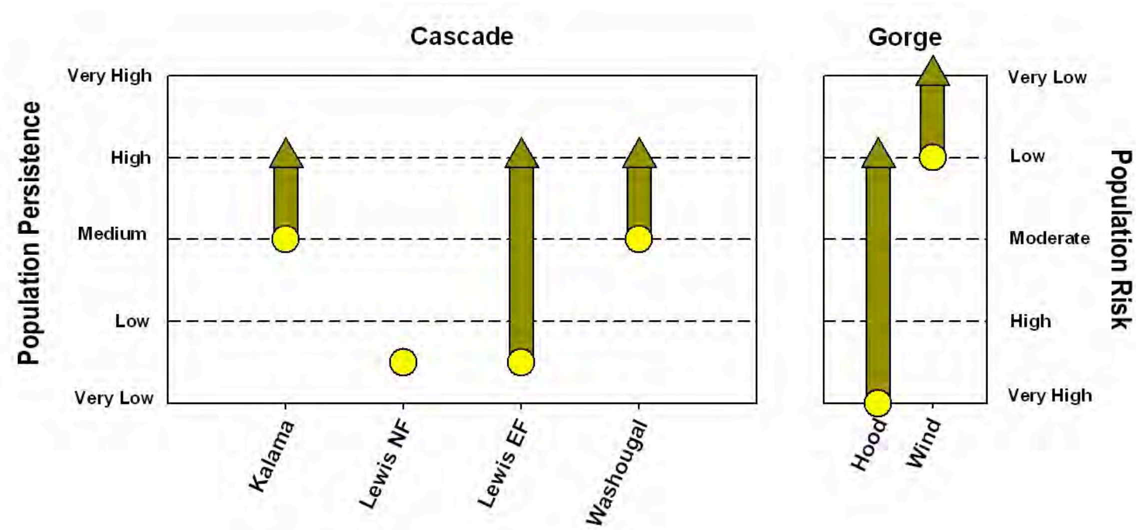

Figure ES-6. *Conservation Gaps for LCR Summer Steelhead Populations (i.e., Difference between Baseline and Target Status)*

Prevalent Limiting Factors: Steelhead

Lower Columbia River steelhead's poor status is due to a host of limiting factors that have affected the ESU for decades, or longer. Tables ES-13 and ES-14 list prevalent limiting factors that the management unit plans identified as having the greatest impact during the baseline period.

Table ES-13
Prevalent Primary Limiting Factors for Winter Steelhead during Baseline Period

Limiting Factor	Populations for Which This Is a Primary Limiting Factor
Degraded riparian conditions along tributaries	Almost all*
Channel structure and form issues[20] in tributaries and the Columbia River estuary	Almost all
Impaired side channel and wetland conditions in tributaries	Almost all
Loss/degradation of floodplain habitat in tributaries	Almost all
Sediment conditions in the estuary	Almost all
Water quantity issues (i.e., altered hydrology) in the estuary	Almost all

* "Almost all" means every population except one in each stratum.

Table ES-14
Prevalent Primary Limiting Factors for Summer Steelhead during Baseline Period

Limiting Factor	Populations for Which This Is a Primary Limiting Factor
Degraded riparian conditions along tributaries	Almost all*
Channel structure and form issues[21] in tributaries	Almost all
Impaired side channel and wetland conditions in tributaries	Almost all
Loss/degradation of floodplain habitat in tributaries	Almost all
Sediment conditions in tributaries and the Columbia River estuary	Almost all
Water quantity issues (i.e., altered hydrology) in the estuary	Almost all

* "Almost all" means every population except one in each stratum.

In addition, tributary hydropower development is a primary limiting factor for the North Fork Lewis summer steelhead population and several populations in the Cascade winter steelhead stratum, as is reduction in population diversity as a result of stray hatchery fish interbreeding with natural-origin fish.

Recovery Strategy: Steelhead

The recovery strategy for the Lower Columbia River steelhead DPS is aimed at restoring the Cascade and Gorge winter and summer strata to a high probability of persistence. Although the strategy involves threat reductions in all categories, the most crucial elements are as follows:

1. Protect favorable tributary habitat and restore degraded but potentially productive habitat, especially in subbasins where large improvements in

[20] Includes conditions such as channelization, reduced instream habitat complexity, fill and scour, and associated loss of spawning habitat.
[21] Includes conditions such as channelization, reduced instream habitat complexity, fill and scour, and associated loss of spawning habitat.

population abundance and productivity are needed to achieve recovery goals. This is the case in the Upper Cowlitz, Cispus, North Fork Toutle, Kalama, and Sandy subbasins for winter steelhead and in the East Fork Lewis and Hood subbasins for summer steelhead.

2. Protect and improve the South Fork Toutle, East Fork Lewis, Clackamas, and Hood winter steelhead populations, which currently are the best-performing winter populations, to a high probability of persistence. This will be accomplished through population-specific combinations of threat reductions, to include protection and restoration of tributary habitat (crucial for all except the Hood population), reductions in hatchery strays on the spawning grounds, and—for the Hood population—removal of Powerdale Dam (this was completed in 2010).

3. Significantly reduce hatchery impacts on the Hood summer steelhead population[22] and, to a lesser degree, on many other populations, especially the Upper Cowlitz, Cispus, Tilton, North Fork Lewis, and Clackamas winter populations and the East Fork summer population. Continue to limit hatchery impacts on the Kalama and Wind summer steelhead populations to improve population diversity.

4. Reestablish naturally spawning winter steelhead populations above tributary dams in the Cowlitz system (Upper Cowlitz and Cispus populations) and improve the status of the Tilton winter steelhead population through hatchery reintroductions and comprehensive threat reductions; reintroduce winter steelhead above dams on the North Fork Lewis River.

5. Reduce predation by birds, non-salmonid fish, and marine mammals.

Loss and degradation of tributary habitat, hatchery effects, and predation are pervasive threats that affect most steelhead populations, but the types of recovery actions that will be of most benefit vary by population. For the Upper Cowlitz, Cispus, Tilton, and North Fork Lewis winter populations, the greatest gains are expected to be achieved by reestablishing natural populations above tributary dams, but reductions in hatchery- and tributary habitat-related threats also will contribute significantly. For the East Fork Lewis summer population, improvements in tributary habitat are projected to provide the greatest benefit. The Sandy winter steelhead population is targeted for significant reductions in hatchery-related threats, but because of fairly recent changes in the management of the hatchery steelhead program, current stray rates in this population already are lower than the 10 percent called for for delisting. Hatchery- and tributary habitat-related actions will be of greatest benefit to Clackamas winter steelhead.

In the Gorge strata, reductions in tributary habitat-related threats will be significant for the Lower and Upper Gorge winter populations, especially in Oregon. For the Hood

---

[22] The Sandy winter steelhead population was also targeted for a significant reduction in hatchery impacts (i.e., 80 percent). However, the Oregon management unit plan states that, because of fairly recent changes in the management of the hatchery steelhead program, current stray rates in the Sandy winter steelhead population already are lower than the 10 percent called for in the threat reduction targets (ODFW 2010 p. 196).

winter population, the greatest gains in persistence probability are expected from reductions in hatchery- and hydropower-related threats. The Hood summer steelhead population is targeted for significant reductions in multiple threat categories, with particularly large reductions in tributary habitat- and hydropower-related threats and a complete elimination of hatchery threats (summer steelhead will no longer be released in the Hood River subbasin).

With harvest impacts on natural-origin winter steelhead having dropped substantially from historical highs, further reductions in harvest impacts do not figure prominently in the threat reduction scenarios for most steelhead populations. The recovery strategy involves continued management of fisheries to limit impacts to baseline levels.

Adaptive Management and Research, Monitoring, and Evaluation

The life cycles of salmon and steelhead are complex, and there is much we do not know about the range of factors that affect these species and how specific actions influence their characteristics and survival. For this recovery plan to be successful, we must do more than implement the strategies and actions the plan calls for. We also must learn during implementation, continually check our progress in reaching recovery goals, and make adjustments as necessary. Thus, the recovery plan calls for data gathering on the status and trends of populations, their habitats, and sources of threats; resolution of the many unknowns (which are referred to as critical uncertainties); and new or continued research, monitoring, and evaluation (RME) to assess the effectiveness of actions once they are implemented.

The recovery plan also incorporates adaptive management, which is the process of adjusting management actions and/or the overall approach to recovery based on new information, such as information derived from RME activities. Adaptive management works by offering a process for explicitly proposing, prioritizing, implementing, and evaluating alternative approaches and actions. This ensures that the best and most effective means of achieving recovery goals are used, even while scientific understanding of fish populations' needs and the benefits of specific actions continues to change and improve.

Local recovery planners have or will develop specific RME plans—for their respective geographic areas—that are based on regional guidance for adaptive management and RME. These RME plans will guide recovery planning RME efforts and funding in each management unit, within a context of ongoing regional guidance and coordination.

Implementation

Recovery actions will be implemented over a 25-year period, as specified in the management unit plans and estuary recovery plan module. Effective implementation will require that the recovery efforts of diverse private, local, state, tribal, and federal parties across two states be coordinated at multiple levels.

At the management unit level, Washington's Lower Columbia Fish Recovery Board will lead implementation of actions in southwest Washington, and the Oregon Department of Fish and Wildlife implementation coordinator and stakeholder team will lead recovery plan implementation in Oregon, supported by the governance structure of the Oregon Plan for Salmon and Watersheds. In the White Salmon, NMFS, in coordination with the Washington Gorge Implementation Team (WAGIT), has taken the lead in coordinating implementation. Each of the lead implementing organizations will develop a series of 3-year or 6-year implementation schedules for their respective management unit. Implementation schedules will identify and prioritize[23] site-specific projects, determine costs and time frames, and identify responsible parties, based on strategies and actions in the recovery plan. Thus, the implementation schedules will provide more detail, clarity, and accountability for implementation than this recovery plan does.

At a higher level than the management units, the Lower Columbia Recovery Planning Steering Committee (which NMFS convened to guide development of this recovery plan) will lead efforts to coordinate the actions of the many entities that will play a role in implementation. For example, there is a need for coordination among the management units and the entities implementing Columbia River estuary recovery actions because the lower, tidal portions of the tributaries, which are within the management unit planning areas, overlap with the planning area of the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead*. The steering committee will perform its coordination functions by working with subcommittees and other regional forums as needed.

Finally, NMFS has a unique role in recovery plan implementation. In addition to ensuring that its statutory responsibilities for recovery under the ESA are met, NMFS will support local recovery efforts by (1) helping to coordinate and encourage recovery plan implementation, (2) using recovery plans to guide regulatory decision making, (3) providing leadership in regional research, monitoring, and evaluation forums, and (4) providing periodic reports on species status and trends, limiting factors, threats, and plan implementation status.

The good news is that some recovery actions already are taking place. Harvest rates have dropped significantly since the first Lower Columbia River species were listed under the Endangered Species Act. Reforms of hatchery practices and programs are being implemented throughout the Columbia Basin. Dams have been removed or breached on the Sandy, Hood, and White Salmon rivers, and improvements in passage and operations to benefit salmon and steelhead are under way at other tributary hydropower facilities and in the Federal Columbia River hydropower system. Tributary and estuary habitat protection and restoration projects are under way. However, considerable additional work is needed to meet the goals of this plan. Habitat activities in particular need to be scaled up if they are to provide the needed benefits.

Conclusion

Recovery of ESA-listed Lower Columbia River salmon and steelhead will require actions that conserve and restore the key biological, ecological, and landscape processes that support the ecosystems that salmonid species depend on. These measures will require

[23] Some prioritization work already has been done, in that the management unit plans identify high-priority reaches for tributary habitat protection and restoration actions. In addition, the Oregon and White Salmon management unit plans offer some guidance on how actions might be prioritized across threat categories.

implementation of specific tributary and estuary habitat protection and restoration actions; changes in management of harvest, hatchery, and hydropower programs; and predation control. Development of an effective implementation framework, coupled with a responsive RME and adaptive management plan, provides the best assurance that this recovery plan will be fully implemented and effective. The plan's identification of target statuses, primary and secondary limiting factors that have caused gaps between baseline and target status, and actions to close those gaps is intended to aid implementing entities as they take actions that will lead to delisting and, eventually, achievement of broad sense recovery goals. The keys to long-term success will be full funding and implementation of this recovery plan and voluntary participation of residents of the Lower Columbia region. It is only through the involvement of all of those who live and work in this region that recovery will be achieved.

Key Documents

Oregon Lower Columbia Conservation and Recovery for Salmon and Steelhead
Oregon Department of Fish and Wildlife, 2010
http://www.dfw.state.or.us/fish/CRP/lower_columbia_plan.asp

ESA Recovery Plan for the White Salmon River Watershed
National Marine Fisheries Service, 2013
http://www.nwr.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/lower_columbia_river/lower_columbia_river_recovery_plan_for_salmon_steelhead.html

Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan
Lower Columbia Fish Recovery Board, 2010
http://www.lcfrb.gen.wa.us/Recovery%20Plans/RP%20Frontpage.htm

Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead
National Marine Fisheries Service, 2011
http://www.nwr.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/recovery_plans_supporting_documents.html

Recovery Plan Module: Mainstem Columbia River Hydropower Projects
National Marine Fisheries Service, 2008
http://www.nwr.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/recovery_plans_supporting_documents.html

2008 Federal Columbia River Power System Biological Opinion and 2010 Supplement
National Marine Fisheries Service, 2008 and 2010
http://www.nwr.noaa.gov/hydropower/fcrps_opinion/federal_columbia_river_power_system.html

1. Introduction

This is a plan for the protection and restoration of Lower Columbia River Chinook salmon (*Oncorhynchus tshawytscha*), Lower Columbia River steelhead (*O. mykiss),* Lower Columbia River coho salmon (*O. kisutch*), and Columbia River chum salmon (*O. keta*), all of which are listed as threatened under the Endangered Species Act of 1973 (ESA). These salmon and steelhead, which spawn and rear in the lower Columbia River and its tributaries in Oregon and Washington, are among 19 evolutionarily significant units (ESUs) or distinct population segments (DPSs) of salmon and steelhead in the Pacific Northwest that have been listed as threatened or endangered under the ESA, out of a total of 40 salmon and steelhead ESUs and DPSs in the region.[1] An ESU or DPS is a group of Pacific salmon or steelhead, respectively, 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 Endangered Species Act, each ESU or DPS is treated as a species.[2]

The National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration (NOAA) is required, pursuant to section 4(f) of the Endangered Species Act of 1973, to develop recovery plans for marine species listed under the ESA.[3] Recovery plans identify actions needed to restore threatened and endangered species to the point that they no longer need the protections of the ESA. A recovery plan serves as a road map for species recovery—it lays out where we need to go and how best to get there. Without a plan to organize, coordinate, and prioritize the many possible recovery actions on the part of federal, state, and local governments, tribal agencies, watershed councils and districts, and private citizens, our efforts may be inefficient or even ineffective. Prompt development and implementation of a recovery plan will help target limited resources effectively. Although recovery plans are guidance documents rather than regulatory documents, the ESA envisions recovery plans as the central organizing tool for guiding each species' recovery process. NMFS developed this ESU-level recovery plan by synthesizing material from (1) three geographically based and locally developed recovery plans for Oregon, White Salmon, and southwest Washington populations of Lower Columbia River salmon and steelhead, (2) related recovery plan modules, and (3) additional analyses as appropriate (see Sections 1.5.2 and 1.5.3).

Over the course of their life cycles, Lower Columbia River salmon and steelhead use habitats across a wide geographic range. They spawn and rear in the upper, middle, and lower reaches of freshwater tributaries to the Columbia River and in parts of the Columbia River estuary and lower mainstem. They then migrate as juveniles downstream through the tributaries and mainstem to the estuary and ocean. After

---

[1] For updates on the number of ESA-listed salmon and steelhead, see the "Snapshot" link at http://www.nwr.noaa.gov/ESA-Salmon-Listings/Salmon-Populations/.

[2] A DPS is defined based on discreteness in behavioral, physiological, and morphological characteristics, whereas the definition of an ESU emphasizes genetic and reproductive isolation. (For a fuller explanation, see Section 1.4.4.)

[3] As anadromous species whose life cycles encompass freshwater, estuarine, and marine ecosystems, salmon and steelhead fall under the jurisdiction of NMFS. Steelhead, which are the migratory form of *Oncorhynchus mykiss*, are distinct from rainbow trout, the resident form of *O. mykiss*. Rainbow trout are under the jurisdiction of the U.S. Fish and Wildlife Service. This recovery plan addresses steelhead and not rainbow trout, as is consistent with the ESA listing decision.

spending years in the ocean, adults migrate back to their natal streams to spawn. The long-term biological success of salmon and steelhead is based on their ability to make use of the diverse habitats from river headwaters to the ocean. Thus, salmon and steelhead's resilience in the face of change depends on maintaining genetic, phenotypic, and behavioral diversity over a wide geographic area.

Human activities have dramatically changed the conditions encountered by Lower Columbia River salmon and steelhead. Although many of the deleterious effects on fish are due to past practices, current human uses of the land and river systems continue to threaten the viability of Lower Columbia River salmon and steelhead across much of their range. In many locations, urban and rural development, agricultural and forest management practices, dredging, and passage obstructions continue to put pressure on salmon and steelhead, whose habitat already has been reduced in amount and quality as a result of extensive loss of channel function and floodplain connectivity. Habitat changes have exacerbated predation by fish, birds, and marine mammals as salmon and steelhead migrate through the lower Columbia River and estuary. Hydropower development has altered river flow, which is a significant force in structuring aquatic and riparian habitats. In addition to eliminating key habitats, hydropower development has altered salmonid food sources, changed freshwater and saltwater balances in the Columbia River estuary, reduced access to habitat in the estuary, and disrupted the timing of salmonid migrations. Harvest mortality of ESA-listed salmon and steelhead occurs in various fisheries—commercial, tribal, and recreational—in the Pacific Ocean, in the lower Columbia River, and in tributaries to the Columbia. Lastly, hatchery-origin fish pose threats in terms of competition, predation, genetic effects, and mixed-stock harvest.

Fortunately, scientific understanding of the threats to Lower Columbia River salmon and steelhead is growing, as is interest in aligning land use, hatchery priorities, harvest practices, and hydropower operations with conservation objectives for salmon and steelhead. More people now recognize the opportunities and benefits of actively protecting and restoring stream corridors, wetlands, stream flows, and other natural features that support native fish and wildlife populations. Management of upland areas is changing to protect or restore watershed function, and cities are undertaking urban watershed protection and restoration. Recovery planning is an opportunity to search for common ground, to organize protection and restoration of salmonid habitat, to reduce other threats to the species, and to secure the economic and cultural benefits that accrue to human communities from healthy watersheds and rivers.

The primary goal of ESA recovery plans is for species to reach the point at which they no longer need the protection of the Endangered Species Act and thus can be delisted. With salmon and steelhead, the final recovery plan is based on locally developed recovery plans. These plans address not just delisting but also local interests and needs based on social, economic, and ecological values. To address these interests, local recovery planners have included "broad sense goals" that go beyond the requirements for delisting. Although the broad sense goals in the locally produced salmon and steelhead recovery plans may be stated in slightly different ways, they usually share some combination of the following elements: ensuring long-term persistence of viable populations of naturally produced salmon and steelhead distributed across their native range, enjoying the social and cultural benefits of meaningful harvest opportunities that are sustainable over the long term, and pursuing salmon recovery using an open and cooperative process that respects local customs and benefits local communities and economies.

The broad sense goal of ensuring the long-term persistence of viable populations of naturally produced salmon and steelhead distributed across their native range is consistent with ESA delisting, and NMFS' approach to recovery planning has been to use open and collaborative processes with extensive local engagement. NMFS is supportive of the broad sense recovery goals in locally developed plans and believes that the most expeditious way to achieve them is by achieving viability of natural populations and delisting. Upon delisting, NMFS will work with co-managers and local stakeholders, using our non-ESA authorities, to pursue broad sense recovery goals while continuing to maintain robust natural populations. Recovery goals and delisting criteria are discussed in more detail in Chapter 3.

1.1 ESA Requirements

Section 4(f) of the ESA requires that a recovery plan be developed and implemented for each species listed as endangered or threatened under the statute.

ESA section 4(a)(1) lists factors for delisting that are to be addressed in recovery plans:

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. The inadequacy of existing regulatory mechanisms
E. Other natural or human-made factors affecting the species' continued existence

ESA section 4(f)(1)(B) directs that recovery plans, to the extent practicable, incorporate all of the following:

1. 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

2. Objective, measurable criteria which, when met, would result in a determination … that the species be removed from the list

3. 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

In addition, it is important for recovery plans to provide the public and decision makers with a clear understanding of the goals and strategies needed to recover a listed species and the science underlying those goals and strategies (NMFS 2004a).

Once a species is deemed recovered and therefore removed from the list, section 4(g) of the ESA requires monitoring of the species for a period of not less than 5 years to ensure that it retains its recovered status.

1.2 How NMFS Intends to Use the Plan

Although recovery plans are not regulatory, 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
- Provide criteria for status reporting and delisting decisions
- Organize, prioritize, and sequence recovery actions
- Organize research, monitoring, and evaluation efforts

NMFS will encourage federal agencies and non-federal jurisdictions to take recovery plans under serious consideration as they make the following sorts of decisions and allocate their resources:

- Actions carried out to meet federal ESA section 7(a)(1) obligations
- 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
- Selection and prioritization of subbasin planning actions
- Development of research, monitoring, and evaluation programs
- Revision of land use and resource management plans
- Other natural resource decisions at the state, tribal, and local levels

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

- The importance of affected populations to listed species' viability
- The importance of the action area to affected populations and species' viability
- How LFs identified in recovery plans inform analysis of the effects of the action on critical habitat
- The relation of the action to recovery strategies and management actions
- The relation of the action to the research, monitoring, and evaluation plan for the affected species

In implementing these programs, recovery plans will be used as a reference and a source of context, expectations, and goals. NMFS staff will encourage the federal "action 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.

1.3 Geographic Setting

With few exceptions, this recovery plan covers naturally produced and some artificially propagated salmon and steelhead in the Lower Columbia recovery subdomain, meaning the area that is drained by the streams and rivers in the lower Columbia Basin. This includes the Columbia River estuary and lower mainstem, the lower Willamette River below Willamette Falls, and all Columbia River tributaries downstream from and including the White Salmon River in Washington and the Hood River in Oregon. The plan does not cover steelhead populations in tributaries downstream of the Willamette River in Oregon and the Cowlitz River in Washington (these are part of the Southwest Washington steelhead DPS, which is not ESA listed),[4] steelhead in the White Salmon and Little White Salmon rivers (which are part of the Middle Columbia DPS),[5] salmon and steelhead populations in the upper Willamette River and its tributaries (which are part of the Upper Willamette ESU), and spring Chinook salmon in the Clackamas River (also part of the Upper Willamette ESU). Listed ESUs in the upper Willamette are addressed in a separate recovery plan.

1.3.1 Topography and Ecological Zones

The lower Columbia Basin is geographically and ecologically diverse. Draining 8,200 square miles, it spans parts of two states and two mountain ranges: the Coast Range and the Cascades. Elevations range from sea level (at the mouth of the Columbia River) to 14,410 feet (at the summit of Mt. Rainier). Topography includes low-elevation tidally influenced floodplains, which are where most of the urban and agricultural development has occurred. Higher elevations are characterized by alluvial valleys; steep, heavily timbered mountains; and volcanic peaks, specifically Mounts Rainier, St. Helens, and Adams in Washington and Mt. Hood in Oregon. Over geologic time the watersheds of the lower Columbia Basin have been shaped by volcanic, glacial, and alluvial processes, such as flooding, erosion, and sedimentation, and these forces continue to influence habitat conditions. As an example, volcanic activity has played a significant role in structuring habitat as recently as 1980, when Mount St. Helens erupted. Together, the various habitats in the region—from tidal marshes to high-elevation coniferous forests—support more than a dozen fish and wildlife species that are officially threatened, endangered, or of other special conservation concern.

For purposes of salmon and steelhead recovery planning, the lower Columbia Basin is divided into three ecological zones—Coast Range, Cascade, and Columbia Gorge—that were adapted in part from the U.S. Environmental Protection Agency's ecoregions (Omernik 1987, Myers et al. 2006). Ecological zones delineate major geographic areas within the ranges of the ESUs and DPS that have distinct environmental characteristics, such as elevation, soil type, vegetative land cover, rainfall, and climate. Each ecological zone spans the Columbia River and includes parts of both Oregon and Washington.

The individual subbasins in each ecological zone are shown in Table 1-1.

---

[4] Steelhead populations within the Coast ecozone are addressed, however, in the Oregon and Washington management unit plans to address state planning needs.

[5] The White Salmon and Little White Salmon steelhead populations are addressed in a separate species-level recovery plan, the *Middle Columbia River Steelhead Distinct Population Segment ESA Recovery Plan* (NMFS 2009a). However, recovery actions for the White Salmon population of Mid-Columbia steelhead are included in the White Salmon management unit plan (*ESA Recovery Plan for the White Salmon River Watershed,* NMFS 2013; see Appendix C of this recovery plan) because this population shares geography with Lower Columbia River coho and Chinook salmon and Columbia River chum in the White Salmon subbasin.

Table 1-1
Lower Columbia Subbasins, by State and Ecological Zone

Ecological Zone	Oregon Subbasins	Washington Subbasins
Coast Range	Youngs Bay Big Creek Clatskanie Scappoose	Estuary tributaries: Chinook, Wallacut, and Deep Grays Elochoman Skamakowa Mill, Abernathy, and Germany creeks
Cascade	Clackamas Sandy	Cowlitz (Lower Cowlitz, Upper Cowlitz, Cispus, Tilton) Coweeman Toutle Kalama North Fork Lewis East Fork Lewis Salmon Creek Washougal
Gorge	Lower Gorge and Upper Gorge tributaries (divided by Bonneville Dam) Hood	Lower Gorge tributaries (including Wind and Little White Salmon) Upper Gorge tributaries (above Bonneville Dam) White Salmon

Ecological zones are considered a meaningful structure to use in recovery planning because salmon and steelhead populations in different zones exhibit differences in life history characteristics. In addition, given the different climates, geology, and ecological processes in each zone, populations in different zones are unlikely to be affected by the same catastrophic event.

1.3.2 Climate

The lower Columbia Basin has a typical Pacific Northwest maritime climate, with cool, dry summers and wet, mild winters. Precipitation patterns are heavily influenced by the Coast and Cascade mountain ranges. In the Coast Range ecological zone, precipitation averages 80 to 95 inches per year, with the vast majority occurring as rain between October and March (Myers et al. 2006). The Cascade zone sees greater variation in precipitation, from 45 to 150 inches annually (Myers et al. 2006). Rain predominates at middle and lower elevations in the Cascade zone, while snow and freezing temperatures are common at high elevations. As in the Coast Range zone, most of the precipitation in the Cascade zone occurs between October and March.

The Columbia Gorge ecological zone has a transitional climate between the high-precipitation area of the Cascades and the drier Columbia Plateau to the east (Myers et al. 2006). Rain shadow effects keep precipitation in the eastern portion of this zone relatively low—to an annual mean of 30 inches in Hood River, Oregon, for example (Western Regional Climate Center 2003). Cooler winter temperatures can occur in this zone as the result of the influx of cold continental air masses from the east (Welch et al. 2002).

1.3.3 Land Uses and Economy

Land uses in the lower Columbia Basin vary from forestry and agriculture to urban and rural residential development. Much of the upper portions of the region's watersheds are forested and managed for timber production. In the Coast Range zone this is usually through private ownership of industrial forests; in the Cascade and Columbia Gorge zones, federal or state ownership of forest land is more common. Within the Cascade zone, forest land in the Coweeman, Toutle, Kalama, lower North Fork Lewis, Salmon Creek, and Washougal subbasins is under predominately state or private ownership, while forest land in the upper Cowlitz, Cispus, Tilton, upper North Fork Lewis, East Fork Lewis, Clackamas, and Sandy subbasins is largely federally owned. Federal ownership in the region includes portions of two national forests (Gifford Pinchot and Mt. Hood), three wilderness areas (Indian Heaven, Salmon-Huckleberry, and Mt. Hood), and other specially managed lands (e.g., Mt. Rainier National Park, Mount St. Helens National Volcanic Monument, and the Columbia River Gorge National Scenic Area).

Large urban and residential zones have developed in lower elevation valley floor areas along the Columbia River and I-5 corridor from Portland, Oregon, to Longview, Washington (LCFRB 2010a). The lower reaches of the Salmon Creek and Clackamas River subbasins, in particular, along with smaller drainages near the city of Portland such as Johnson Creek and Kellogg Creek, are heavily urbanized. High technology, manufacturing, and professional services support the economy of the area's two major population centers: Portland, Oregon (the state's largest city), and Vancouver, Washington (fourth largest city in Washington). Dozens of smaller cities and towns are located in the more rural portions of the region, which has a total human population of more than 2.5 million. Other common land uses in the lower reaches of most subbasins are rural residential development and agriculture, in the form of fruit and vegetable crops, nursery stock, and beef and dairy cattle.

Bonneville is the only dam on the lower mainstem of the Columbia River, but major hydropower or flood control facilities are located on a number of tributaries. Interstate Highway 84, the Union Pacific Railroad line, and the Columbia River constitute a key east-west transportation corridor. Five deep-water ports serve a shipping industry that transports 30 million tons of goods annually. Six major pulp mills contribute to the region's economy and, until the early 2000s, aluminum smelters along the Columbia River produced 40 percent of the country's aluminum. Commercial and recreational fishing continue to support some local communities, and outdoor recreation in general (fishing, wildlife observation, hunting, boating, hiking, and windsurfing) is a growing economic influence.

1.3.4 Human Population

An estimated 5 million people live in the Columbia Basin, and many more are expected to move to the area in the coming decades. Population forecasts predict that, by the end of the twenty-first century, between 40 million and 100 million people will be living in the region (National Research Council 2004). Expected population growth rates vary throughout the area. However, some communities—both urban and rural—can expect their populations to double between 2000 and 2020. Significant growth also is projected for unincorporated areas. In Oregon, particularly fast population growth is predicted in Clackamas, Clatsop, Columbia, Hood River, and Multnomah counties—areas that support Lower Columbia River salmon and steelhead. The population of these counties is expected to increase by 41 percent from 2003 to 2040 (State of Oregon Office of Economic Analysis 2004). In Washington, the populations of Clark and Cowlitz counties are projected to grow by 65 and 53 percent, respectively, from 2000 to 2030 (Washington State Department of Transportation).

1.4 Species Covered by the Plan

Of the 19 ESUs or DPSs of salmon and steelhead in the Pacific Northwest that have been listed as threatened or endangered under the ESA, four occur in the lower Columbia Basin and are addressed in this plan: Lower Columbia River Chinook salmon, steelhead, and coho salmon, and Columbia River chum salmon.

Because ESA recovery is predicated on having enough natural production for the ESU to be self-sustaining, natural populations are the primary focus of most of the analyses and recovery actions in this plan. However, NMFS recognizes that in certain circumstances, hatchery populations are closely related to local natural populations and are representative of the genetic legacy of the ESU or DPS in question. NMFS' 2005 hatchery listing policy provides that the agency will include in ESUs or DPSs hatchery programs that are no more than moderately divergent from a natural population that is included in the ESU or DPS (70 *Federal Register* 37204) For this reason, each of the species described below consists of both natural- and hatchery-origin fish.

1.4.1 Lower Columbia River Coho Salmon ESU

The Lower Columbia River coho salmon ESU (*Oncorhynchus kisutch*) was listed as threatened under the federal Endangered Species Act on June 28, 2005 (70 *Federal Register* 37160). The ESU includes the following:

- All naturally spawned populations of coho salmon in the lower Columbia River and its tributaries, from the mouth of the Columbia upstream to and including the Hood River (in Oregon) and the White Salmon River (in Washington), and including the Willamette River up to Willamette Falls
- Coho salmon from 25 artificial propagation programs[6]

1.4.2 Lower Columbia River Chinook Salmon ESU

The Lower Columbia River Chinook salmon ESU (*O. tshawytscha*) was listed as threatened under the federal Endangered Species Act on March 24, 1999 (64 *Federal Register* 14308). The listing was reaffirmed on June 28, 2005 (70 *Federal Register* 37160).

The Lower Columbia River Chinook salmon ESU includes the following:

[6] For a list of the hatchery programs included in the ESU, along with changes that NMFS proposed in its 2011 5-year review of the ESU's status, see Section 6.1.2.

- All naturally spawned populations of Chinook salmon from the Columbia River and its tributaries from the river's mouth at the Pacific Ocean upstream to and including the Hood River in Oregon and the White Salmon River in Washington, including the Willamette River to Willamette Falls, Oregon, but excluding spring-run Chinook salmon in the Clackamas River[7]
- Chinook salmon from 17 artificial propagation programs[8]

1.4.3 Columbia River Chum Salmon ESU

The Columbia River chum salmon ESU (*O. keta*) was listed as threatened on March 25, 1999 (64 *Federal Register* 14507). The listing was reaffirmed on June 28, 2005 (70 *Federal Register* 37160).

The Columbia River chum salmon ESU includes the following:

- All naturally spawned populations of chum salmon in the Columbia River and its tributaries in Oregon and Washington[9]
- Chum salmon from three artificial propagation programs[10]

1.4.4 Lower Columbia River Steelhead DPS

"Steelhead" are the anadromous (migratory) form of the biological species *Oncorhynchus mykiss*. Rainbow trout are the non-anadromous (resident) form of *O. mykiss*. NMFS originally listed Lower Columbia River steelhead as threatened on March 29, 1998, under the ESU policy (63 *Federal Register* 13347). NMFS revised the listing on January 5, 2006 (71 *Federal Register* 8844), this time applying the DPS policy (61 *Federal Register* 4722).[11] This recovery plan addresses steelhead only, not rainbow trout (which are under the jurisdiction of the U.S. Fish and Wildlife Service). To avoid confusion, references to ESUs in this recovery plan should be understood to include the steelhead DPS as well.

---

[7] Spring Chinook salmon in the Clackamas subbasin are part of the Upper Willamette River spring Chinook ESU. Lower Columbia River coho salmon, chum salmon, steelhead, and fall Chinook salmon also occur in the Clackamas subbasin. For planning purposes, Oregon addressed all the Clackamas populations, including Clackamas River spring Chinook salmon, in its Lower Columbia recovery planning process (ODFW 2010). For ESA purposes, the Clackamas River spring Chinook salmon population is addressed in the *Upper Willamette River Conservation and Recovery Plan for Chinook Salmon and Steelhead* (ODFW and NMFS 2011)

[8] For a list of the hatchery programs included in the ESU, along with changes that NMFS proposed in its 2011 ESA 5-year review, see Section 7.1.2.

[9] The historical upstream boundary for chum salmon is generally considered to have been Celilo Falls, which historically was located approximately where The Dalles Dam is located.

[10] For a list of the hatchery programs included in the ESU, see Section 8.1.2.

[11] The ESA allows listing agencies to list at the level of a species, subspecies, or distinct population segment. For salmon, NMFS applies its ESU policy and treats ESUs as distinct population segments. For steelhead (*O. mykiss*) NMFS shares jurisdiction with the U.S. Fish and Wildlife Service. In 2006, NMFS and the U.S. Fish and Wildlife Service made a determination to apply the DPS policy to *O. mykiss*. The DPS policy recognizes discreteness in behavioral, physiological, and morphological characteristics as contributing to the distinctness of a population segment, whereas the ESU policy emphasizes genetic and reproductive isolation.

Steelhead found within the geographical boundaries of the Lower Columbia recovery subdomain fall into three separate DPSs as defined by NMFS: Lower Columbia, Middle Columbia, and Southwest Washington. The Middle Columbia DPS includes steelhead from the White Salmon and Little White Salmon rivers, while the Southwest Washington DPS includes steelhead from the Grays and Elochoman rivers and Skamakowa, Mill, Abernathy, and Germany creeks in Washington, and from the Youngs Bay, Big Creek, Clatskanie, and Scappoose subbasins in Oregon.

This recovery plan addresses steelhead from the Lower Columbia DPS only, not populations from the Middle Columbia and Southwest Washington DPSs.[12] Specifically, the Lower Columbia River steelhead DPS includes the following:

- All naturally spawned anadromous *O. mykiss* populations below natural and manmade impassable barriers in streams and tributaries to the Columbia River between and including the Cowlitz and Wind rivers in Washington

- All naturally spawned anadromous *O. mykiss* populations below natural and manmade impassable barriers in streams and tributaries to the Columbia River between and including (1) the Willamette River up to Willamette Falls, and (2) the Hood River in Oregon

- Steelhead from 10 artificial propagation programs[13]

1.5 Context of Plan Development

This plan is the product of a collaborative process initiated by NMFS that involves the State of Washington, regional salmon recovery organizations within Washington (the Lower Columbia Fish Recovery Board, in particular), the State of Oregon (led by the Oregon Department of Fish and Wildlife, with extensive participation by the Oregon Governor's Natural Resources Office), the Lower Columbia Estuary Partnership, regional stakeholder teams within Oregon, other federal and state agencies, tribal and local governments, representatives of industry and environmental groups, and the public.

While NMFS is directly responsible for ESA recovery planning for salmon and steelhead, the agency believes that ESA recovery plans for salmon and steelhead should

[12] The Mid-Columbia steelhead DPS, which includes the White Salmon population, is addressed in a separate recovery plan, the *Middle Columbia River Steelhead Distinct Population Segment ESA Recovery Plan* (National Marine Fisheries Service [Northwest Region] November 2009). Steelhead in the Youngs Bay, Big Creek, Grays, Elochoman, Skamakowa, Clatskanie, Mill, Abernathy, Germany, and Scappoose watersheds are part of the Southwest Washington DPS, which is not listed under the ESA(61 *Federal Register* 41541). However, these populations are included in the Oregon and Washington management unit plans because their status needs to be improved, they share geographic range and life history traits with the ESA-listed Lower Columbia River species, and they are expected to benefit from recovery actions targeted at the listed species. Similarly, the White Salmon management unit plan (NMFS 2013) covers the White Salmon steelhead population, which is part of the Mid-Columbia DPS, because of this population's shared geography with the White Salmon coho, Chinook, and chum salmon populations, all of which are part of the Lower Columbia River ESUs.

[13] For a list of the hatchery programs included in the DPS, along with changes that NMFS proposed in its 2011 ESA 5-year review, see Section 9.1.2.

be based on the many state, regional, tribal, local, and private conservation efforts already under way 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. NMFS therefore supports and participates in locally led collaborative efforts to develop recovery plans that involve local communities; state, tribal, and federal entities; and other stakeholders.

NMFS developed this recovery plan with assistance from the Lower Columbia Recovery Plan Steering Committee, a group convened by NMFS (see Chapter 11) to provide input to the ESU-level plan. NMFS developed this plan by drawing upon the best available scientific information provided by three regional recovery plans, related recovery plan modules, the work of the Willamette-Lower Columbia Technical Recovery Team (see below) and technical experts from NMFS, Washington, Oregon, the Yakama Nation, and regional planning groups. The draft plan went through multiple reviews and revisions in response to comments from both technical reviewers and steering committee members and then was further revised in response to comments received during two public review periods in 2012.

1.5.1 Recovery Domains and Technical Recovery Teams

Currently, there are 19 ESA-listed ESUs and DPSs of Pacific salmon and steelhead in the Pacific Northwest. NMFS' Northwest Region also shares jurisdiction of an additional ESU—the Southern Oregon/Northern California coho salmon—with the agency's Southwest Region. For the purpose of recovery planning for these species, the Northwest Region designated five geographically based "recovery domains": the Interior Columbia, Willamette-Lower Columbia, Puget Sound, Oregon Coast, and Southern Oregon/Northern California Coast domains (see Figure 1-1). NMFS' Northwest Region delineated these domains by considering ESU or DPS boundaries, ecosystem boundaries, and local planning units.

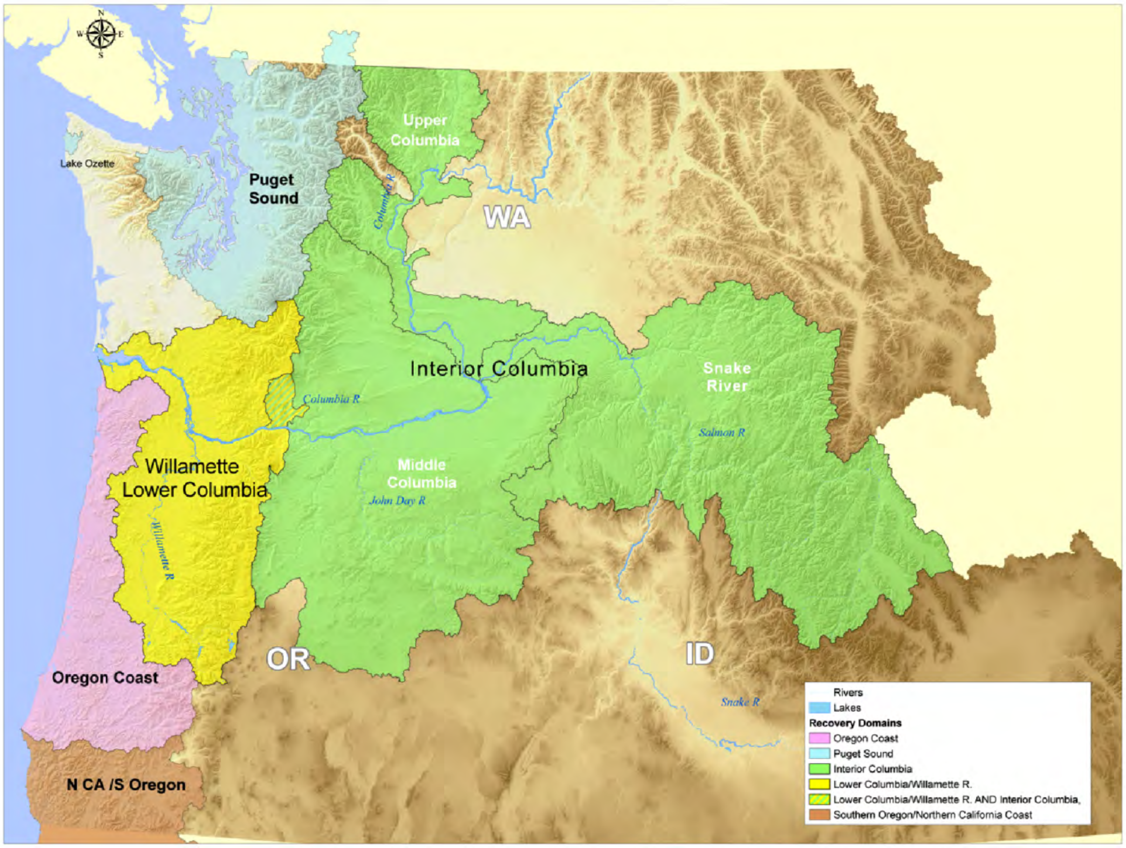

Figure 1-1. *NMFS Northwest Region Recovery Domains*

In the case of the Willamette-Lower Columbia domain, the domain was further divided into two subdomains to accommodate different planning processes and timelines. The range of the Lower Columbia River salmon and steelhead ESUs and DPS is within the Lower Columbia subdomain of the Willamette-Lower Columbia domain (see Figure 1-2).

For each domain, NMFS appointed a team of scientists who have geographic and species expertise to provide a solid scientific foundation for recovery plans. The charge of each Technical Recovery Team (TRT) was to define the historical population structure of each ESU or DPS, to recommend biological viability criteria for each ESU or DPS and its component populations, to provide scientific support to local and regional recovery planning efforts, and to provide scientific evaluations of proposed recovery plans. The Willamette-Lower Columbia TRT (WLC TRT) was formed in May 2000 and included representatives from NMFS' Northwest Fisheries Science Center, the Washington Department of Fish and Wildlife (WDFW), the U.S. Fish and Wildlife Service (USFWS), the University of Portland, and a private consultant.

Each TRT used the same biological principles to develop its recommended ESU and population viability criteria; these criteria will be used in combination with criteria based on mitigation of the factors for decline to determine whether a species has recovered sufficiently to be downlisted or delisted. The biological principles that underlie the viability criteria are described in the NMFS technical memorandum *Viable*

Salmonid Populations and the Recovery of Evolutionarily Significant Units (McElhany et al. 2000). A viable ESU or DPS is naturally self-sustaining over the long term. McElhany et al. describe viable salmonid populations (VSP) in terms of four parameters: abundance, population productivity or growth rate, population spatial structure, and life history and genetic diversity.

Each TRT's recommendations are based on the VSP framework and considerations related to data availability, the unique biological characteristics of the ESU or DPS and the habitats in the domain, and the TRT members' collective experience and expertise. Although NMFS has encouraged the TRTs to develop regionally specific approaches for evaluating viability and identifying factors limiting recovery, each TRT was working from a common scientific foundation to ensure that the recovery plans are scientifically sound and based on consistent biological principles.

TRT recommendations were used by NMFS and local planning groups to develop goals for the recovery plans. As the agency with ESA jurisdiction for salmon and steelhead, NMFS makes final determinations of ESA delisting criteria.

1.5.2 Management Units and Integration of Management Unit Plans

In each domain, NMFS collaborates with other federal agencies and state, tribal, and local entities to develop planning forums appropriate to the domain, building to the extent possible on ongoing, locally led recovery efforts. These planning forums use the TRT and other technical resources to agree on recovery goals and limiting factors and then to develop locally appropriate and locally supported recovery actions needed to achieve recovery goals. Although the planning forums were working from a consistent set of assumptions regarding needed recovery plan elements, the process by which they develop those elements—and the form those elements take—may differ among domains.

The structure of recovery planning in the Willamette-Lower Columbia recovery domain, which includes parts of Washington and Oregon, differs in the two states. To accommodate the different planning efforts and jurisdictional boundaries, NMFS partitioned the domain into four management units: Washington (the portion of the Lower Columbia River salmon ESUs and steelhead DPS that occurs within the planning area of Washington's Lower Columbia Fish Recovery Board), White Salmon (the White Salmon subbasin in Washington), Oregon Lower Columbia (the portion of the Lower Columbia River salmon ESUs and steelhead DPS that occurs within Oregon), and Upper Willamette (predominantly the Willamette Basin above Willamette Falls). (See Figure 1-2.)

Figure 1-2. *Management Units of the Willamette-Lower Columbia Recovery Domain*

A locally developed recovery plan has been completed for each of these management units. This ESU-level recovery plan is a synthesis of relevant information from three of the management unit plans—Washington, White Salmon, and Oregon Lower Columbia. The three management unit plans and their associated planning processes are described below.

1.5.2.1 Washington Management Unit Recovery Plan

The recovery plan for the Washington management unit covers the portion of the Lower Columbia River salmon ESUs and steelhead DPS that occurs in Washington within the planning area of the Lower Columbia Fish Recovery Board (LCFRB), which was established by Washington statute in 1998 to oversee and coordinate salmon and steelhead recovery efforts in the lower Columbia region of Washington. The LCFRB comprises representatives from the state legislature, city and county governments, the Cowlitz Tribe, the environmental community, hydroelectric utilities, and concerned citizens.

The LCFRB led and coordinated a collaborative process to develop the Washington management unit plan, titled the *Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan* (LCFRB 2010a). Partners in the planning process included federal agencies, tribal governments, Washington state agencies, regional organizations, and city and county governments. In addition, workshops, presentations, and public comment periods offered opportunities for broader community and public input. The resulting document is an integrated plan that serves planning needs associated with the Endangered Species Act, the Northwest Power and Conservation Council's fish and wildlife subbasin planning process, and state salmon recovery and watershed planning. The plan is intended to protect and restore native fish, aquatic habitats, and sensitive wildlife species in Washington's lower Columbia River watersheds. In February 2006, NMFS approved the December 2004 version of the plan as an interim regional recovery plan for the listed salmon ESUs and steelhead DPS. In May 2010, the LCFRB completed a revision of its earlier plan. This ESU-level recovery plan includes the *Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan* (LCFRB 2010a) as Appendix B.[14]

1.5.2.2 White Salmon Management Unit Recovery Plan

The recovery plan for the White Salmon management unit covers the portions of the Lower Columbia River Chinook, coho, and chum salmon ESUs that occur in the White Salmon subbasin in Washington. It also covers steelhead in the White Salmon subbasin, which are part of the ESA-listed Middle Columbia River DPS and are addressed in the *Middle Columbia River Steelhead Distinct Population Segment ESA Recovery Plan* (NMFS 2009a).

In the absence of a local planning forum for salmon recovery, NMFS developed the White Salmon management unit recovery plan for ESA-listed salmon and steelhead in the White Salmon subbasin in cooperation with the Yakama Nation, Klickitat County, WDFW, and other stakeholders. The plan, titled *ESA Recovery Plan for the White Salmon River Watershed* (NMFS 2013) is included in this ESU-level recovery plan as Appendix C.[15]

In 2009, NMFS, in coordination with the Yakama Nation, WDFW, U.S. Geological Survey, Klickitat County, Washington Gorge Conservation District, Washington Department of Ecology, and other local groups, established the Washington Gorge Implementation Team to support continued coordination of salmon and steelhead recovery efforts.

---

[14] The Washington management unit plan is available at http://www.lcfrb.gen.wa.us/default1.htm.
[15] The White Salmon management unit plan is available at www.nwr.noaa.gov.

1.5.2.3 Oregon Lower Columbia Management Unit Recovery Plan

The recovery plan for the Oregon Lower Columbia management unit covers the portion of the Lower Columbia River salmon ESUs and steelhead DPS that occurs within Oregon. The Oregon Department of Fish and Wildlife (ODFW) led development of this plan in collaboration with NMFS and numerous stakeholders, including other federal agencies, state agencies, local governments, tribes, industry and environmental representatives, and the public. An expert panel, stakeholder team, and planning team provided additional input and guidance. The resulting plan serves both as a federal recovery plan under the ESA and a State of Oregon conservation plan under Oregon's Native Fish Conservation Policy. The plan also influences actions implemented for the Oregon Plan for Salmon and Watersheds, some of which are coordinated by the Oregon Watershed Enhancement Board. This ESU-level plan includes the *Lower Columbia River Conservation and Recovery Plan for Oregon Populations of Salmon and Steelhead* (ODFW 2010) as Appendix A.[16]

1.5.2.4 Relationship Between Management Unit Plans and ESU-Level Plan

This ESU-level recovery plan for the Lower Columbia River ESUs and DPS is a synthesis of the Washington, White Salmon, and Oregon Lower Columbia management unit plans, additional analyses as appropriate, and related recovery plan modules that address estuary habitat and hydropower (see Section 1.5.3). The ESU-level recovery plan provides an ESU-level perspective on the baseline status of the Lower Columbia River ESUs and DPS, goals and delisting criteria, limiting factors, scenarios for reducing threats, recovery actions, implementation, and research, monitoring and evaluation. As required by the ESA, this ESU-level recovery plan fully addresses the recovery needs of the Lower Columbia River salmon ESUs and steelhead DPS, throughout their life cycle and across their geographic range, which encompasses multiple management units.

The more detailed Washington, White Salmon, and Oregon Lower Columbia management unit recovery plans are part of this ESU-level plan, which includes them as appendices. By doing so, the ESU-level plan endorses the management unit plans' recommendations and acknowledges that certain recovery decisions (such as decisions about site-specific habitat actions) are most appropriately left to local recovery planners and implementers, as represented in the management unit plans. Where there are differences between the ESU-level plan and the management unit plans that affect regulatory decisions, management decisions, and implementation of recovery actions, NMFS will coordinate with the management unit leads (Washington's Lower Columbia Fish Recovery Board, the Oregon Department of Fish and Wildlife, and the Washington Gorge Implementation Team) to resolve those discrepancies.

1.5.3 Challenges of Bi-State Coordination and Multiple Management Units

The fact that the Lower Columbia River salmon ESUs and steelhead DPS span two states and three separate management units presents certain challenges in developing an ESU-level recovery plan. First, the sheer volume of information generated through three

[16] The Oregon management unit plan is available at http://www.dfw.state.or.us/fish/CRP/lower_columbia_plan.asp.

separate planning processes is large. This ESU-level plan selects the most relevant information from the three management unit plans to present a coherent overview of the baseline status and potential future of the listed ESUs and DPS; where appropriate, the document refers the reader to more detailed information available in the individual management unit plans.

Second, the level of effort needed to recover the listed ESUs and DPS also is large, and how the responsibility for achieving recovery is apportioned between Oregon and Washington has significant financial and organizational implications for implementing entities in each state. Early in the recovery planning process, management unit planners decided to share the recovery burden between the two states. However, they agreed that in doing so they would consider the historical proportion of populations in each state and where the prospects for recovery are most promising (LCFRB 2010a). Thus, for some ESUs the burden of recovery falls more heavily on one side of the Columbia River than the other. For example, Washington carries the greatest burden in recovering tule fall Chinook salmon, in part because most of the historical fall Chinook salmon populations were in Washington.

Third, the three management unit planning teams took different approaches to developing their recovery plans, in part because different salmon recovery planning structures are in place in Oregon and Washington but also because NMFS encourages recovery plans to be locally developed and supported. This naturally leads to unique approaches. Although each management unit plan contains the elements required for a recovery plan and draws on common scientific principles and resources provided by the WLC TRT, the specific approaches used to develop the required elements, and sometimes the results, varied among the management unit plans. Where relevant, this ESU-level plan acknowledges and describes the differences in approaches and results and discusses the implications of those differences.

Fourth, given the complexity of the salmonid life cycle, some regional issues that affect the Lower Columbia River ESUs and DPS are beyond the scope of any one management plan. Examples include the Federal Columbia River Power System (FCRPS) and the role of the Columbia River estuary in the life cycle of the listed ESUs and DPS. Such issues need to be addressed at the regional level. Thus, NMFS developed the following recovery plan modules that analyze regional issues:

- *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a; see Appendix D.) The estuary document focuses on habitat in the lower Columbia River below Bonneville Dam and how it affects the survival of ESA-listed, coho, Chinook, chum, and steelhead from throughout the Columbia Basin, including the Lower Columbia River ESUs and DPS. Geographically, the module covers the tidally influenced reaches of the lower river, estuary, and plume. The module identifies and prioritizes limiting factors and threats in the estuary that affect salmonid viability and describes 23 broad actions that, if implemented, would increase the survival of salmon and steelhead during their time in the estuary and plume. Costs, implementation considerations, and research, monitoring, and evaluation needs also are addressed. The actions and recommendations in the estuary module have been incorporated into this ESU-level recovery plan for the Lower Columbia River salmon ESUs and steelhead DPS.

- *Recovery Plan Module: Mainstem Columbia River Hydropower Projects* (NMFS 2008a; see Appendix E.) The hydropower module summarizes the general effects of Columbia River mainstem hydropower projects on all 13 ESA-listed anadromous salmonids in the Columbia Basin. The module's geographical area consists of the accessible mainstem habitat in the upper Columbia River (to the tailrace of Chief Joseph Dam) and Snake River (to the tailrace of Hells Canyon Dam) and downstream to the tailrace of Bonneville Dam. The module describes how salmon and steelhead use the mainstem, habitat limiting factors and threats related to mainstem hydropower projects and operations, and expected actions (including site-specific management actions) or strategy options to address those threats. The actions are those found in the 2008 Federal Columbia River Power System Biological Opinion and its 2010 Supplement (NMFS 2008f and 2010a), which constitute mitigation and recovery actions for the FCRPS through 2018. The hydropower module presents recent survival estimates for ESA-listed populations migrating past mainstem hydroelectric project, and prospective passage survival rates for juveniles for 2014 and beyond.

The estuary and hydropower recovery plan modules provided a consistent set of assumptions and recovery actions for regional-scale issues that management unit planning teams then incorporated into their management unit plans. Additional bi-state consultation and coordination were needed to ensure consistent treatment of hydropower and estuary issues across the management unit plans, as well as of hatchery and harvest issues. Chapter 4 presents additional information on regional-scale limiting factors and recovery strategies.

Topics such as implementation, monitoring, adaptive management, and funding priorities also have both local-scale and regional aspects. This ESU-level recovery plan presents a regional perspective on such topics. Again, considerable bi-state consultation and coordination were needed to integrate these topics across the individual management plans and to develop a regional perspective and approach for the ESU-level recovery plan.

1.5.4 Challenges of Addressing Multiple ESUs/DPSs in a Single Recovery Plan

Preparing a single recovery plan for multiple ESUs presents challenges in terms document organization, level of detail, and prioritization of actions. In some cases, the same limiting factors and threats affect more than one ESU, and the species-specific recovery strategies have the same or similar components. For example, for each ESU the management unit plans propose some similar tributary habitat actions to improve watershed health overall, which will benefit every ESU. In other cases the limiting factors, threats, and recovery actions are unique to an ESU or a run component of a species. To avoid unnecessary repetition from one species analysis to the next, this ESU-level recovery plan includes a chapter on regional-scale limiting factors and recovery strategies; this information applies to multiple ESUs. When appropriate, the individual species analyses refer readers to the regional chapter (Chapter 4) instead of repeating the same or similar recovery strategy information from one ESU to the next. This is the case with watershed-based tributary habitat actions, the estuary habitat strategy, mainstem hydropower actions, the predation strategy, and certain elements of the harvest and hatchery strategies.

Given the large amount of information available in three management unit plans on four different species, another (and related) challenge is to present relevant material at the appropriate level of detail in the ESU-level recovery plan. To maintain a cohesive narrative while not overwhelming the reader, this plan presents some information at a relatively abstract, summary level, with the understanding that readers will refer to the management unit plans for additional detail as their needs and interests dictate.

Lastly, addressing multiple ESUs in a single plan raises the question of how recovery actions will be prioritized across ESUs. This is an issue that the management unit plans, for the most part, did not explicitly address, although they did offer some guidance on the topic. As described in Section 11.2, additional prioritization work is needed at both the management unit and subdomain levels, both within and among threat categories. Section 11.2 discusses prioritization in more detail, summarizing the management unit plans' approaches and offering perspectives for potential consideration during implementation of this recovery plan.

1.5.5 Relationship to Other Processes

Development of this ESU-level recovery plan has been informed by many different conservation and recovery planning processes in Oregon, Washington, and the Pacific Northwest region. Some of these planning processes have been completed, but many are still under way and will continue to influence the content of this recovery plan as it is finalized, along with its implementation in the Lower Columbia subdomain. Planning efforts that have a significant bearing on the design or implementation of this recovery plan are described below.

1.5.5.1 Willamette-Lower Columbia ESA Executive Committee (Ex Com)

The Willamette-Lower Columbia ESA Ex Com performed a coordinating role during the early stages of recovery planning for this domain. Members included the Oregon and Washington Departments of Fish and Wildlife, the governors' offices of Oregon and Washington, federal agencies, the Lower Columbia Estuary Partnership, the Lower Columbia Fish Recovery Board, and the Willamette Partnership. During its tenure, the Ex Com worked to help align ongoing regional, state, and local processes with recovery planning; address bi-state and tribal coordination issues; develop agreement on recovery goals and other elements of recovery plans; ensure adequate integration of scientific information with recovery actions and strategies; and ensure that locally developed management unit plans address the needs of the full ESUs or DPSs.

1.5.5.2 Northwest Power and Conservation Council Subbasin Plans

Congress created the Northwest Power and Conservation Council (NPCC) in 1980 to give Washington, Oregon, Idaho, and Montana a voice in regional energy planning and in mitigating the effects of the Federal Columbia River Power System on fish and wildlife. The NPCC developed the Columbia Basin Fish and Wildlife Program, which solicits and evaluates proposals for on-the-ground projects and research to meet these responsibilities. The Bonneville Power Administration (BPA) provides funding for NPCC-identified priority projects. In 2005, to update the Columbia Basin Fish and Wildlife Program, the NPCC completed a watershed planning effort that resulted in locally developed plans for 58 of 62 designated subbasins (tributary watersheds or mainstem segments) in the Columbia Basin, including subbasins within the geographic range of the Lower Columbia River salmon ESUs and steelhead DPS. The plans address the needs of both fish and wildlife.

The subbasin plans provide valuable information on watershed-scale freshwater habitat conditions, limiting factors, and threats, as well as strategies at a subbasin level for addressing those limiting factors and threats. NMFS and its planning partners are using subbasin plans as building blocks for ESA salmon and steelhead recovery plans, and information from the Lower Columbia, White Salmon, Columbia Gorge, Hood, and Willamette subbasin plans has been incorporated into this ESU-level recovery plan. NMFS will continue to work with the NPCC and BPA to coordinate implementation of the Columbia Basin Fish and Wildlife program and ESA salmon recovery plans.

1.5.5.3 2008 FCRPS Biological Opinion and 2010 Supplement

As described in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) and elsewhere, a limiting factor for Lower Columbia River salmon and steelhead during their time in the Columbia River estuary and, potentially, the plume is flow regulation and other effects related to the Federal Columbia River Power System (FCRPS) and non-federal Columbia and Snake River dams. The FCRPS is a series of dams and reservoirs that are managed for multiple purposes: power production, flood control, irrigation, navigation, recreation, and fish, wildlife, and cultural resource protection. Dam-related alterations of natural flow patterns in the lower Columbia River, estuary, and plume are responsible for decreased water velocity, longer migratory travel time (which increases exposure to predators) and higher water temperatures during the spring freshet. Each of these factors is associated with mortality of ESA-listed salmon and steelhead.

The ESA requires that federal actions neither jeopardize the continued existence of a listed species nor result in destruction or adverse modification of designated critical habitat. Under law, the agencies that operate the FCRPS—the Bonneville Power Administration, U.S. Army Corps of Engineers, and Bureau of Reclamation (collectively referred to as the Action Agencies)—must consult with NMFS on proposed FCRPS operations that may affect a listed fish species or its habitat. The product of such consultation is a Biological Opinion.

In preparation for NMFS' 2008 Biological Opinion on the FCRPS, the Action Agencies concluded that, without further mitigation, operation of FCRPS projects would jeopardize listed species. Consequently, the Action Agencies presented NMFS with a package of additional measures designed to benefit listed species, including the Lower Columbia River salmon ESUs and steelhead DPS. Some of these actions were drawn from the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NOAA Fisheries 2009), which describes the FCRPS's effects on fish and presents recommendations and strategies for action. NMFS incorporated the Action Agencies' proposed additional mitigation measures into its analysis for the 2008 FCRPS Biological Opinion, which considers the mainstem Columbia from Bonneville Dam to the river's mouth.

The 2008 FCRPS Biological Opinion was issued on May 5, 2008. In February 2010, NMFS issued the 2010 Supplemental Biological Opinion for the FCRPS (NMFS 2010a). This Supplemental Biological Opinion integrated elements from the 2008 Biological Opinion and the Adaptive Management Implementation Plan (AMIP). The AMIP included accelerated and enhanced actions to protect Columbia Basin salmon and steelhead, including commitments to additional estuary habitat improvement actions under a new agreement with the state of Washington and additional efforts to control native and exotic predators. It also included enhanced research and monitoring and specific biological triggers for contingencies linked to unexpected declines in the abundance of listed salmon and steelhead.

At the time this recovery plan was being drafted, it was the position of the State of Oregon that additional or alternative actions should be taken in mainstem operations of the FCRPS for ESA-listed salmon and steelhead. Some additional or alternative actions recommended by Oregon, while considered, were not included in NMFS' 2008 FCRPS Biological Opinion and its 2010 Supplement because NMFS is not in agreement regarding the need for or efficacy of these additional actions. At this time, Oregon is a plaintiff in litigation against various federal agencies, including NMFS, challenging the adequacy of the measures contained in the current FCRPS Biological Opinion. On August 2, 2011, Judge James A. Redden of the U.S. District Court (District of Oregon) issued an opinion and order that remanded the 2008 Biological Opinion and its 2010 Supplement back to NMFS. Judge Redden left the Biological Opinion in place until a new opinion is issued no later than January 1, 2014, and ordered that all of the opinion's mitigation measures be funded and implemented in that time.

1.5.5.4 Columbia River Hatchery Scientific Review Group (HSRG)

In 2005, Congress directed NMFS to use the Puget Sound and coastal Washington hatchery reform project as a model for similar reform in the Columbia Basin. The Columbia River Hatchery Scientific Review Group (HSRG) conducted a collaborative, scientific review and identified alternatives for managing hatchery programs and fisheries to meet managers' goals for harvest and recovery (Hatchery Scientific Review Group 2009).

The HSRG concluded that hatcheries play an important role in the management of salmon and steelhead populations in the Pacific Northwest. Nevertheless, the traditional practice of replacing natural populations with hatchery fish to mitigate for habitat loss and mortality resulting from hydropower dams is not consistent with contemporary conservation principles and scientific knowledge. Hatchery fish cannot replace lost habitat or the natural populations that rely on that habitat.

The HSRG concluded that hatchery programs should be viewed as tools that can be managed as part of a coordinated strategy to meet watershed or regional resource goals, in concert with actions affecting habitat, harvest rates, water allocation, and other factors that influence salmon and steelhead survival. The HSRG summary conclusions regarding areas where current hatchery and harvest practices need to be reformed through policy, management, research, and monitoring practices were as follows:

- Manage hatchery broodstocks to achieve proper genetic integration with, or segregation from, natural populations.
- Promote local adaptation of natural and hatchery populations.
- Minimize adverse ecological interactions between hatchery- and natural-origin fish.
- Minimize effects of hatchery facilities on the ecosystem.
- Maximize survival of hatchery fish.

The HSRG also developed three principles for hatchery management that are applicable to hatchery programs across Puget Sound, the Washington Coast, and the Columbia Basin: (1) develop clear, specific, and quantifiable harvest and conservation goals for natural and hatchery populations within an "all-H" context, (2) design and operate hatchery programs in a scientifically defensible manner, and (3) monitor, evaluate, and adaptively manage hatchery programs. The HSRG concluded that the more closely hatchery programs adhere to these principles, the greater the likelihood of their contribution to the managers' harvest and conservation goals.

Local recovery planners considered the HSRG's general and population-specific recommendations in developing hatchery actions for their recovery plans.

1.5.5.5 State-Level Planning Processes

Native Fish Conservation Policy

The Oregon Fish and Wildlife Commission adopted the Native Fish Conservation Policy (NFCP) in November 2002 to provide a basis for managing fisheries, habitat, hatcheries, predators, competitors, and pathogens in balance with sustainable production of naturally produced native fish. The three goals of the policy are to (1) prevent the serious depletion of native fish, (2) restore and maintain naturally produced fish in order to provide substantial ecological, economic and cultural benefits to the citizens of Oregon, and (3) foster and sustain opportunities for fisheries consistent with the conservation of naturally produced fish and responsible use of hatcheries. The NFCP is to be implemented and its goals achieved through the development of conservation plans for individual groups of populations, or species management units. The *Lower Columbia River Conservation and Recovery Plan for Oregon Populations of Salmon and Steelhead* (Oregon Department of Fish and Wildlife 2010) meets the requirements for NFCP conservation plans as well as those for an ESA recovery plan for salmon and steelhead.

Oregon Plan for Salmon and Watersheds

In 1997 Oregon's Governor and Legislature adopted the Oregon Plan for Salmon and Watersheds to begin state-led recovery efforts. The mission of the plan is to restore Oregon's native fish populations and the aquatic systems that support them to productive and sustainable levels that will provide substantial environmental, cultural, and economic benefits. The plan has a strong focus on salmon, with actions designed to improve water quality and quantity and restore habitat.

Oregon is implementing the Oregon Plan for Salmon and Watersheds in a manner that is consistent with ESA recovery planning and other Oregon programs related to salmon. Watershed councils and soil and water conservation districts lead efforts in many subbasins, with support from landowners and other private citizens, recreational and commercial fishing interests, the timber industry, environmental groups, agriculture, utilities, businesses, tribes, and all levels of government. The Oregon Plan relies on volunteerism and stewardship, public education and awareness, scientific oversight, coordinated tribal and government efforts, and ongoing monitoring and adaptive management to achieve program success.

Oregon Watershed Enhancement Board

The Oregon Watershed Enhancement Board (OWEB) is a state agency that supports Oregon's efforts to improve water quality, strengthen ecosystems, and restore salmon runs. OWEB coordinates the Oregon Plan for Salmon and Watersheds' implementation of recovery plans for both state and federally listed species, including ESA-listed salmonids in the Columbia River and Upper Willamette basins. OWEB administers a grant program funded from Oregon Lottery proceeds and salmon license plate sales. The program funds the cooperative conservation work of a wide variety of participants, with up to 70 percent of the grant funding apportioned to on-the-ground restoration projects. OWEB also administers three other salmon-related programs: (1) the federal Pacific Coastal Salmon Recovery Funds (PCSRF) for the state, for projects that measurably contribute to the recovery of ESA-listed salmon and steelhead, (2) the OWEB Small Grant Program for local watershed restoration, and (3) the Conservation Reserve Enhancement Program (CREP), a voluntary land retirement program that helps agricultural landowners establish riparian vegetation along streams.

Washington Watershed Planning

The state Watershed Management Act (Revised Code of Washington [RCW] 90.82) gives local communities the opportunity to plan for the future use of their water resources in consultation with state agencies. To facilitate this planning, the state has been divided into Water Resource Inventory Areas (WRIAs), seven of which are within the Lower Columbia recovery planning area.[17] The Lower Columbia Fish Recovery Board coordinates watershed planning in four of the seven lower Columbia WRIAs. Klickitat County coordinates watershed planning in the White Salmon WRIA. Watershed plans for these WRIAs will address issues associated with water quantity, water quality, stream flows, and habitat, including the current condition of fish habitat and measures to protect or enhance habitat to support salmon recovery efforts.

Water quantity and quality and stream flow studies and data collected by the watershed planning initiatives have been incorporated into the *Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan* (LCFRB 2010a), and habitat data collected

---

[17] WRIA 24 is partially in the Lower Columbia River subdomain; WRIAs 25, 26, 27, 28, and 29 are wholly within the Lower Columbia River subdomain; WRIA 29 is split into 29A (Wind) and 29B (White Salmon).

through the recovery planning effort has been shared with the watershed planning effort. Policies, strategies, actions, and priorities associated with ESA recovery planning and water resource planning are being coordinated to ensure that they are compatible and complement each other.

Washington Salmon Habitat Protection and Restoration

The Washington Salmon Recovery Act (RCW 77.85) provides for the funding of habitat protection and restoration efforts, requires local and regional program organizations to identify and prioritize project needs, and directs the Washington Department of Fish and Wildlife to develop guidance for regional salmon recovery efforts.

The Salmon Recovery Funding Board (SRFB) coordinates the funding process on the statewide level. It establishes program policies and directions and grant requirements, screens project proposals, and awards grants. Lead entities coordinate the process on the local or regional level. They develop habitat protection and restoration strategies for their area and solicit, evaluate, rank, and propose projects to the SRFB. The Lower Columbia Fish Recovery Board serves as the lead entity for most of the lower Columbia subdomain. In this capacity, the LCFRB has developed and annually updated and expanded a lower Columbia habitat strategy that provides a basis for prioritizing proposed habitat projects. Development of the strategy has been merged with ESA recovery planning in Washington such that elements of the strategy became an integral part of the *Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan* (LCFRB 2010a) and thus this ESU-level recovery plan. Klickitat County serves as the lead entity for the White Salmon subbasin and has developed a strategy to guide prioritization of proposed habitat projects for that watershed.

1.6 Tribal Treaty and Trust Responsibilities

The salmon and steelhead that were once abundant in the watersheds of the lower Columbia Basin were crucial to Native Americans throughout the region. Pacific Northwest Indian tribes today retain strong spiritual and cultural ties to salmon and steelhead, based on thousands of years of use for tribal religious/cultural ceremonies, subsistence, and commerce. Many Northwest Indian tribes have treaties reserving their right to fish in usual and accustomed fishing places, including areas covered by this recovery plan. Additionally, four Washington coastal tribes have treaty rights to ocean salmon harvest that may include some Lower Columbia River salmon stocks. These Columbia Basin and Washington Coast treaty tribes are co-managers of salmon stocks and participate in management decisions, including those related to hatchery production and harvest. Some other tribes in the Columbia Basin, whose reservations were created by Executive Order, do not have treaty reserved rights but do have a trust relationship with the federal government and an interest in salmon and steelhead management, including harvest and hatchery production. Other Indian tribes, while not asserting treaty reserved rights, do fish for subsistence and ceremonial purposes in areas covered by this plan, in compliance with agreements with the state of Oregon.

The NMFS Regional Administrator, in testimony before the U.S. Senate Indian Affairs Committee (Lohn 2003), emphasized the importance of this co-manager relationship: "We have repeatedly stressed to the region's leaders, tribal and non-tribal, the importance of our co-management and trust relationship to the tribes. NMFS enjoys a positive working relationship with our Pacific Northwest tribal partners. We view the relationship as crucial to the region's future success in recovery of listed salmon."

Native American treaty-reserved fishing rights in the Columbia basin are under the continuing jurisdiction of the U.S. District Court for the District of Oregon in the case *United States v. Oregon*, No. 68-513 (filed in 1968). In *U.S. v. Oregon*, the Court affirmed that certain treaties reserved for the tribes up to 50 percent of the harvestable surplus of fish destined to pass through their usual and accustomed fishing areas. The *U.S. v. Oregon* process affects the allocation of harvest among various fisheries and thus affects how fisheries are managed in the lower Columbia River; in addition, Lower Columbia River populations that spawn above Bonneville Dam are intercepted in tribal fisheries.

Restoring and sustaining a sufficient abundance of salmon and steelhead for harvest is an important requirement in fulfilling tribal fishing aspirations. It is NMFS' policy to promote restoration of salmon and steelhead runs sufficient for tribal harvest. This policy is described in a July 21, 1998, letter from Terry D. Garcia, Assistant Secretary for Oceans and Atmosphere, U.S. Department of Commerce, to Mr. Ted Strong, Executive Director of the Columbia River Inter-Tribal Fish Commission. This letter states that recovery "must achieve two goals: (1) the recovery and delisting of salmonids listed under the provisions of the ESA, and (2) the restoration of salmonid populations over time, to a level to provide a sustainable harvest sufficient to allow for the meaningful exercise of tribal fishing rights." Thus it is appropriate for recovery plans to acknowledge tribal harvest goals. Where tribal harvest goals can only be met through hatchery production, recovery plans will identify strategies and actions to ensure that the hatchery production is consistent with recovery of naturally spawning populations.

2. Defining Viability for Salmon and Steelhead

This chapter presents biological background information that will aid the reader in understanding the limiting factor and threats analyses, recovery criteria and goals, and recovery strategies that are part of this ESU-level recovery plan. Specifically, the chapter describes basic concepts in salmonid biology (i.e., biological structure, population viability, and critical habitat), presents biological criteria the WLC TRT developed for assessing the viability of Lower Columbia River salmon and steelhead, and briefly summarizes methods and benchmarks the WLC TRT recommends for evaluating individual population status. (Chapter 5 provides additional details on methods.) Recovery goals in the management unit plans and NMFS' criteria for delisting the Lower Columbia River species are both based on this work of the WLC TRT. (See Chapter 3 for recovery goals and delisting criteria.)

2.1 ESU/DPS Biological Structure

Salmonid species' homing propensity (their tendency to return to the locations where they originated) creates unique patterns of genetic variation and connectivity among spawning areas across the landscape. Diverse genetic, life history, and morphological characteristics have evolved in salmon and steelhead over generations, creating runs adapted to diverse environments. It is this variation that gives a salmonid species as a whole the resilience to persist over time.

Historically, a salmon ESU or steelhead DPS typically contained multiple populations connected by some small degree of genetic exchange that reflected the geography of the river basins in which they spawned. Thus, the overall biological structure of the ESU or DPS is hierarchical, and spawners in the same area of the same stream share more characteristics than those in the next stream over. Fish whose natal streams are separated by hundreds of miles generally have less genetic similarity. The ESU or DPS is essentially a metapopulation defined as a group of populations connected by limited exchange of migrants. Recovery planning efforts focus on this biologically based hierarchy, which reflects the degree of connectivity between the fish at each geographic and conceptual level.

McElhany et al. (2000) identified two levels in this hierarchy for recovery planning purposes: the evolutionarily significant unit and the independent population. The WLC TRT identified an additional level between the population and ESU/DPS levels: the stratum (McElhany et al. 2003). Strata are analogous to major population groups (MPGs) as defined by the Interior Columbia TRT and to geographic regions described by the Puget Sound TRT.

This recovery plan adopts the ESU/DPS, stratum, and population structure described below. NMFS and the WLC TRT identified the ESUs/DPS, strata, and populations of Lower Columbia River salmon and steelhead based on geography, migration rates, genetic attributes, life history patterns, phenotypic characteristics, population dynamics, and environmental and habitat characteristics (Myers et al. 2006), as well as an understanding of the characteristics of viable salmonid populations (McElhany et al. 2000).

2.1.1 Evolutionarily Significant Units and Distinct Population Segments

Two criteria define an ESU of salmon under NMFS' ESU policy: (1) it must be substantially reproductively isolated from other conspecific units, and (2) it must represent an important component of the evolutionary legacy of the species (Waples 1991).

Two similar but slightly different criteria define a DPS of steelhead under the joint NMFS-U.S. Fish and Wildlife Service DPS policy: (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.

An ESU or DPS can 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.

2.1.2 Strata

Within an ESU or DPS, independent populations can be grouped into larger groups based on ecological zone and dominant life history strategy, expressed as run timing, meaning the time of year when salmon return to native freshwater systems. These major population groups, or strata, share similar genetic, geographic, and/or habitat characteristics. Strata are isolated from one another over a longer time scale than that defining the individual populations, but they retain a degree of connectivity greater than that between different ESUs or DPSs. Figure 2-1 shows the relationship between ESU/DPS, strata, and independent populations.

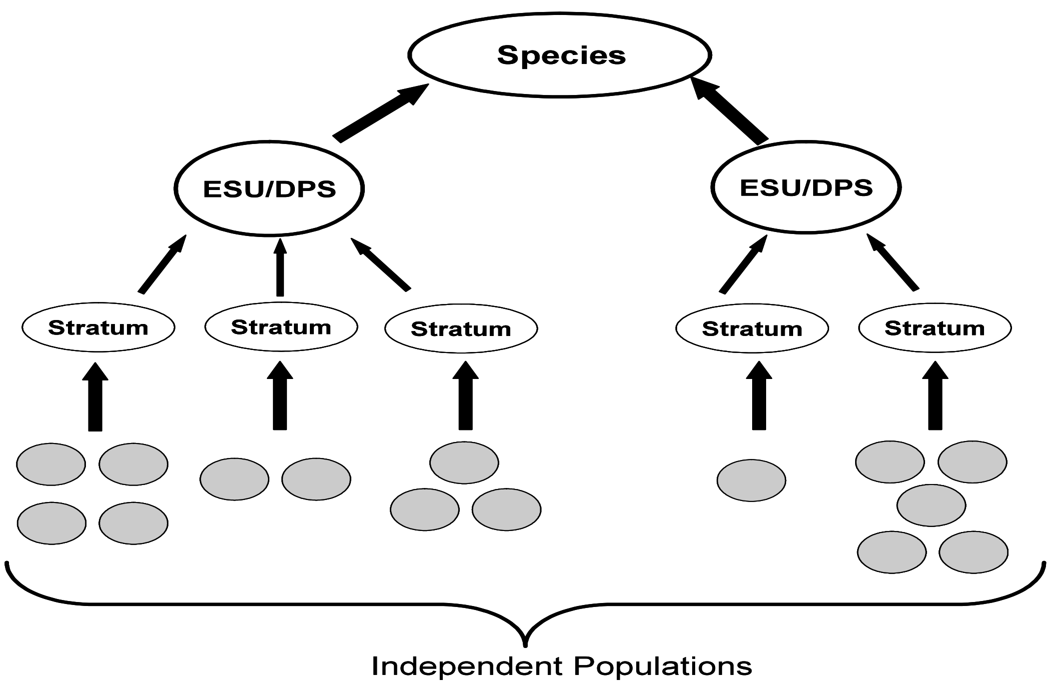

Figure 2-1. *Hierarchical Levels of Salmonid Species Structure for ESU/DPS Recovery Planning*
Source: ODFW 2010.

In the case of Lower Columbia River salmon and steelhead, strata are defined by a combination of ecological zone—Coast, Cascade, or Gorge—and dominant life history strategy, such as spring, fall, or late fall run timing. For example, Cascade fall Chinook and Cascade spring Chinook are separate strata. (See Tables 6-2, 7-2, 8-1, and 9-2 for the historical populations and strata for the salmon ESUs and steelhead DPS covered by this recovery plan.)

2.1.3 Independent Populations

McElhany et al. (2000) defined an independent population as follows:

> "… 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 our purposes, 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."

It is seldom possible to obtain exact measures of the degree of interbreeding between groups of fish. Therefore, the WLC TRT used several kinds of information to build up an understanding of population boundaries: geography, migration rates, genetic attributes, patterns of life history and phenotype (visible characteristics), abundance data, and environment (Myers et al. 2006). According to WLC TRT definitions, a population cannot be larger than a stratum or an ESU or DPS.

2.2 Viable Salmonid Populations

Viability is a key concept within the context of the Endangered Species Act. A viable salmonid ESU or DPS is naturally self-sustaining over the long term. A viable salmonid population has a negligible risk of extinction over a 100-year time frame (McElhany et al. 2000). McElhany et al. (2000) describe viable salmonid populations (VSPs) in terms of four parameters: abundance, population productivity or growth rate, population spatial structure, and life history and genetic diversity. Although these parameters sometimes are analyzed discretely, they are closely associated, such that improvements in one parameter typically cause or are related to improvements in another. For example, productivity improvements might depend on increased diversity or habitat quality and be accompanied by increased abundance and distribution.

2.2.1 Abundance and Productivity

Abundance refers to the number of spawners (adults on the spawning ground), averaged over a time period sufficient to account for year-to-year fluctuations that are due to natural environmental variation. The productivity of a population (the average number of surviving offspring per parent) is a measure of the population's ability to sustain itself. Productivity can be measured as spawner-to-spawner ratios (returns per spawner or recruits per spawner, meaning adult progeny to parent), annual population growth rate, or trends in abundance. Population-specific estimates of abundance and productivity are derived from time series of annual estimates, which typically are subject to a high degree of annual variability and sampling-induced uncertainties.

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 salmonid 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.

The VSP guidelines for abundance recommend that a viable population should (1) be large enough to have a high probability of surviving environmental variation observed in the past and expected in the future, (2) be resilient to environmental and anthropogenic disturbances, (3) maintain genetic diversity, and (4) provide ecosystem functions (McElhany et al. 2000). Factors suggesting that a population is at a critically low size include decreased reproductive success because individuals cannot efficiently find mates, fixation of harmful genetic mutations or reduced fitness as a result of inbreeding, and random demographic effects, such as if the variation in individual reproduction becomes important.

Productivity guidelines for viability are reached when a population's productivity is such that abundance can be maintained above the viable level, viability is independent of hatchery subsidy, viability is maintained even during sequences of poor environmental conditions, declines in abundance are not sustained, life history traits are not in flux, and conclusions about a population's productivity are independent of uncertainty in parameter estimates (McElhany 2000).

Viability analyses of Lower Columbia River salmon and steelhead suggest that, in general, populations of at least 500 fish are needed to ensure that critically low numbers do not result from normal variations in environmental conditions (McElhany et al. 2003). However, this number does not reflect actual minimum viable population sizes for the purposes of recovery planning. The abundance and productivity needed for recovery varies from one population to the next because of differences in habitat quantity, habitat quality, fish distribution, juvenile production, spatial structure, and life history and genetic diversity. The recovery goals in Chapter 3 reflect these variations.

2.2.2 Spatial Structure and Diversity

Considerations of spatial structure and diversity are combined in the evaluation of a salmonid population's status because they often overlap. 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. Spatial structure influences the viability of salmon and 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, 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. (However, excessive exchange of migrants above historical levels can impede the process of local adaptation.)

Diversity refers to the distribution of life history, behavioral, and physiological traits within and among populations. Some 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).

Like spatial structure, population-level diversity is important for long-term persistence of salmon and steelhead. Populations exhibiting greater diversity are generally more resilient to short-term and long-term environmental changes. Phenotypic diversity, which includes variation in morphology and life history traits, allows more diverse populations to use a wider array of environments, and protects populations against short-term temporal and spatial environmental changes. Underlying genetic diversity provides the ability to survive long-term environmental changes.

Because neither the precise role that diversity plays in salmonid population viability nor the relationship of spatial processes to viability is completely understood, the management unit plans and this ESU-level recovery plan adopt the principle from McElhany et al. (2000) that historical spatial structure and diversity should be taken as a "default benchmark," on the assumption that historical, natural populations did survive many environmental changes and therefore must have had adequate spatial structure and diversity.

McElhany et al. (2000) also offers spatial structure and diversity guidelines for viable salmonid populations. Spatial structure guidelines are reached when the number of habitat patches is stable or increasing, stray rates are stable, marginally suitable habitat patches are preserved, refuge source populations are preserved, and uncertainty is taken into account. Diversity guidelines are reached when variation in life history, morphological, and genetic traits is maintained; natural dispersal processes are maintained; ecological variation is maintained; and the effects of uncertainty are considered.

For all four of the viable salmonid population parameters, the guidelines recommend that population-specific status evaluations, goals, and criteria take into account the level of scientific uncertainty about how an individual parameter relates to a population's viability (McElhany 2000).

2.3 Critical Habitat

The ESA requires the federal government to designate critical habitat for any species it lists under the ESA, with critical habitat defined as occupied areas that contain physical or biological features that are essential for the conservation of the species and that may require special management or protection, and unoccupied areas that are essential for conservation. Critical habitat designations must be based on the best scientific information available, in an open public process, within specific time frames. The designations are one factor to consider during the identification and prioritization of recovery actions in recovery plans.

A critical habitat designation applies only when federal funding, permits, or projects are involved. Under section 7 of the ESA, all federal agencies must ensure that any actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of a listed species, or destroy or adversely modify its designated critical habitat. Before critical habitat is designated, careful consideration must be given to its economic impacts, impacts on national security, and other relevant impacts. The Secretary of Commerce may exclude an area from critical habitat if the benefits of exclusion outweigh the benefits of designation, unless excluding the area will result in the extinction of the species concerned.

In determining which areas should be critical habitat, NMFS identified the geographic areas occupied by the species and the physical or biological features essential for the conservation of the species. For all salmon ESUs and steelhead DPSs this includes sites and habitat components that support one or more life stages; examples include (1) freshwater spawning sites, (2) freshwater rearing sites, (3) freshwater migration corridors, and (4) estuarine areas. NMFS also identified features associated with these types of sites that play an essential role in maintaining habitat health. These features also describe the habitat factors associated with viability for all ESUs and DPSs (although the specific habitat requirements for each ESU and DPS differ by life history type and life stage).

On September 2, 2005, NMFS published a final rule (70 *Federal Register* 52630) to designate critical habitat for 13 ESUs and DPSs of ESA-listed salmon and steelhead. Lower Columbia River Chinook, steelhead, and chum were included in this rule, but critical habitat for Lower Columbia River coho has not yet been designated. Critical Habitat Assessment Review Teams rated the conservation value of all watersheds that supported populations of the listed species and, depending on the importance of the watersheds to salmonid survival, assigned ratings of high, medium, or low. These ratings were used in determining the final critical habitat designations.

The final designations focus on certain physical and biological elements that support one or more salmonid life stages (spawning, rearing, migration, and foraging) and that are essential to the conservation of the species. The designations balanced ratings of the areas that provide the greatest biological benefits for listed salmon and steelhead with economic and other costs.

Maps of the critical habitat areas are available at http://www.nwr.noaa.gov/Salmon-Habitat/Critical-Habitat/CH-Maps.cfm and in the Federal Register notice, which also contains legal descriptions of the critical habitat areas.

NMFS recognizes that salmon habitat is dynamic and that current understanding of areas important for conservation will likely change as recovery planning sheds light on areas that can and should be protected and restored. NMFS will update the critical habitat designations as needed based on information developed during recovery plan implementation.

2.4 WLC TRT Biological Viability Criteria

The WLC TRT developed biological viability criteria that it recommends be used to assess long-term extinction risk at the ESU, stratum, and population level. Based on best available science, these criteria consist of a combination of general statements and metrics that characterize viability; the WLC TRT also suggested methods of applying the criteria to assess the probability that a population, stratum, or ESU will persist. As described in Chapter 3, the biological viability criteria summarized below served as an important foundation from which the management unit planners decided on recovery goals and NMFS developed delisting criteria for Lower Columbia River salmon and steelhead ESUs.

2.4.1 Background

NMFS asked the WLC TRT to develop biological viability criteria for use as the basis of recovery goals and delisting criteria. Biological viability criteria describe ESU or DPS characteristics associated with a low risk of extinction for the foreseeable future and are defined at the ESU/DPS, stratum, and population levels. (A stratum is a group of independent populations that share similar environments, life-history characteristics, and geographic proximity.) The status of a salmon ESU or steelhead DPS as a whole is evaluated by considering the status of each of its strata; the status of a stratum, in turn, is determined by considering the status of each of its component populations.

At the ESU or DPS level, viability criteria inform the questions of how many and which populations need to be viable (i.e., at a low risk of extinction) and what the appropriate risk levels are for other populations so that the ESU or DPS as a whole has a low risk of extinction. For the Lower Columbia River salmon ESUs and steelhead DPS, biological viability criteria are based on guidelines developed by NMFS' Northwest Fisheries Science Center and published as a NMFS technical memorandum, *Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units* (McElhany et al. 2000). The guidelines in McElhany et al. (2000) are intended to aid in the following:

1. Management of risks to the ESU or DPS from catastrophic events. Having multiple, geographically dispersed populations in an ESU or DPS reduces the risk of extinction from a single catastrophic event.

2. Maintenance of long-term demographic processes. Having multiple populations in an ESU or DPS—some in proximity and some dispersed—allows natural demographic processes to occur, such as population-level extinction and recolonization.

3. Maintenance of long-term evolutionary potential. Having multiple populations distributed across the geography of the ESU or DPS and representing diverse life histories and phenotypes allows for the genetic processes characteristic of long-term evolution.

At the stratum level, the WLC TRT developed criteria to guide decisions about which populations to target for various levels of viability. At the population level, the TRT developed criteria that describe viable salmonid populations (VSPs) in terms of the parameters of abundance, productivity, spatial distribution, and diversity, according to guidelines in McElhany et al. (2000). (See Section 2.5.5 of this recovery plan for the VSP guidelines.)

The TRT's biological viability criteria take the form of general statements that characterize viability, metrics that describe viable populations and strata, methodologies for evaluating whether a population or stratum is viable, and, if not, what its current extinction risk (or persistence probability) is. This chapter presents the WLC TRT's biological viability criteria and their recommended methods and metrics for evaluating population status.

2.4.2 Viability Criteria Technical Reports

The WLC TRT outlined its viability criteria for Lower Columbia River salmon and steelhead populations, strata, and ESUs in a series of technical reports. The *Interim Report on Viability Criteria for Willamette and Lower Columbia Basin Pacific Salmonids* (McElhany et al. 2003) presents the WLC TRT's initial recommendations regarding ESU-, stratum-, and population-level viability criteria. For population-level criteria, this report considered five population-level attributes: (1) adult abundance and productivity (combined into a single attribute because abundance and productivity are so interlinked in their effect on extinction risk), (2) juvenile outmigrant growth rate, (3) spatial structure, (4) habitat, and (5) diversity. The 2003 interim report also introduced general principles and approaches for evaluating current population status and suggested a qualitative scoring system based on the five population attributes.[1]

In 2006 the WLC TRT produced *Revised Viability Criteria for Salmon and Steelhead in the Willamette and Lower Columbia Basins* (McElhany et al. 2006). The revised criteria relied on three population-level attributes instead of five: (1) abundance and productivity (still combined into a single attribute), (2) spatial structure, and (3) diversity. (Juvenile outmigrant productivity was incorporated into abundance and productivity, and habitat attributes were addressed as part of the discussion of listing factors criteria [McElhany et al. 2006]). The revised viability criteria also recommended the use of viability curves and minimum abundance thresholds to evaluate abundance and productivity—rather than the population change criteria approach suggested in McElhany et al. (2003)—and provided initial viability curves and benchmarks for the Lower Columbia River ESUs.[2]

Additional work to refine approaches for evaluating population status was captured in *Viability Status of Oregon Salmon and Steelhead Populations in the Willamette and Lower Columbia Basins* (McElhany et al. 2007). This document is not a WLC TRT product, as the WLC TRT had dissolved in 2006 after completing the revised viability criteria in McElhany et al. (2006). Instead, *Viability Status of Oregon Salmon and Steelhead Populations*

[1] The 2003 interim report was supplemented in 2004 by the *Status Evaluation of Salmon and Steelhead Populations in the Willamette and Lower Columbia River Basins* (McElhany et al. 2004), which applied the methodology described in McElhany et al. (2003) to Lower Columbia River salmon and steelhead populations and some Upper Willamette populations.

[2] The 2006 report also discussed methods for evaluating population status in more depth than previous reports; refined analyses, metrics, and benchmarks; and applied the spatial structure methodology to Oregon LCR coho as a demonstration and test case, using newly available habitat accessibility maps published in 2005 (Maher et al. 2005). For more detail on the TRT's population status assessment methodology, see Section 2.6 of this recovery plan.

in the Willamette and Lower Columbia Basins (McElhany et al. 2007) was a collaborative effort of NMFS Northwest Fisheries Science Center staff, ODFW staff, and a private consultant working for the Lower Columbia Fish Recovery Board to refine population status assessments for the Oregon and Washington management unit plans. The document is described here because it made valuable contributions to methods for population status assessment.

McElhany et al. (2007) provides modified minimum abundance thresholds and viability curves for the Lower Columbia River ESUs. It also provides additional detail on how to evaluate the diversity attribute. Lastly, the 2007 document applies the WLC TRT recommendations for evaluating population status to Oregon populations of Lower Columbia River salmon and steelhead. Especially for spatial structure, the methods and approaches are similar to those in the 2006 report; where they differ, the methods described and demonstrated in *Viability Status of Oregon Salmon and Steelhead Populations in the Willamette and Lower Columbia Basins* (McElhany et al. 2007) supersede those in the 2006 report and earlier WLC TRT documents.

The WLC TRT's viability criteria are summarized below.

2.4.3 TRT ESU-Level Viability Criteria

2.4.3.1 Defining ESU-Level Viability

As described in Section 2.1, each Lower Columbia River salmon and steelhead stratum is defined by a combination of ecological zone (Coast, Cascade, or Gorge) and dominant life history strategy, expressed as run timing (fall, winter, etc.). The WLC TRT defined a viable Lower Columbia River ESU or DPS in terms of the status of its component strata:

> In a viable ESU or DPS, "every stratum (life history and ecological zone combination) that historically existed should have a high probability of persistence" (McElhany et al. 2003 and 2006).

The strata represent major diversity units within the ESU or DPS. Given the correlation between diversity and species resilience, the persistence of every historical stratum provides a substantial buffer against the negative effects of environmental variation, catastrophic events, and loss of genetic variation. It is the TRT's view that the loss of any particular stratum within an ESU or DPS would significantly reduce the resilience of that ESU or DPS and significantly increase its risk of extinction.

2.4.3.2 ESU-Level Recovery Strategy Guidelines

The WLC TRT also suggested two guidelines for use in developing ESU-level recovery strategies:

- **Non-deterioration**: Until all ESU viability criteria have been achieved, no population should be allowed to deteriorate in its probability of persistence.

- **Safety factors:** High levels of recovery should be attempted in more populations than recommended for strata-level viability because not all attempts will be successful. (McElhany et al. 2003 and 2006)

These guidelines emphasize the uncertainties inherent in the recovery process and build in safety factors to increase the likelihood of achieving viability goals. The WLC TRT illustrated the benefit of targeting more than the minimum number of populations for high levels of recovery by calculating that the chances of recovering at least three populations within an ESU go from 51 percent to 95 percent if the number of populations in which recovery is attempted goes from three to six, assuming that the probability of successful recovery for any given population is 80 percent (McElhany et al. 2003).

2.4.4 TRT Stratum-Level Viability Criteria

If a viable ESU or DPS is one in which every stratum that existed historically has a high probability of persistence, what constitutes a high-persistence stratum? It is the WLC TRT's view that, although representative populations need to be preserved, not every historical population needs to be restored for a stratum to be highly persistent. The WLC TRT defined a high-persistence stratum in terms of two criteria, the first concerning the number of populations that need to be viable and the second concerning which populations need to be viable.

2.4.4.1 Criterion 1: How Many Populations in the Stratum Should Be Viable?

> **Criterion 1:** Individual populations within a stratum should have persistence probabilities consistent with a high probability of strata persistence (McElhany 2003 and 2006).

The WLC TRT further described this criterion in terms of an adequate persistence probability for each individual population, using a four-point scale. As shown in Table 2-1, 0 indicates a population that has a very low probability of persisting over a 100-year time frame and 4 indicates a population that has a very high probability of persisting.

Table 2-1
Population Viability Categories, Corresponding to 100-Year Extinction Risk

Probability of Persistence*	Extinction Risk	Population Viability	Persistence Score
0 – 40%	Extinct or very high risk of extinction (VH)	Very low (VL)	0
40 – 75%	Relatively high risk of extinction (H)	Low (L)	1
75 – 95%	Moderate risk of extinction (M)	Medium (M)	2
95 – 99%	Low/negligible risk of extinction (L)	High (H)	3
> 99%	Very low risk of extinction (VL)	Very high (VH)	4

* Probability of population persisting over a 100-year time frame.
Source: McElhany et al. (2006).

The extinction risk of the entire stratum is determined by averaging the viability scores for the individual populations that make up the stratum, with an average of 2.25 or higher indicating a stratum that has a high probability of persistence. Additionally, the WLC TRT recommended that a stratum have at least two populations with a viability score of 3 or higher for the stratum to be considered highly likely to persist. (Table 2-2 shows the stratum-level extinction risks associated with different averages of population risk.)

In other words, for a stratum to have a high probability of persistence, at least two populations must be at least 95 percent likely to persist over a 100-year time frame and the average viability of all the populations in the stratum must be 2.25 or higher. (This is roughly equivalent to requiring that at least 50 percent of the populations in a stratum be viable, but using the average population persistence score recognizes that population status is a continuum and not a simple dichotomy of viable or not viable.)

Table 2-2
Stratum-Level Extinction Risk Associated with Population Risk

Probability of Stratum Persistence	Population Persistence
Low Persistence	Average score: < 2
Moderate Persistence	Average score: 2 to < 2.25 At least two populations: 3 or higher
High Persistence	Average score: 2.25 or higher At least two populations: 3 or higher

Source: McElhany et al. (2003).

2.4.4.2 Criterion 2: Which Populations in the Stratum Should Be Viable?

The TRT presented a second stratum-level criterion that offers guidance on which populations need to be viable:

Criterion 2: Within a stratum, the populations restored/maintained at viable status or above should be selected to:

a. Allow for normative metapopulation processes, including the viability of "core" populations, which are defined as the historically most productive populations.

b. Allow for normative evolutionary processes, including the retention of the genetic diversity represented in relatively unmodified historical gene pools.

c. Minimize susceptibility to catastrophic events. (McElhany 2003 and 2006)

Thus, a stratum with a high probability of persistence should include "core" populations, meaning those that historically were the most productive; "genetic legacy" populations, which best represent historical genetic diversity; and populations dispersed in a way that protects against the effects of catastrophic events.

2.4.5 TRT Population-Level Viability Criteria

The status of an ESU and its component strata depend on the viability status of the individual populations that make up that stratum and the ESU. The WLC TRT developed criteria to describe a viable population, based on the population attributes of abundance, productivity, diversity, and spatial structure as described in McElhany et al. (2000). These attributes, also known as viable salmonid population (VSP) parameters, are important indicators of population extinction risk—or, conversely, a population's probability of persistence. Guidelines from McElhany et al. (2000) that describe viable populations in terms of the VSP attributes are described in Section 2.2 of this recovery plan and presented in Table 2-3.

The population-level viability criteria developed by the WLC TRT for Lower Columbia River salmon and steelhead can be summarized as follows:

- **Abundance/productivity:** A viable population demonstrates growth rates, productivity, and abundance that produce an acceptable probability of population persistence. In highly viable populations, average abundance is approximately equivalent to the estimated historical average and the population is either stable in size or growing.

- **Spatial structure:** A viable population has a spatial structure that supports the population at the desired productivity, abundance, and diversity levels through short-term environmental perturbations, longer-term environmental oscillations, and natural patterns of disturbance regimes.

- **Diversity:** A viable population has sufficient life-history and genetic diversity to sustain the population through short-term environmental perturbations and provide for long-term evolutionary processes.

Table 2-3 presents the WLC TRT's population-level viability criteria, along with its stratum- and ESU-level viability criteria and its ESU-level strategy guidelines. TRT-recommended metrics and methodologies for use in evaluating the current risk status of independent populations are presented in McElhany et al. 2006 and 2007 and explained in more detail in Section 2.6 of this recovery plan. In general, the WLC TRT advises that the viability of a population be evaluated by first scoring each VSP parameter individually and then integrating the VSP scores into an overall viability score using a weighted average that emphasizes abundance/productivity, as described in McElhany et al. (2007). This approach is recommended because abundance and productivity are considered better predictors of extinction risk than are spatial structure and diversity (McElhany et al. 2007).

Although the population assessment techniques described in McElhany et al. (2007) represent the most current methods available during the recovery planning process for Lower Columbia River ESUs, it is expected that evaluation techniques will be refined as more data become available and scientific understanding increases.

Table 2-3
Viability Criteria and Guidelines from the Willamette-Lower Columbia Technical Recovery Team

ESU-Level Viability Criteria

1. Every stratum (life history and ecological zone combination) that historically existed should have a high probability of persistence. For a stratum to have a high probability of persistence, at least two populations must be at least 95 percent likely to persist over a 100-year time frame and the average viability of all populations in the stratum must be 2.25 or higher, using the scoring system presented in McElhany et al. 2003. (This is roughly equivalent to requiring that at least 50 percent of the populations in a stratum be viable, but using the average population persistence score recognizes that population status is a continuum and not a simple dichotomy of viable or not viable.)

ESU-Level Strategy Guidelines

1. Until all ESU viability criteria have been achieved, no population should be allowed to deteriorate in its probability of persistence.
2. High levels of recovery should be attempted in more populations than identified in the strata viability criteria because not all attempts will be successful.

Stratum-Level Viability Criteria

1. Individual populations within a stratum should have persistence probabilities consistent with a high probability of stratum persistence.
2. Within a stratum, the populations restored/maintained at viable status or above should be selected to:
   a. Allow for normative meta-population processes, including eth viability of “core” populations, which are defined as the historically most productive populations.
   b. Allow for normative evolutionary processes, including the retention of the genetic diversity represented in relatively unmodified historical gene pools.
   c. Minimize susceptibility to catastrophic events.

Population-Level Viability Criteria

Abundance and Productivity

Recommendation 1: In general, viable populations should demonstrate a combination of population growth rate, productivity, and abundance that produces an acceptable probability of population persistence. Various approaches for evaluating population productivity and abundance combinations may be acceptable but must meet reasonable standards of statistical rigor.

Recommendation 2: A population with a non-negative growth rate and an average abundance approximately equivalent to estimated historical average abundance should be considered to be in the highest persistence category. The estimate of historical abundance should be credible, the estimate of current abundance should be averaged over several generations, and the growth rate should be estimated with an adequate level of statistical confidence. This criterion takes precedence over Recommendation 1.

Within-Population Diversity

Sufficient life-history diversity must exist to sustain a population through short-term environmental perturbations and to provide for long-term evolutionary processes. The metrics and benchmarks for evaluating the diversity of a population should be evaluated over multiple generations and should include:

a. Substantial proportion of the diversity of a life-history trait(s) that existed historically
b. Gene flow and genetic diversity should be similar to historical (natural) levels and origins
c. Successful utilization of habitats throughout the range
d. Resilience and adaptation to environmental fluctuations

Within-Population Spatial Structure

The spatial structure of a population must support the population at the desired productivity, abundance, and diversity levels through short-term environmental perturbations, longer-term environmental oscillations, and natural patterns of disturbance regimes. The metrics and benchmarks for evaluating the adequacy of a population's spatial structure should specifically address:

a. Quantity: Spatial structure should be large enough to support growth and abundance, and diversity criteria.
b. Quality: Underlying habitat spatial structure should be within specified habitat quality limits for life-history activities (spawning, rearing, migration, or a combination) taking place within the patches.
c. Connectivity: Spatial structure should have permanent or appropriate seasonal connectivity to allow adequate migration between spawning, rearing, and migration patches.
d. Dynamics: The spatial structure should not deteriorate in its ability to support the population. The processes creating spatial structure are dynamic, so structure will be created and destroyed, but the rate of flux should not exceed the rate of creation over time.
e. Catastrophic Risk: The spatial structure should be geographically distributed in such a way as to minimize the probability of a significant portion of the structure being lost because of a single catastrophic event, either anthropogenic or natural.

Source: McElhany et al. (2003).

2.4.6 Population Size

All else being equal, a small population is at greater risk of extinction than a large population because of the populations' responses to environmental variability and other processes. Very small populations (in the range of a few hundred fish or fewer) are subject to elevated risks from catastrophic events, random fluctuations in individual reproductive success (i.e., demographic stochasticity), genetic inbreeding, failure to find mates, and other effects. Populations at such small sizes are said to be below a quasi-extinction threshold (QET) or critical risk threshold (CRT).[3] The WLC TRT documents and McElhany et al. (2007) provide estimated CRT values for Lower Columbia River salmon and steelhead populations.

The CRT values vary by species and historical watershed size. Among species, different life histories suggest different demographic and other risks. Watershed size is a factor because some processes, such as finding a mate, depend on the density of fish rather than the absolute number of fish.

At abundances above the CRT but still relatively small, populations are at elevated risk because random fluctuations may drive them below the CRT. For example, a population with 200 fish that lost half its members because of environmental fluctuations would have 100 fish and might be below the CRT. A population with 2,000 fish that lost half its members would still have 1,000 fish, which is likely to be above any CRT. The WLC TRT referred to the abundance at which a population was substantially vulnerable to elevated extinction risk because of environmental fluctuation as a minimum abundance threshold (MAT). The most recent MAT values for Lower Columbia River salmon and steelhead populations are in McElhany et al. (2007). The MAT values differ by species

[3] McElhany et al. (2000) and the WLC TRT (McElhany et al. 2003 and 2006) used the term quasi-extinction threshold. McElhany et al. (2007) adopted the term critical risk threshold.

and historical watershed size because CRT values differ based on these same attributes and because responses to environmental fluctuations vary by species.

2.5 WLC TRT Approach to Assessing Population Status

The WLC TRT provided guidelines, recommended methodologies, and suggested benchmarks for evaluating the status of Lower Columbia River salmon and steelhead populations in two technical reports: the *Interim Report on Viability Criteria for Willamette and Lower Columbia Basin Pacific Salmonids* (McElhany et al. 2003) and *Revised Viability Criteria for Salmon and Steelhead in the Willamette and Lower Columbia Basins* (McElhany et al. 2006). Refinements in methodology were captured in *Viability Status of Oregon Salmon and Steelhead Populations in the Willamette and Lower Columbia Basins* (McElhany et al. 2007), which was prepared by the WLC TRT chair, other NMFS Northwest Fisheries Science Center staff, ODFW staff, and a consultant working for the Lower Columbia Fish Recovery Board.

The WLC TRT initially applied its techniques for scoring population status in a report completed in 2004 (McElhany et al. 2004). In 2006, the TRT applied revisions in its scoring methods to Oregon coho populations (McElhany et al. 2006). In 2007, the TRT chair, working with other Northwest Fisheries Science Center staff and technical recovery planning staff in Oregon and Washington, refined the TRT's approach and applied it to all Oregon salmon and steelhead populations (see McElhany et al. 2007).

The methodologies that the WLC TRT recommended for assessing population status are based on evaluation of the population parameters of abundance, productivity, spatial structure, and diversity, consistent with guidelines in the NOAA technical memorandum *Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units* (McElhany et al. 2000). In general, the WLC TRT recommended that the status of a population be determined by first evaluating each population attribute separately and assigning it a numerical value, on a 0-to-4 scale, and then integrating those values to yield a score, also on a 0-to-4 scale, that reflects the overall status of that population (see Table 2-4).

As shown in Table 2-4, a score of zero includes a relatively broad range of persistence probabilities (i.e., 0 to 40 percent). The WLC TRT documents characterized this as either "very high risk" or "extirpated or nearly so."[4] It often is difficult to distinguish a truly extirpated population from one that is at significant short-term risk but not entirely extirpated, and the WLC TRT's 0-to-4 scale does not make this distinction. In discussions of population status in this document, we use the terms "very high risk" or "extirpated or nearly so" unless a population has been completely blocked from access to historical habitat and/or is assumed to have no remnants either in a hatchery program or in the

[4] The term "extirpated" is preferred to the term "extinct" when describing a population because extirpation tends to refer to a small unit (e.g., a population), whereas extinction usually refers to a global phenomenon (e.g., an entire ESU). Extirpation also suggests a possibility for recolonization, whereas global extinction does not. Despite the preference for the term extirpation over extinction when referring to populations, the term extinction is used throughout older WLC TRT documents and the management unit plans.

wild. In this latter case (e.g., White Salmon and Hood River spring Chinook salmon) we refer to the populations as extirpated.[5]

Table 2-4
Population Scores and Corresponding Probability of Persistence (or Extinction)

Score*	Probability of Persistence**	Population Status	Probability of Extinction**	Extinction Risk
0	0 – 40%	Very low (VL)	60 – 100%	Extinct or at very high risk of extinction (VH)
1	40 – 75%	Low (L)	25 – 60%	Relatively high risk of extinction (H)
2	75 – 95%	Medium (M)	5 – 25%	Moderate risk of extinction (M)
3	95 – 99%	High (H)	1 – 5%	Low/negligible risk of extinction (L)
4	> 99%	Very high (VH)	< 1%	Very low risk of extinction (VL)

* Population scores between whole numbers are rounded. For example, a score of 2.75 would be rounded up to 3; a score of 2.45 would be rounded down to 2.

** Probability over a 100-year time frame.

Source: McElhany et al. (2006).

In some cases, the WLC TRT suggested quantitative methods of evaluating a particular population parameter; when this was not possible because of limitations of data or analytical technique, the TRT suggested qualitative approaches (see Table 2-3). Even where the TRT did develop quantitative evaluation methods, data for use in evaluating the individual VSP attributes often are limited. For these reasons, the WLC TRT noted the necessity of applying professional judgment when assessing population status. (For more information on the WLC TRT's approach to evaluating and scoring the population attributes of abundance/productivity, spatial structure, and diversity, see McElhany et al. 2004, 2006, and 2007.)

The WLC TRT recommended that the abundance and productivity attributes be combined and receive a single attribute score, and that overall population status be determined by averaging the population attribute scores for abundance/productivity, diversity, and spatial structure, with abundance/productivity weighted twice as heavily as the other attributes because abundance and productivity are considered better predictors of extinction risk (i.e., total score = 2/3 A&P + 1/6 spatial + 1/6 diversity). Furthermore, the WLC TRT recommended that, if the abundance/productivity score is lower than the diversity or spatial structure score, the abundance/diversity score be used to characterize overall population status, instead of the weighted average method. This approach avoids what could be a misleadingly high characterization of overall status in cases where a risk factor is driving down a population's abundance and productivity but not affecting its diversity and spatial structure. (For additional guidance on how to integrate the population attribute scores for to yield a score that reflects overall population status, see McElhany et al. 2007, p. 8).

[5] A reintroduction program for spring Chinook salmon in the Hood subbasin is under way using out-of-ESU broodstock. Some natural production is occurring there. At this time, the origin of that natural production is unknown. For additional discussion of this reintroduction program, see Section 7.4.3.6.

The WLC TRT-recommended methods and benchmarks for evaluating population status reflect scientific understanding at the time they were developed. In NMFS' view, the WLC TRT's approach represents one of several possible ways of evaluating population status that are scientifically credible and that follow WLC TRT guidelines. The WLC TRT's approach itself is not static, as evidenced by the many refinements in technique described in the technical reports between 2000 and 2007. NMFS expects that techniques for assessing population status will continue to improve over time as scientific understanding increases, and that future status evaluations will not necessarily use the exact techniques demonstrated by the WLC TRT. As more data become available and scientific understanding increases, NMFS expects to work with its recovery planning partners to further refine techniques for assessing population status.

3. Recovery Goals and Delisting Criteria

This chapter provides an overview of the recovery goals in the management unit plans and the delisting criteria NMFS will use in future status reviews of the Lower Columbia River salmon ESUs and steelhead DPS to determine whether delisting is warranted. This overview is supplemented with additional detail at the species level in Chapters 6 through 9.

Management unit plans incorporate several types of recovery goals. These include biological goals that are intended to be consistent with delisting, as well as "broad sense" recovery goals that go beyond the requirements for delisting under the ESA to address other legislative mandates or social, economic, and ecological values. Broad sense recovery goals may have a biological component, or they may be expressed solely in terms of aspirations to provide these other values. The biological components of management unit plan recovery goals rely heavily on biological viability criteria developed by the TRTs.

The formal delisting criteria are determined by NMFS and must meet ESA requirements. The ESA requires that recovery plans, to the maximum extent practicable, incorporate objective, measurable criteria that, 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 Code of Federal Regulations [CFR] 17.11 and 17.12). These criteria are of two kinds: biological viability criteria, which deal with population or demographic parameters, and threats criteria, which relate to the five listing factors detailed in the ESA (see Sections 1.1 and 3.2.2 of this plan). The threats criteria define the conditions under which the listing factors, or threats, can be considered to be addressed or mitigated. Together the biological viability and threats criteria make up the "objective, measurable criteria" required under section 4(f)(1)(B) for the delisting decision.

Delisting criteria may include both technical and policy considerations, such as acceptable risk levels at the population, stratum, and ESU/DPS scales. They are based on the best available scientific information (including the WLC TRT's biological viability criteria) and incorporate the most current understanding of the ESU or DPS and the threats it faces. As this recovery plan is implemented, additional information may become available that improves our understanding of the status of populations and ESUs/DPSs, how best to evaluate population and ESU/DPS status, threats and how to evaluate their impacts on population and ESU/DPS status, or the extent to which threats have been abated. If appropriate, NMFS will review and revise delisting criteria in the future based on this new information.

NMFS has ultimate responsibility for final recovery plans and delisting decisions and must take into account all relevant information, including, but not limited to, biological and policy considerations developed during the recovery planning process.

3.1 Management Unit Plan Recovery Goals

Each management unit plan includes broad, conceptual statements of purpose and objectives, as well as broad sense recovery goals and biological goals that local planners believe are consistent with delisting.[1] Goals are identified at the population level but also have been coordinated among management unit plans to produce stratum- and ESU-level recovery scenarios. These recovery scenarios and their corresponding population-level biological goals are an important linkage between the management unit plans and the NMFS delisting criteria.

3.1.1 Plan Purposes and Broad Sense Recovery Goals

3.1.1.1 Washington Management Unit Recovery Plan

The Washington management unit plan is an integrated, ecosystem-focused plan that is intended to serve planning needs associated with the Endangered Species Act, the Northwest Power and Conservation Council's fish and wildlife subbasin planning process, and state salmon recovery and watershed planning. For this reason, the Washington plan includes some species that are not addressed in this recovery plan, such as steelhead in the Coast ecozone, which are part of the Southwest Washington DPS and not listed under the ESA, and also bull trout, a freshwater trout species that is listed as threatened under the ESA and is under the jurisdiction of the U.S. Fish and Wildlife Service.

The Washington management unit plan's overall vision is twofold:

- To recover Washington Lower Columbia River salmon, steelhead, and bull trout to healthy, harvestable levels that will sustain productive recreational, commercial, and tribal fisheries through the restoration and protection of the ecosystems upon which they depend and the implementation of supportive hatchery and harvest practices

- To sustain and enhance the health of other native fish and wildlife species in the lower Columbia through the protection of the ecosystems upon which they depend, the control of non-native species, and the restoration of balanced predator/prey relationships (LCFRB 2010a p. 1-2)

The first part of this vision encompasses a goal of delisting Lower Columbia River salmon and steelhead as one component of achieving the overall vision.

Harvestability is a key aspect of the vision for recovery presented in the Washington management unit plan and represents what is considered a "broad sense" recovery goal. The plan defines a viable species as one that is no longer in danger of extinction or likely to become endangered in the foreseeable future and can therefore be removed from listing under the ESA. The plan defines a harvestable species as one that has achieved viability and has abundance sufficient to allow direct and sustainable recreational, commercial, and tribal harvest without jeopardizing the species' viability (LCFRB 2010a).

---

[1] Section 3.2 discusses NMFS' view of the management unit plans' recovery goals.

The Washington management unit plan also states that harvestability goals are reached when adult natural production exceeds recovery targets and fish can be directly harvested at levels that maintain spawning escapement at or above those targets (LCFRB 2010a). Harvest of listed fish that have not achieved their target status is typically limited to indirect harvest in mixed-stock fisheries targeted on strong wild runs or hatchery fish. Allowable levels of indirect harvest impacts are established through ESA regulatory processes (LCFRB 2010a).

3.1.1.2 Oregon Lower Columbia Management Unit Recovery Plan

Like the Washington management unit recovery plan, the Oregon Lower Columbia management unit recovery plan is designed to meet multiple needs. It serves as both a federal recovery plan under the U.S. Endangered Species Act and a state conservation plan under Oregon's Native Fish Conservation Policy. The document's overall purpose is to guide the implementation of actions needed to recover Lower Columbia River salmon and steelhead in Oregon (ODFW 2010). In addition, the plan addresses some species and populations that are not part of the Lower Columbia River ESUs or DPS, such as steelhead in the Coast ecozone (these are part of the Southwest Washington DPS and not listed under the ESA) and Clackamas River spring Chinook salmon (which are part of the Upper Willamette ESU).

Also like the Washington management unit recovery plan, the Oregon Lower Columbia management unit plan contains broad sense goals that encompass ESA delisting. The plan's goals are as follows:

- To achieve ESA delisting.

- To achieve broad sense recovery, defined as having Oregon populations of naturally produced salmon and steelhead sufficiently abundant, productive, and diverse (in terms of life histories and geographic distribution) that the ESU as a whole will be self-sustaining and will provide significant ecological, cultural, and economic benefits (ODFW 2010)

The second goal was developed to fulfill the mission of the Oregon Plan for Salmon and Watersheds to restore "Oregon's native fish populations and the aquatic systems that support them to productive and sustainable levels that will provide substantial environmental, cultural, and economic benefits" (ODFW 2010).

Oregon's broad sense goal is consistent with ESA delisting but is designed to achieve levels of performance that are more robust than those needed to remove ESUs/DPSs from ESA protection. The plan's vision is that ESA delisting goals would be achieved first, during an extended and stepwise process of achieving the broad sense recovery goal, which would be based on a combination of legislative mandates, cultural commitments, social values, and voluntary contributions (ODFW 2010).

Oregon broke down its broad sense recovery goal into two criteria:

- All Oregon LCR salmon and steelhead populations have a very low extinction risk and are highly viable over 100 years throughout their historical range. A very low extinction risk means a less than 1 percent probability of extinction over a 100-year period, based on an integrated assessment of the population's abundance, productivity, spatial structure, and diversity.

- The majority of Lower Columbia salmon and steelhead populations are capable of contributing social, cultural, economic and aesthetic benefits on a regular and sustainable basis (ODFW 2010).

In working toward the broad sense recovery goal, the Oregon Lower Columbia plan focuses on the status of Oregon populations only; meeting the broad sense recovery criteria does not depend on the performance of populations in Washington.

3.1.1.3 White Salmon Management Unit Recovery Plan

The primary goal of the White Salmon management unit recovery plan is to restore White Salmon populations of the Lower Columbia River salmon ESUs to a status consistent with overall ESU delisting criteria. The White Salmon management unit plan incorporates a general broad sense recovery goal to achieve a status beyond ESA delisting that incorporates local and traditional uses of salmon, including those associated with rural and Native American values. Local recovery planners and plan implementers may choose to define additional broad sense goals for the White Salmon management unit recovery plan in the future (NMFS 2013).

3.1.2 Management Unit Plan Biological Recovery Goals

Recovery planners at the management unit level largely followed the guidelines of the WLC TRT in assessing the viability of salmon and steelhead populations, strata, and ESUs/DPS for the purposes of setting recovery goals. The plans adopted the WLC TRT's definitions of a viable ESU or DPS (i.e., every historical stratum having a high probability of persistence) and a viable stratum (at least two populations being highly likely to persist and the average population persistence score being 2.25 or higher). In addition, the management unit planners relied heavily on the WLC TRT's guidelines regarding abundance and productivity, spatial structure, and diversity in setting viability goals for individual populations. In some cases, however, their approaches differed somewhat from the TRT's and from each other. Detail on methodologies, including discussion of any differences, can be found in Chapter 5. Chapters 6 through 9 present population-specific goals, such as abundance and productivity targets.

3.1.3 Recovery Scenarios for ESU/DPS

Although the WLC TRT defined ESU- and stratum-level viability, it did not specify target viability levels for individual populations consistent with those definitions. Conceivably, the TRT's ESU-level viability criteria could be met through many different combinations of individual population status, with the "best" combination being a function of biological and ecological conditions on the ground and local community values and interests. Management unit recovery planners used the TRT's ESU-level viability criteria to guide decisions about which populations to target for which levels of persistence probability.

Through an iterative process, recovery planners for the Washington Lower Columbia, Oregon Lower Columbia, and White Salmon management units collaborated to reach agreement on a target status for each population. The target statuses within an ESU or DPS are referred to collectively as the "recovery scenario" for that ESU or DPS. Setting the target status for each population in an ESU or DPS (i.e., developing the recovery scenario) involved consideration of several factors:

- Productivity. Which populations are "core" populations that historically were the most highly productive?
- Genetic diversity. Which populations are "legacy" populations that represent important historical genetic diversity?
- Geographical location. Are the populations targeted for high persistence probabilities dispersed in a way that minimizes risk from catastrophic events?
- Feasibility. Which populations can be expected to make significant progress toward recovery because of existing programs, the absence of apparent impediments to recovery, and other management considerations?

The recovery scenarios for the salmon ESUs and steelhead DPS are presented in Table 3-1. The table shows the target status of each population and that population's expected level of contribution to ESU/DPS recovery, using the terminology of "primary" (P), "contributing" (C), and "stabilizing" (S), taken from the Oregon and Washington management unit plans. Primary populations are targeted for restoration to a high or very high probability of persistence. Many primary populations currently have a medium probability of persistence, and some are at low or very low but are targeted for high or very high persistence probability in order to achieve a high probability of stratum and ESU persistence. Contributing populations are those for which some restoration will be needed to achieve a stratum-wide average persistence probability of 2.25 or higher. Stabilizing populations are those that are targeted for maintenance at their baseline persistence probabilities, which are likely to be low or very low. A population might be designated as stabilizing if the feasibility of restoration is low and the uncertainty associated with restoration is high. Chapters 6 through 9 describe the target status of each population further in terms of the viability parameters of abundance and productivity, diversity, and spatial structure (see Tables 6-4, 7-4, 8-2, and 9-4).

Table 3-1
Recovery Scenarios for LCR Chinook, Columbia River Chum, LCR Steelhead, and LCR Coho

		Chinook						Chum				Steelhead				Coho	
		Fall		Late Fall		Spring		Fall		Summer		Winter[3]		Summer			
		Contribu-tion [1]	Target [2]	Contribu-tion	Target	Contribu-tion	Target	Contribu-tion	Target	Contribu-tion	Target	Contribu-tion	Target	Contribu-tion	Target	Contrib-ution	Target
COAST	Youngs Bay (OR)	S	L	--	--	--	--	S	VL	--	--			--	--	S	VL
	Grays/Chinook (WA)	C	M+	--	--	--	--	P	VH	--	--			--	--	P	H
	Big Creek (OR)	C	L	--	--	--	--	S	VL	--	--			--	--	S	VL
	Eloch./Skam. (WA)	P	H	--	--	--	--	P	H	--	--			--	--	P	H
	Clatskanie (OR)	P	H	--	--	--	--	P	H	--	--			--	--	P	VH
	Mill/Aber./Ger. (WA)	P	H	--	--	--	--	P	H	--	--			--	--	C	M
	Scappoose (OR)	P	H	--	--	--	--	P	H	--	--			--	--	P	VH
CASCADE	Lower Cowlitz (WA)	C	M+	--	--	--	--	C (Cowlitz)	M	C (Cowlitz)	M	C	M	--	--	P	H
	Coweeman (WA)	P	H+	--	--	--	--					P	H	--	--	P	H
	SF Toutle (WA)	P (Toutle)	H+	--	--	C (Toutle)	M					P	H+	--	--	P	H
	NF Toutle (WA)			--	--							P	H	--	--	P	H
	Upper Cowlitz (WA)	S (Upper Cowlitz)	VL	--	--	P	H+					P	H	--	--	P	H
	Cispus (WA)			--	--	P	H+	--	--	--	--	P	H	--	--	P	H
	Tilton (WA)			--	--	S	VL	--	--	--	--	C	L	--	--	S	VL
	Kalama (WA)	C	M	--	--	C	L	C	M	--	--	P	H+	P	H	C	L
	NF Lewis (WA)	P (Lewis)	H+	P	VH	P	H	P (Lewis)	H	--	--	C	M	S	VL	C	L
	EF Lewis (WA)			--	--	--	--			--	--	P	H	P	H	P	H
	Salmon (WA)	S	VL	--	--	--	--	S	VL	--	--	S	VL	--	--	S	VL
	Clackamas (OR)	C	M	--	--	--[4]		C	M	--	--	P	H[6]	--	--	P	VH
	Sandy (OR)	C	M	P	VH	P	H	P	H	--	--	P	VH	--	--	P	H
	Washougal (WA)	P	H+	--	--	--	--	P	H+	--	--	C	M	P	H	C	M+
GORGE	Lower Gorge (WA/OR)	C[5]	M	--	--	--	--	P[5]	VH	--	--	P[5]	H	--	--	P[5]	H
	Upper Gorge (WA/OR)	C[5]	M	--	--	--	--	C[5] (Upper Gorge)	M	--	--	S[5]	L	P (Wind)	VH	P (U. Gorge/W. Salmon)	H
	White Salmon (WA)	C	M	--	--	C	L+			--	--	--	--	--	--		
	Hood (OR)	P	H[6]	--	--	P	VH			--	--	P	H	P	H[6]	P (U.Gorge/ Hood)	H[6]

[1] Indicates contribution to recovery: P = primary, C = contributing, S = stabilizing; for description, see Section 3.1.3.
[2] VL = very low persistence probability , L = low persistence probability, M = moderate persistence probability , H = high persistence probability, VH = very high persistence probability.
[3] Winter steelhead of the Coast stratum are included in the Washington and Oregon management unit plans for state-level planning purposes, but they are not included in this table because they are part of the unlisted Southwest Washington DPS, not the listed Lower Columbia River DPS.
[4] Clackamas spring Chinook are part of the Upper Willamette spring Chinook ESU.
[5] Designation for shared population based on WA objectives, with support to be provided by OR portion of population, since WA has a larger proportion of the population area.
[6] The Oregon management unit plan (ODFW 2010) notes that achieving this target status is highly unlikely for various reasons (see pp. 176-77, 186, 195, 200 of ODFW 2010).

The scenarios in Table 3-1 meet the WLC TRT criteria for high probability of persistence at the stratum and ESU or DPS levels with the exceptions of the Gorge fall Chinook, Gorge spring Chinook, and Gorge chum strata. In each of these strata, only one population is targeted to achieve a high probability of persistence. Local recovery planners documented the basis for this divergence from the TRT's criteria.

In Washington, planners factored feasibility into target status designations. Thus for the Gorge fall Chinook, spring Chinook, and chum strata, Washington recovery planners set the target status at levels they believed were feasible, even though these levels were not consistent with the WLC TRT's criteria for high probability of stratum persistence (LCFRB 2010a). Washington planners noted that the likelihood of meeting TRT criteria was highly uncertain because the Bonneville Dam reservoir inundates historical spawning habitat for fall Chinook and chum salmon that spawn in tributaries above the dam, the dam creates passage impediments, there is uncertainty regarding the extent to which some populations functioned independently historically, and, in the case of White Salmon spring Chinook, the population has been extirpated. In contrast, Oregon recovery planners set target viability status at levels consistent with the WLC TRT's criteria. However, in the case of the Hood River populations and the Oregon portions of the shared Gorge populations, Oregon recovery planners noted a very low probability of meeting those goals, in part because there is little habitat currently available and because anthropogenic impacts are unlikely to change in the near future (ODFW 2010).

In addition, both the Washington and Oregon management unit planners raised questions regarding stratum and population delineations and the historical role of the Gorge populations (LCFRB 2010a, ODFW 2010). Questions included whether the populations were highly persistent historically, whether they functioned as independent populations within their stratum in the same way that the Coast and Cascade populations did, and whether the Gorge stratum itself should be considered a separate stratum from the Cascade stratum. While the Washington management unit plan simply raised issues of uncertainty in stratum delineations between the Cascade and Gorge strata and in Chinook and chum population delineations (LCFRB 2010a), the Oregon management unit plan discussed the issue in more depth (see Appendix B of ODFW 2010). For example, the Oregon management unit plan cites a NMFS GIS analysis (see Busch et al. 2011) that used an intrinsic habitat potential model to show that potential habitat for Gorge populations, based on existing geomorphic features, is very small, even in relatively large watersheds (ODFW 2010). This suggests that, even historically, many Gorge populations might not have been sufficiently sized to be reproductively isolated from other populations and to exhibit the productivity required to ensure long-term sustainability. For all three salmon ESUs and the steelhead DPS, the Oregon management unit plan recommends that the Gorge stratum's historical status and population structure be reevaluated and that recovery goals be revised if modifications are made (ODFW 2010).

Finally, for Gorge fall and spring Chinook and Gorge chum, management unit planners developed recovery scenarios that exceed the TRT criteria in the Cascade stratum as a way of mitigating for increased risk to the ESU as a result of not achieving the WLC TRT's stratum-level criteria in the Gorge.

3.2 NMFS Delisting Criteria

The requirement for determining that a species no longer requires the protection of the ESA is that the species is no longer in danger of extinction or likely to become endangered within the foreseeable future, based on evaluation of the listing factors specified in ESA section 4(a)(1). To remove the Lower Columbia River Chinook ESU, Lower Columbia River steelhead DPS, Lower Columbia River coho ESU, or Columbia River chum ESU from the Federal List of Endangered and Threatened Wildlife and Plants, NMFS must determine that the ESU or DPS, as evaluated under the ESA listing factors, is no longer likely to become endangered.

The ESA requires that recovery plans, to the maximum extent practicable, incorporate objective, measurable criteria that, 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; 50 CFR 223.102 and 224.101). The biological and threats criteria in this plan, taken together, meet this statutory requirement.

3.2.1 Biological Criteria

NMFS has considered the WLC TRT's viability criteria (McElhany et al. 2003 and 2006, summarized in Table 2-3), the additional recommendations in McElhany et al. (2007), the recovery scenarios (summarized in Table 3-1) and population-level goals in the management unit plans, and the questions the management unit planners raised regarding the historical role of the Gorge strata.

NMFS has concluded that the WLC TRT's criteria adequately describe the characteristics of an ESU that meet or exceed the requirement for determining that a species no longer needs the protection of the ESA. These criteria provide a framework within which to evaluate specific recovery scenarios. NMFS has evaluated the management unit plan recovery scenarios (summarized in Table 3-1 of this recovery plan) and population-level abundance, productivity goals[2] (see Chapters 6 through 9) and has concluded that they also adequately describe the characteristics of an ESU that no longer needs the protections of the ESA.[3] NMFS endorses the recovery scenarios and population-level goals in the management unit plans (summarized here in Table 3-1 and Sections 6.3, 7.3, 8.3, and 9.3) as one of multiple possible scenarios consistent with delisting.

As noted above, the recovery scenarios in Table 3-1 are consistent with the WLC TRT's recommendations at the stratum and ESU or DPS level, except for the Gorge fall Chinook, Gorge spring Chinook, and Gorge chum strata. In those strata, the recovery scenarios target only one population to achieve a high probability of persistence. As a way of mitigating for increased risk in the Gorge strata, the recovery scenarios exceed

---

[2] NMFS also evaluated the goals for spatial structure and diversity in the Oregon management unit plan (ODFW 2010). Washington recovery planners assumed that productivity and abundance levels consistent with significant improvements in persistence probability could not be achieved without also addressing limitations in spatial structure and diversity. Thus, spatial structure and diversity improvements are implicit in the abundance and productivity targets in the Washington management unit plan (LCFRB 2010a).
[3] See Sections 6.7, 7.7, 8.7, and 9.7 for additional detail on biological criteria at the species level.

the WLC TRT criteria in the Cascade fall Chinook, Cascade spring Chinook, and Cascade chum strata.

In its revised viability criteria (McElhany et al. 2006), the WLC TRT noted the need for case-by-case evaluations of the continuum of ESU-level risk associated with some strata not meeting the TRT's persistence criteria. In commenting on the recovery scenarios presented in the interim Washington management unit plan[4]—and by extension the recovery scenarios in Table 3-1 of this plan—the WLC TRT stated that achieving the recovery scenarios would improve the status of the Gorge strata, even if the TRT's criteria for those strata were not met. The TRT also noted that targeting the Cascade strata for very high persistence (above the minimum TRT criteria) would help lower ESU extinction risk. In addition, the TRT noted that the Gorge and Cascade strata are relatively similar compared to the Cascade and Coast strata. Also significant in the TRT's view was that options for recovery of the Gorge strata would be preserved, in case future conditions or analyses were to require high stratum persistence for ESU viability (McElhany et al. 2006).

Based on the information provided by the WLC TRT and the management unit recovery planners, NMFS concludes that the recovery scenarios in Table 3-1 and the associated population-level abundance and productivity goals in Sections 6.3, 7.3, 8.3, and 9.3 represent one of multiple possible scenarios that would meet biological criteria for delisting.

NMFS also agrees with the management unit planners that the historical role of the Gorge populations and strata merits further examination. The extent to which compensation in the Cascade strata is ultimately considered necessary to achieve an acceptably low risk level at the ESU or DPS level will depend on how questions regarding the historical role of the Gorge populations are resolved.

NMFS therefore has developed the following biological criteria for the four listed ESUs and DPS addressed by this plan (NMFS has amended the WLC TRT's criteria for clarity and to incorporate the concept that each stratum should have a probability of persistence consistent with its historical condition, thus allowing for resolution of questions regarding the Gorge strata):

- All strata that historically existed have a high probability of persistence or have a probability of persistence consistent with their historical condition.
- High probability of stratum persistence is defined as:
    a. At least two populations in the stratum have at least a 95 percent probability of persistence over a 100-year time frame (i.e., two populations with a score of 3.0 or higher based on the TRT's scoring system).
    b. Other populations in the stratum have persistence probabilities consistent with a high probability of stratum persistence (i.e., the average of all stratum

[4] In February 2006, NMFS approved the December 2004 *Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan* as in interim regional recovery plan. The 2010 revised version of that plan (LCFRB 2010a) is incorporated into this ESU-level plan as Appendix B.

population scores is 2.25 or higher, based on the TRT's scoring system). (See Section 2.6 for a brief discussion of the TRT's scoring system.)

c. Populations targeted for a high probability of persistence are distributed in a way that minimizes risk from catastrophic events, maintains migratory connections among populations, and protects within-stratum diversity.

- A probability of persistence consistent with historical condition refers to the concept that strata that historically were small or had complex population structures may not have met Criteria A through C, above, but could still be considered sufficiently viable if they provide a contribution to overall ESU viability similar to their historical contribution.

The recovery scenarios in Table 3-1 are consistent with these biological criteria.

3.2.2 Threats Criteria

In addition to a species achieving a certain biological status to be considered for reclassification or delisting, the threats to a listed species must have been ameliorated so as not to limit attainment of its desired biological status. Section 4(a)(1) of the ESA organizes NMFS' consideration of threats into five factors:

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. The inadequacy of existing regulatory mechanisms
E. Other natural or human-made factors affecting the species' continued existence

These factors may not all be equally important in securing the continuing recovery of a particular ESU, and each ESU faces a different set of threats. It also is possible that current perceived threats will become insignificant in the future as a result of changes in the natural environment or changes in the way threats affect the entire life cycle of salmon and steelhead.

NMFS will use the listing factor criteria below in determining whether an ESU or DPS has recovered to the point that it no longer requires the protections of the ESA:

A. The present or threatened destruction, modification, or curtailment of a species' habitat or range:
   1. Habitat-related threats have been ameliorated such that they do not limit attainment of the desired status of the ESU/DPS and its constituent populations as defined by the biological criteria in this recovery plan, and such that the desired status will be maintained.
      a. Recovery plan actions addressing habitat limiting factors have been substantially implemented, including related research, monitoring, and evaluation actions.
      b. The threat reduction targets for habitat outlined in Sections 6.5, 7.4.2, 7.5.2, 7.6.2, 8.5, and 9.5 of this recovery plan have been met

or habitat impacts are otherwise consistent with the desired status of the ESU/DPS and its constituent populations. To evaluate whether this criterion has been met, and to track and periodically evaluate progress, specific metrics for assessing habitat conditions and action effectiveness will be needed.

c. Trends in overall habitat conditions, based on evaluation of the combined effect of factors, including, but not limited to, habitat access, hydrograph/water quantity, physical habitat quality and quantity, and water temperature and other water quality parameters, are stable or improving.

d. Functioning habitat areas, including those expected to be less vulnerable to impacts from climate change, have been protected. Other actions to support adaptation to climate change impacts have been implemented.

2. Hydropower and/or flood control dam-related threats have been ameliorated such that they do not limit attainment of the desired status of the ESU/DPS and its constituent populations, as defined by the biological criteria in this recovery plan, and such that the desired status will be maintained.
    a. Recovery plan actions addressing hydropower limiting factors have been substantially implemented, including related research, monitoring, and evaluation actions.
    b. FERC Settlement Agreements and relevant actions from the applicable FCRPS Biological Opinion have been substantially implemented.
    c. The threat reduction targets for hydropower outlined in Sections 6.5, 7.4.2, 7.5.2, 7.6.2, 8.5, and 9.5 of this recovery plan have been met or hydropower impacts are otherwise consistent with the desired status of the ESU/DPS and its constituent populations. To evaluate whether this criterion has been met, and to track and periodically evaluate progress, specific metrics related to hydropower impacts (including passage, and flow, temperature, and sediment), population performance (where populations are being reestablished above dams), and action effectiveness will be needed.
    d. Hydropower management actions will support ESU persistence given projected effects of climate change.

B. Overutilization for commercial, recreational, or educational purposes:

1. Harvest-related threats have been ameliorated such that they do not limit attainment of the desired status of the ESU/DPS and its constituent populations as defined by the biological criteria in this recovery plan, and such that the desired status will be maintained.
    a. Recovery plan actions addressing harvest-related limiting factors have been substantially implemented, including related research, monitoring, and evaluation actions.

    b. The threat reduction targets for harvest outlined in Sections 6.5, 7.4.2, 7.5.2, 7.6.2, 8.5, and 9.5 of this recovery plan have been met or harvest impacts are otherwise consistent with the desired status of the ESU/DPS and its constituent populations. To evaluate whether this criterion has been met, and to track and periodically evaluate progress, specific metrics related to harvest impacts and action effectiveness will be needed.
  2. Any other threats related to overutilization for commercial, recreational, or educational purposes (for example, utilization for research purposes) have been ameliorated such that they do not limit attainment of the desired status of the ESU/DPS and its constituent populations as defined by the biological criteria in this recovery plan, and such that the desired status will be maintained.

C. Disease or predation:
  1. Predation-related threats have been ameliorated such that they do not limit attainment of the desired status of the ESU/DPS and its constituent populations as defined by the biological criteria in this recovery plan, and such that the desired status will be maintained.
    a. Recovery plan actions related to threats from predation by marine mammals, birds, and fish (including predation among salmon species and predation by hatchery-origin salmon on natural-origin salmon) have been substantially implemented, including related research, monitoring, and evaluation actions.
    b. The threat reduction targets for predation outlined in Sections 6.5, 7.4.2, 7.5.2, 7.6.2, 8.5, and 9.5 of this recovery plan have been met or threats from predation are otherwise consistent with the desired status of the ESU/DPS and its constituent populations. To evaluate whether this criterion has been met, and to track and periodically evaluate progress, specific metrics related to predation and action effectiveness will be needed.
  2. Disease-related threats have been ameliorated such that they do not limit attainment of the desired status of the ESU/DPS and its constituent populations as defined by the biological criteria in this recovery plan, and such that the desired status will be maintained.
    a. Hatchery management practices sufficient to limit disease-related threats are being implemented.
    b. Monitoring is in place to detect disease and disease impacts on population status.

D. The inadequacy of existing regulatory mechanisms:
  1. Regulatory mechanisms have been maintained and/or established and are being implemented in a way that supports attaining and maintaining the desired status of the ESU/DPS and its constituent populations, as defined by the biological criteria in this recovery plan.
    a. Regulatory programs that govern land use and resource utilization are in place and are adequate to protect salmon and steelhead habitat, including water quality, water quantity, and

stream structure and function, and to attain and maintain the biological recovery criteria in this recovery plan.

b. States have established and protected instream flow levels in a manner consistent with achieving and maintaining the desired status for the ESU/DPS and its constituent populations as defined by the biological criteria in this recovery plan.

c. Regulatory programs are in place and are adequate to manage fisheries at levels consistent with the biological recovery criteria of this recovery plan.

d. Regulatory, control, and education measures are in place to prevent introductions of non-native plant and animal species.

e. Regulatory programs have adequate funding, prioritization, enforcement, coordination mechanisms, and research, monitoring, and evaluation to ensure habitat protection and effective management of fisheries.

E. Other natural or man-made factors affecting continued existence:

1. Hatchery-related threats have been ameliorated such that they do not limit attainment of the desired status of the ESU/DPS and its constituent populations as defined by the biological criteria in this recovery plan, and such that the desired status will be maintained.

   a. Recovery plan actions related to threats from hatcheries have been substantially implemented, including related research, monitoring, and evaluation actions. Hatchery and Genetics Management Plans are complete for all hatchery programs and NMFS has authorized all programs under the ESA.

   b. The threat reduction targets for hatcheries outlined in Sections 6.5, 7.4.2, 7.5.2, 7.6.2, 8.5, and 9.5 of this recovery plan have been met or hatchery impacts are otherwise consistent with the desired status of the ESU/DPS and its constituent populations. To evaluate whether this criterion has been met, specific metrics for evaluating the genetic and ecological risks posed to natural-origin salmon and steelhead by hatchery-origin salmon and steelhead may need to be developed, tracked, and periodically evaluated.

   c. Hatchery programs are being operated in a manner consistent with the target status of each population, and appropriate criteria are being used for managing the interaction of hatchery and natural populations, including hatchery-origin fish spawning naturally.

   d. Hatcheries are operated using appropriate ecological, genetic, and risk containment measures for (1) release of hatchery juveniles, (2) handling of natural-origin adults, (3) withdrawal of water for hatchery use, (4) discharge of hatchery effluent, and (5) maintenance of fish health during propagation in the hatchery.

   e. Monitoring and evaluation plans are in place and being implemented to measure population status, hatchery effectiveness, and ecological, genetic, and demographic risk containment measures.

2. Other natural or human-caused factors have been accounted for such that they do not limit attainment of the desired status of the ESU/DPS and its constituent populations as defined by the biological criteria in this recovery plan, and such that the desired status will be maintained.

3.2.3 Delisting Criteria Conclusion

NMFS will propose to delist the four listed ESUs addressed by this plan when the following criteria are achieved:

1. All strata that historically existed have a high probability of persistence or have a probability of persistence consistent with their historical condition.

   High probability of stratum persistence is defined as:

   a. At least two populations in the stratum have at least a 95 percent probability of persistence over a 100-year time frame (i.e., two populations with a score of 3.0 or higher based on the TRT's scoring system).

   b. Other populations in the stratum have persistence probabilities consistent with a high probability of stratum persistence (i.e., the average of all stratum population scores is 2.25 or higher, based on the TRT's scoring system). (See Section 2.6 for a brief discussion of the TRT's scoring system.)

   c. Populations targeted for a high probability of persistence are distributed in a way that minimizes risk from catastrophic events, maintains migratory connections among populations, and protects within-stratum diversity.

   A probability of persistence consistent with historical condition refers to the concept that strata that historically were small or had complex population structures may not have met Criteria A through C, above, but could still be considered sufficiently viable if they provide a contribution to overall ESU viability similar to their historical contribution.

2. The threats criteria identified in Section 3.2.2 have been met.

The recovery scenarios in Table 3-1 and the associated population-level abundance and productivity goals presented in Sections 6.3, 7.3, 8.3, and 9.3 of this recovery plan illustrate one possible set of scenarios in which these criteria could be met. The criteria stated above represent a point at which delisting is very likely but not necessarily the only scenario under which NMFS would propose to delist. Nothing in these criteria should be understood as precluding a delisting determination under a different scenario, provided that the ESU is no longer in danger of extinction or likely to become endangered within the foreseeable future.

In accordance with our responsibilities under section 4(c)(2) of the Act, NMFS will conduct reviews of status of each ESU at least once every 5 years to evaluate the ESUs' status and determine whether the ESUs should be removed from the list or changed in status. NMFS will base such evaluations on the best scientific information available at that time.

3.3 Achieving Broad Sense Goals after Delisting

NMFS is supportive of the broad sense recovery goals in the management unit plans and believes that the most expeditious way to achieve them is by achieving viability of natural populations and delisting. Upon delisting, NMFS will work with co-managers and local stakeholders, using our non-ESA authorities, to pursue broad sense recovery goals while continuing to maintain robust natural populations.

4. Regional Limiting Factors and Strategies

The reasons for a species' decline are generally described in terms of limiting factors and threats. Limiting factors are biological, physical, or chemical conditions and associated ecological processes and interactions that limit a species' viability. Threats are human activities or natural events, such as floodplain development or drought, that cause or contribute to limiting factors.[1] A single limiting factor may be caused by one or more threats. Likewise, a single threat may cause or contribute to more than one limiting factor and may affect more than one life stage. In addition, the impact of past threats may continue to contribute to current limiting factors through legacy effects. For example, current high water temperature could be the result of earlier riparian practices that removed vegetation from the streambank. Or the effects of previous harvest practices may be evident in the relatively small number of life history strategies that currently exist among salmon and steelhead. Designing effective recovery strategies and actions requires an understanding of the range and impact of limiting factors and threats affecting the species, across its entire life cycle.

Addressing multiple ESUs in a single recovery plan presents an opportunity to evaluate limiting factors and threats at the regional scale, discern large-scale patterns in ecological conditions, and identify regional approaches to recovery. This regional, multi-species perspective is useful in understanding the scale and scope of actions needed to recover the four species addressed by this plan; it also should aid in identifying recovery approaches that provide maximum biological benefit and make effective use of limited resources. Toward that end, this chapter takes a subdomain-scale look at recovery. The chapter gives overviews of limiting factors, at the regional scale, that have affected Lower Columbia River salmon and steelhead and describes regional strategies to address the specific limiting factors identified and analyzed in the management unit plans (see Chapters 6 through 9). The regional strategies are general approaches that either will benefit multiple ESUs or can be applied in ways that target the specific needs of each species. Chapters 6 through 9 supplement the regional strategies with complementary strategies that provide greater specificity at the species and stratum levels.

The regional strategies also highlight the need for domain-scale coordination to implement effective recovery strategies in tributary habitat, estuary habitat, hydropower, hatcheries, harvest, and ecological interactions. Coordination needs are discussed in Chapter 11, "Implementation."

4.1 Tributary Habitat

Historically, tributary habitat in the ranges of the Lower Columbia River salmon ESUs and steelhead DPS supported millions of fish in populations that were adapted to the characteristics of individual watersheds. Stream channels contained abundant large wood from the surrounding riparian forests that helped structure pools and create

---

[1] In this recovery plan, the term limiting factors is used to indicate the full range of factors that are believed to be affecting the viability of salmon and steelhead, and not to indicate the single factor that is most limiting.

complex habitat in streams. Beaver activity also contributed to diverse instream habitats, with deep pools and strong connections to floodplains. Water temperatures sufficient to support salmon and steelhead throughout the year were common. Upland and riparian conditions allowed for the storage and release of cool water during the dry summer months and provided sufficient shade to keep water temperatures cool. Extensive and abundant riparian vegetation armored streambanks, thus shading the water, protecting against erosion, and supporting an abundant food supply. Dynamic patterns of channel migration in floodplains continually created complex channel, side-channel, and off-channel habitats. Over the last 150 years, tributary habitat conditions have been severely degraded.

4.1.1 Tributary Habitat Limiting Factors and Threats

Tributary habitat degradation from past and/or current land and water use is a limiting factor for all Lower Columbia River salmon and steelhead populations. Widespread development and other land use activities have disrupted watershed processes, reduced water quality, and diminished habitat quantity, quality, and complexity in most of the lower Columbia River subbasins. Past and/or current land use or water management activities have adversely affected stream and side channel structure, riparian conditions, floodplain function, sediment conditions, and water quality and quantity, as well as the watershed processes that create and maintain properly functioning conditions for salmon and steelhead (LCFRB 2010a, ODFW 2010). Specific activities and their impacts include the following:

- Logging and other forest management practices. Logging on unstable slopes and in riparian areas has led to the degradation of watershed processes. Improperly located, constructed, or maintained forest roads have disrupted stream flow patterns and sediment supply processes, disconnected streams from floodplains, and, in riparian areas, reduced wood recruitment to streams. The historical use of splash dams to transport logs reduced instream structure and available spawning gravel in several stream systems. Impacts continue in many areas, and the legacy of historical practices will continue for some time.

- Agricultural activities. Agricultural activities have diminished overall habitat productivity and connectivity and degraded riparian areas and floodplains in many areas of the lower Columbia region, especially along lowland valley bottoms. Historical floodplain habitats have been lost through levee construction and the filling of wetlands. Runoff from agricultural lands where pesticides, herbicides, and fertilizers are applied has reduced water quality. Water withdrawal for irrigation has altered stream flow and raised water temperatures. Livestock grazing has affected soil stability (via trampling), reduced streamside vegetation (via foraging), and delivered potentially harmful bacteria and nutrients (animal wastes) to streams.

- Construction of fish passage barriers. The main barriers in lower Columbia watersheds are dams and culverts, with occasional barriers such as irrigation diversion structures, fish weirs, beaver dams, road crossings, tide gates, channel alterations, and localized temperature increases (LCFRB 2010a). Although dams are responsible for the greatest share of blocked habitat, inadequate culverts make up the vast majority of all barriers (LCFRB 2010a). Many barriers have been corrected, but a substantial number of barriers remain. Physical and thermal barriers limit access to spawning and rearing habitats in some areas. Hatchery structures also sometimes act as passage barriers in tributaries (ODFW 2010, LCFRB 2010a). (See Section 4.3 for information on passage issues at hydropower dams and Section 4.4.1.3 for more information on hatchery structures.)

- Urban and rural development. Development has diminished overall habitat productivity and connectivity and led to the degradation of riparian and floodplain conditions and an increase in surface water runoff from cities and towns. The drainage network from roads, ditches, and impervious surfaces alters the hydrograph and delivers sediment and contaminants to streams, thus reducing water quality and affecting the health and fitness of salmonids and other aquatic organisms. Loss of riparian vegetation to development has increased stream temperatures, and bank hardening and channelization of streams have simplified habitat and altered flow. Water withdrawal for municipal uses has contributed to altered stream flows and increases in water temperatures.

- Mining. Sand and gravel mining along some lower Columbia streams has altered instream substrate and sediment volumes (ODFW 2010).

Together these factors have reduced the amount and quality of spawning and rearing habitats available to Lower Columbia River salmon and steelhead, severed access to other historically productive habitats, and degraded watershed processes and functions that once created healthy ecosystems for salmon and steelhead production. Today, many streams have lower pool complexity and frequency compared to historical conditions. Channels also lack the complex structure needed to retain gravels for spawning and invertebrate production. Also missing from many channels is the connectivity with shallow, off-channel habitat and floodplain areas that once provided productive early-rearing habitat, flood refugia and overwintering habitat, and cover from predators. In many areas, contemporary watershed conditions are so different from those under which native fish species evolved that they now pose a significant impediment to achieving recovery (LCFRB 2010a, ODFW 2010).

Table 4-1 lists common tributary habitat limiting factors that adversely affect populations of Lower Columbia River salmon and steelhead.[2] As the table illustrates, Lower Columbia River salmon and steelhead commonly are limited by the shape, structure, and connectivity of the waterways they use; the amount of water (and thus habitat) available to them at different times of year; and the suitability of gravel for spawning. The fact that many of the most common limiting factors are related to basic ecosystem functions underscores the need for fundamental, widespread improvement in watershed processes through much of the lower Columbia Basin. Another message is that any actions implemented to address these most common limiting factors have the potential to benefit more than one ESU, especially when ESUs have overlapping habitat preferences (such as lower elevation off-channel rearing habitat used by both chum and

---

[2] Table 4-1 uses terminology from a "data dictionary" of ecological concerns developed by the NMFS Northwest Fisheries Science Center but is based on characterizations of limiting factors and threats in the management unit plans, as compiled in the species-specific NMFS limiting factors "crosswalk" tables presented in Appendix H (see also Section 5.4 for a description of the data dictionary and crosswalk tables).

fall Chinook salmon). Even so, Table 4-1 does not represent all of the limiting factors that affect any particular ESU, or even necessarily the most important limiting factors for a particular ESU or population; when implementing recovery actions, it is important to consider the specific needs of each ESU or population to ensure that important but less common limiting factors are not overlooked (see Chapters 6 through 9).

It also is worth noting that some of the limiting factors in Table 4-1, such as hydrology and sediment conditions, or loss of riparian cover, temperature, and sediment supply, are interrelated. This raises the possibility of synergistic or compounded effects of recovery actions. Future monitoring may clarify the nature of such effects and provide opportunities for adaptive management to ensure that such effects are realized.

Table 4-1
Common Tributary Habitat Limiting Factors and Threats

Limiting Factor	Subcategory	Associated Threats
Riparian conditions		Past/current land use practices
Peripheral and transitional habitats	Side channel and wetland conditions	Past/current land use practices Transportation corridor development and maintenance
	Floodplain condition	Past/current land use practices Transportation corridor development and maintenance
Impaired channel structure and form	Bed and channel form	Past/current land use practices Transportation corridor development and maintenance Inundation from Bonneville Reservoir
	Instream structural complexity	Past/current land use practices Transportation corridor development and maintenance Inundation from Bonneville Reservoir
Sediment conditions[3]	Decreased sediment quantity (impaired sediment/sand routing and gravel recruitment)	Dams
	Increased sediment quantity	Past and/or current land use practices (e.g., rural roads) Transportation corridor development and maintenance
Water quality	Elevated water temperature	Land uses that impair riparian function/decrease stream flow Large dam reservoirs

[3] The limiting factors crosswalk also identified turbidity as a common limiting factor (as a subcategory of the water quality limiting factor); however, when NMFS developed the limiting factors crosswalk, it indicated turbidity as a limiting factor for every population affected by sediment conditions, because the management unit plans did not necessarily distinguish between sediment and turbidity. The crosswalk results for turbidity should be validated at some point in the future and are not included in Table 4-1 or the species-specific limiting factor summary tables in Chapters 6 through 9 because of this uncertainty.

Limiting Factor	Subcategory	Associated Threats
Water quantity	Altered hydrology Decreased water quantity/downstream flows Altered flow timing	Low-head hydro diversions Upslope land uses Withdrawals for irrigation, hatchery, or municipal uses Hydropower dams

4.1.2 Regional Strategy for Tributary Habitat

To address the limiting factors and threats described above and in Chapters 6 through 9, the regional tributary habitat strategy is directed toward protecting and restoring high-quality, well-functioning salmon and steelhead habitat through a combination of (1) site-specific projects that will protect habitat or provide benefits relatively quickly, (2) watershed-based actions that will repair habitat-forming processes and provide benefits over the long term, and (3) landscape-scale programmatic actions that affect a class of activities (such as stormwater management or forest practices) over multiple watersheds. Although many habitat-related actions already have been undertaken, current activities do not reflect the scale of habitat improvements needed. Recovery of the listed species will require concerted efforts to protect remaining areas of favorable habitat and restore habitat quality in significant historical production areas. The management unit plans place a high value on protecting currently functioning habitat as a means of retaining and building out from current production. However, restoration also is essential because current habitat in most subbasins is inadequate to support viable populations of Lower Columbia River salmon and steelhead. Federal lands will play a significant role in providing and protecting anchor habitats, but substantial improvements also are needed in marginal areas of potentially productive habitat (LCFRB 2010a). Especially at low elevations, much of the land is in private ownership, where restoration activities are likely to be challenging and expensive.

Representative actions to address the most common limiting factors affecting Lower Columbia River salmon and steelhead are shown in Table 4-2.

There is an immediate need to develop prioritization frameworks and get additional targeted, site-specific protection and restoration actions, as well as programmatic approaches, on the ground as soon as possible, especially because the benefits of some habitat actions will take years to accrue. Some prioritization work has already occurred. The Washington management unit plan, for instance, has prioritized tributary actions by stream reach based on the needs of all populations in a particular watershed (LCFRB 2010a). The Oregon management unit plan has done some prioritization based on where an action will have the greatest beneficial effect and where implementation is most feasible (ODFW 2010), but in many Oregon watersheds additional assessment is needed to determine protection and restoration priorities at a meaningful spatial scale (ODFW 2010). The White Salmon management unit plan also identifies areas that are a high priority for habitat actions but points to the need for additional information to identify and prioritize specific habitat actions (NMFS 2013). For example, now that Condit Dam has been removed,[4] habitat conditions downstream of the dam site, and in the area previously occupied by Northwestern Lake, will need to be assessed and priority restoration actions identified (NMFS 2013). In addition, site-specific protection and restoration actions need to be prioritized at the subdomain scale, funding sources need to be coordinated, and benchmarks established by which to assess progress in implementation and evaluate biological benefits. In these efforts, opportunities to consider ecosystem function and benefits need to be balanced with individual species' needs.

Table 4-2
Representative Actions to Address Limiting Factors Affecting Most Populations

Limiting Factor	Subcategory	Representative Actions
Impaired channel structure and form	Bed and channel form	Restore degraded off-channel habitats Streamline delivery of large wood to restoration sites Restore degraded riparian areas through planting or fencing
	Instream structural complexity	Restore riparian areas to improve water quality, provide long-term supply of large wood to streams, and reduce impacts that alter other natural processes
Sediment conditions and water quality[5]	Decreased sediment quantity (impaired sediment/sand routing and gravel recruitment)	Place gravel for spawning (below dams) Remove Little Sandy River diversion (completed)
	Increased sediment quantity (turbidity from excessive fine sediment)	Conduct sediment source analyses and reduce inputs Develop/implement stormwater management plans for urban areas and roads Identify and rectify problem legacy roads
Water quantity	Altered hydrology Decreased water quantity/downstream flows Altered flow timing	Protect intact riparian areas via easements and acquisition Explore cooperative water conservation measures Restore connectivity to small tributaries Restore degraded off-channel and riparian habitat Establish minimum ecosystem-based instream flows Identify and halt illegal water withdrawals

Watershed-based actions of particular importance will include efforts to restore hydrologic, riparian, and sediment processes. Accordingly, the management unit plans identify systemic actions related to land use planning and management. In the Washington plan, such actions include managing forest lands to protect and restore watershed processes, managing growth and development to protect watershed processes and habitat conditions, and protecting and restoring stream corridor structure and function, hillslope processes, floodplain function, and channel migration (LCFRB

[4] Condit Dam was breached in October 2011 and completely removed in September 2012.
[5] The data dictionary and limiting factors crosswalk consider turbidity as a subcategory of the water quality limiting factor and thus separately from sediment conditions, but the two limiting factors are presented together in this table because their mechanisms, causes, and effects in the lower Columbia River basin are so similar.

2010a). The Oregon plan includes actions to (1) develop land management scenarios that address hydrograph changes resulting from altered runoff and climate change, (2) protect and restore riparian areas to provide long-term supplies of large wood to streams, (3) develop stormwater management plans, (4) conduct sediment source analyses and implement needed actions, (5) ensure that future development impacts in the 100-year floodplain are either low-impact or are mitigated, and (6) prohibit development of new dikes, levees, and floodwalls in the 100-year floodplain unless they will not increase flood volume, size, and/or intensity (ODFW 2010).

Managing the impacts of growth and development on watershed processes and habitat conditions will be key to protecting and improving habitat conditions for Lower Columbia River salmon and steelhead. Accordingly, the recovery strategy proposes actions such as managing urban stormwater and agricultural runoff to reduce contaminants in streams (LCFRB 2010a), limiting water withdrawals to maintain instream flows (LCFRB 2010a) and temperatures, and using land use planning to encourage low-impact development and to direct future development away from ecologically sensitive areas (LCFRB 2010a, ODFW 2010).

Subbasins vary in the role they will play in recovery, with some subbasins targeted to support several primary populations from different ESUs,[6] some that will not support any primary populations,[7] and some targeted to support a mix of primary and contributing populations. Table 4-3 shows subbasins targeted in the management unit plans to support three or more primary populations. Together, these are the subbasins used by most of the core and genetic legacy populations from the Lower Columbia River ESUs. These subbasins will play a key role in the recovery of multiple species and populations and are where much of the improvements in population status will take place, across ESUs.

---

[6] As described in Section 3.1.3, primary populations are those targeted for high or very high probability of persistence, based on their historical productivity, their genetic contribution to the ESU, the geographical distribution of primary populations within the ESU (to reduce catastrophic risk), and the feasibility of improving a given population's status.

[7] Subbasins that the management unit plans designate as having no primary populations under the recovery scenario are the Youngs Bay, Big Creek, Tilton, and Salmon Creek. Because the Youngs Bay and Big Creek subbasins are terminal fishing areas, the impact of hatchery production and harvest on natural-origin fish in these subbasins is expected to remain high. The Tilton subbasin has passage barriers to its upper reaches, along with habitat degradation in its lower reaches. Habitat degradation also is an issue in the heavily urbanized Salmon Creek subbasin, where urban and rural development pressures are increasing. In the White Salmon subbasin, recovery prospects are highly uncertain and recovery is expected to take considerable time as habitat recovers from the impacts of Condit Dam, which was breached in October 2011 and completely removed in September 2012. Uncertainties include the habitat response to dam breaching and removal and the success of recolonization or reintroduction efforts. In addition, the Lower Cowlitz subbasin has only one primary population—coho salmon—because of passage barriers to upper reaches, the largely non-forested state of the lower reaches, and growing cities and towns; however, some habitat in the Lower Cowlitz subbasin will support primary populations outmigrating from upstream subbasins (i.e., the Upper Cowlitz, Cispus, Toutle, and Coweeman).

Table 4-3
Subbasins Targeted to Support Three or More Primary Populations

Ecozone	Subbasin	Primary Populations
Coast	Elochoman	Fall Chinook, chum, coho
	Clatskanie	Fall Chinook, chum, coho
	Scappoose	Fall Chinook, chum, coho
Cascade	Coweeman	Fall Chinook, winter steelhead, coho
	SF Toutle	Fall Chinook, winter steelhead, coho
	NF Toutle	Fall Chinook, winter steelhead, coho
	Cispus	Spring Chinook, winter steelhead, coho
	Upper Cowlitz	Spring Chinook, winter steelhead, coho
	NF Lewis	Fall Chinook, late-fall Chinook, spring Chinook, chum
	EF Lewis	Fall Chinook, chum, winter steelhead, summer steelhead, coho
	Washougal	Fall Chinook, chum, summer steelhead
	Sandy	Late-fall Chinook, spring Chinook, chum, winter steelhead, coho
Gorge	Lower Gorge tribs	Chum, winter steelhead, coho
	Hood	Fall Chinook, spring Chinook, winter steelhead, summer steelhead, coho

NMFS encourages implementers of this recovery plan to carry out tributary habitat protection and restoration actions specified in the Oregon, Washington, and White Salmon management unit plans in a manner that addresses limiting factors at the population scale. NMFS also encourages relevant entities to revise or add regulatory and/or incentive programs where monitoring indicates that habitat function and conditions are not improving. Particularly relevant are programs that address activities in floodplains and riparian areas and that affect sedimentation and other watershed processes.

NMFS welcomes opportunities to work with implementers to pursue ESA regulatory assurances to ensure that programs meet the conservation needs of salmon and steelhead. Among non-federal programs, for example, NMFS has determined that Washington's habitat conservation plans for state-owned forest land and its Forest Practices Rules for private forest land meet conservation needs for salmon and steelhead. (There are two distinct habitat conservation plans in Washington: one covering state lands in Washington state [west of the Cascades crest], and a second applied to forest practices on private and industrial forestlands statewide.) NMFS' view is that some state land management and regulatory programs (e.g., state forest management and forest practice rules in Oregon and regulation of certain agricultural practices in Oregon and Washington) do not provide adequate certainty that they will protect and restore salmon and steelhead habitat in a manner sufficient to recover the subject ESA-listed species. Where population-level habitat monitoring indicates statistically significant trends in degradation of key habitat features, the Oregon management unit plan calls for encouraging new or revised regulatory measures to eliminate further degradation of key habitat features, protect existing high-quality areas, and allow long-term passive restoration (ODFW 2010); the management unit plan does not identify a specific implementing entity for this action. NMFS considers this action a high priority and intends to work with ODFW and other appropriate agencies on its implementation.

Among federal programs, since 1994, for example, land management by the U.S. Forest Service and Bureau of Land Management in western Oregon has been guided by the Northwest Forest Plan (U.S. Department of Agriculture and U.S. Department of Interior 1994). The aquatic conservation strategy in this plan includes elements such as designated riparian management zones, activity-specific management standards, watershed assessment, watershed restoration, and identification of key watersheds (USDA and USDI, 1994). The Northwest Forest Plan has large riparian management zones and relatively protective, activity-specific management standards (USDA and USDI, 1994). NMFS considers the Northwest Forest Plan, when fully implemented, sufficient to provide for the habitat needs of Lower Columbia River salmon and steelhead and Columbia River chum on federal lands. (Although maintaining high-quality habitat on federal lands is necessary for the recovery of these species, recovery is unlikely unless habitat also can be improved in streams with high potential on non-federal lands.)

Many other federal programs are also important to protection and restoration of salmon and steelhead habitat. In addition to working with agencies to fulfill their ESA section 7(a)(2) responsibilities, NMFS welcomes opportunities to work with federal agencies to develop ESA section 7(a)(1) conservation programs that provide a more localized approach to priority threats and limiting factors.

For information on stratum-level tributary habitat strategies, see Sections 6.6.2, 7.4.3.2, 7.5.3.2, 7.6.3.1, 8.6.2, and 9.6.1.

4.2 Estuary Habitat

Habitat conditions in the Columbia River estuary and plume are important to the survival of all Columbia Basin salmon and steelhead during critical rearing, migration, and saltwater acclimation periods in their life cycle. For purposes of this recovery plan, the Columbia River estuary is defined as extending from the mouth of the Columbia River 146 miles upstream to Bonneville Dam and includes the Willamette River below Willamette Falls and the tidally influenced portions of other tributaries below Bonneville Dam. The Columbia River plume is generally defined by a reduced-salinity contour near the ocean surface off the immediate coasts of both Oregon and Washington and extending outward to the continental shelf.

The estuary and plume provide salmon and steelhead with a food-rich environment where they undergo the physiological changes needed to make the transition to and from saltwater and achieve the growth needed to bolster their marine survival (NMFS 2011a, LCFRB 2010a). Areas of adjacent habitat types distributed across the estuarine salinity gradient may be necessary to support annual migrations of juvenile salmonids (Bottom et al. 2005, cited in LCFRB 2010a). Observations of juveniles moving from low-tide refuge areas in deeper channels to salt marsh habitats at high tide and back again

(Healey 1982, cited in LCFRB 2010a) reinforce the belief that access to suitable low-tide refugia near marsh habitat is an important factor in production and survival of salmonid juveniles in the Columbia River estuary. Ocean-type salmonids in particular (i.e., fall Chinook and chum salmon) rely on the estuary for rearing opportunities. Ocean types typically spend weeks to months in the estuary, making use of shallow, vegetated habitats such as marshes and tidal swamps (NMFS 2011a). The plume—a unique low-salinity, high-productivity environment that extends well into the ocean—appears to serve a similar function for stream-type salmonids, offering feeding opportunities for coho salmon, spring Chinook salmon, and steelhead and distributing juveniles in the coastal environment (NMFS 2011a). These species typically make more use of the plume than ocean types do, spend less time in the estuary, and use mostly deeper, main-channel estuarine habitats rather than shallow vegetated wetlands (NMFS 2011a). However, feeding and refuge areas in the estuary may be important even for salmonid species that move through the estuary relatively quickly (LCFRB 2010a).

In addition, the physical refugia and turbidity in the estuary and possibly also the plume historically helped protect both ocean- and stream-type juveniles from predators (NMFS 2011a).

For more information on the Columbia River estuary, see the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a).[8]

4.2.1 Estuary Habitat Limiting Factors and Threats

Currently a lack of habitat opportunity and reduced habitat quality limit the viability of salmon and steelhead in the Columbia River estuary and plume. The amount and accessibility of in-channel, off-channel, and plume habitat have been reduced as a result of habitat conversion for agricultural, urban, and industrial uses, hydroregulation and flood control, channelization, and higher bankfull elevations, which have been facilitated by diking, dredging, and filling. Overbank flooding that normally would aid juveniles in accessing off-channel refugia and food resources has been virtually eliminated, and sediment transport processes that structure habitat (and offer protection from predators) have been impaired (NMFS 2011a). Access to up to 77 percent of historical tidal swamps and many other peripheral wetlands has been eliminated, and the surface area of the estuary has decreased by approximately 20 percent over the past 200 years (Fresh et al. 2005). Similarly, over roughly the last century the annual mean river flow through the estuary has declined by about 16 percent and peak spring flows have declined about 44 percent (Jay and Naik 2002 as cited in NMFS 2011a).

---

[8] The *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) synthesizes recently available information on the Columbia River estuary and plume to identify and analyze (1) limiting factors and threats in the estuary and plume that affect the viability of salmon and steelhead populations, (2) management actions whose implementation would reduce the threats and thus increase survival of salmon and steelhead during their time in the estuary, (3) the estimated cost of implementing each action over a 25-year period, and (4) monitoring, research, and evaluation needs related to the estuary and plume. Key source documents for the estuary module included two NMFS technical memoranda (Bottom et al. 2005 and Fresh et al 2005) and the subbasin plan for the lower Columbia River estuary and mainstem (Northwest Power and Conservation Council 2004a). Information from these sources was supplemented by input from NMFS' Northwest Fisheries Science Center and Northwest Regional Office, the Lower Columbia Estuary Partnership, and the Lower Columbia Fish Recovery Board. For more on the estuary module, see Section 1.5.3.

Some reductions in Columbia River flow are attributable to water withdrawals for irrigation and commercial, industrial, municipal, domestic, and other human uses. Irrigation needs account for approximately 96 percent of surface water withdrawals and 75 percent of groundwater withdrawals (National Research Council 2004). In total, water withdrawals have reduced flows of the Columbia River by 7 percent since the latter part of the nineteenth century (Jay and Kukulka 2003).

Meanwhile, the quality of the habitat available to salmon and steelhead in the estuary has been compromised. Water temperatures above the upper thermal tolerance range for salmon and steelhead are occurring earlier and more often (NMFS 2011a) and are likely to continue to climb as a result of global climate change (Independent Scientific Advisory Board 2007a, as cited in NMFS 2011a). A variety of toxic contaminants have been found in water, sediments, and salmon tissue in the estuary at concentrations above the estimated thresholds for health effects in juvenile salmon. These contaminants include polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), DDT, and copper (Lower Columbia River Estuary Partnership 2007). Pesticides in current use also have been detected in the estuary, along with emerging contaminants such as pharmaceuticals, personal care products, and brominated fire retardants (Lower Columbia River Estuary Partnership 2007). Although the effects of emerging contaminants on salmon and steelhead are not well understood, these compounds appear to pose risks to salmonid development, health, and fitness through endocrine disruption, bioaccumulative toxicity, or other means. Toxic contaminants are widespread in the estuary, both geographically and in the food chain (Lower Columbia River Estuary Partnership 2007).

Construction of revetments, disposal of dredged material, removal of large wood, and reductions in flow in the estuary have altered the diet of juvenile salmon in the estuary by eliminating much of the vegetated wetlands that historically supplied insect prey for juvenile salmonids and macrodetrital inputs to the estuarine food web. The shift in diet has been compounded by increased microdetrital inputs to the estuary; microdetrital inputs originate in decaying phytoplankton delivered from upstream reservoirs and nutrient inputs from urban, industrial, and agricultural development. The microdetrital-based food web may be less efficient for salmon and steelhead and favor other fish species in the estuary, such as American shad. It is likely that estuarine food web dynamics are being furthered altered by the presence of native and exotic fish, introduced invertebrates, invasive plant species, and thousands of over-water and instream structures, which alter habitat in their immediate vicinity. These and other changes in habitat have left the estuary and plume in a degraded state compared to historical conditions (NMFS 2011a).

In addition, current habitat conditions in the estuary and plume support increased predation on salmonids by northern pikeminnow, pinnipeds, Caspian terns, and cormorants, and juvenile salmon and steelhead in the estuary are subject to mechanical hazards from dredging activities, ship ballast intake, and beach stranding as a result of ship wakes (NMFS 2011a).

The degraded habitat conditions in the estuary and plume affect the abundance, productivity, spatial structure, and diversity of ESA-listed salmon and steelhead and have led to estuarine habitat issues being identified in the Oregon and Washington management unit plans as one of six general categories of threats that limit the viability of Lower Columbia River Chinook, coho, and steelhead and Columbia River chum salmon. Both management unit plans cite water quantity and flow timing, impaired sediment and sand routing, altered channel structure, and loss or degradation of peripheral and transitional habitats in the Columbia River estuary and plume as primary limiting factors that affect all Lower Columbia River Chinook, coho, and steelhead and Columbia River chum salmon juveniles. Management unit recovery planners estimated baseline anthropogenic mortality in the estuary and plume—excluding mortality attributable to predation—at between 9 and 50 percent, depending on species and population; for most populations, the estimates range from 10 to 32 percent (see ODFW pp. 169-200 and LCFRB 2010a pp. 6-17, 6-38, 6-50, and 6-66). These estimates were based in part on mortality estimates in the estuary module (NMFS 2011a).

Additional information about limiting factors, threats, and mortality in the Columbia River estuary and plume is available in Chapters 3 and 4 of the estuary module (NMFS 2011a), ODFW (2010) pp. 88-90, and LCRFB (2010a) pp. 3-33 through 3-47.

4.2.2 Regional Strategy for Estuary Habitat

Actions and strategies presented in the Oregon and Washington management unit plans to reduce estuarine habitat-related threats are consistent with those in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a), which describes and analyzes actions to benefit all Columbia Basin salmon and steelhead species, including the Lower Columbia River ESUs. In general, estuary habitat strategies focus on providing adequate off-channel and intertidal habitats, such as tidal swamp and marsh; restoring habitat complexity in areas modified by agricultural or rural residential use; decreasing exposure to toxic contaminants; and lowering late summer and fall water temperatures. This will be accomplished over the long term by restoring hydrologic, sediment, and riparian processes that structure habitat in the estuary. Representative actions include protecting and restoring high-quality off-channel habitats and riparian areas; identifying and reducing current sources of pollutants; restoring contaminated sites; adjusting the timing, magnitude, and frequency of flows[9]; and breaching and lowering dikes and levees. Together, these actions are expected to increase the complexity and accessibility of estuarine habitat and improve water quality and flow patterns in the estuary and, potentially, the plume. A host of additional actions, such as preventing new introductions of invasive species, also are expected to improve habitat conditions in the estuary, to a lesser degree.

Because the mechanisms of estuary habitat impacts and the techniques for reducing them are poorly understood, estuary habitat actions will need to be implemented under an adaptive management framework. Both the estuary module and the management unit plans identify research needs to reduce critical uncertainties and increase the effectiveness of actions (see Table 5-6 of NMFS 2011a, pp. 233-238 of ODFW 2010, and p. 9-72 of LCFRB 2010a).

[9] Adjusting timing, magnitude, and frequency of flows would be limited by international treaties, the need for flood control, fish management objectives, and power production. However, even slight modifications in the flow regime have the potential to provide significant ecosystem benefits.

An aggressive, strategic approach needs to be developed for implementation of actions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The estuary module refrains from explicitly prioritizing habitat actions because it considers all of the management actions it identifies as necessary in improving the survival of juvenile salmonids in the Columbia River estuary and plume. But the module does identify priority reaches for each action and offers several analyses intended to inform future decisions about prioritization (i.e., actions likely to be most beneficial to stream-type salmonids, those that will benefit ocean types, and those that are most cost-effective; see Tables 7-2, 7-3, and 7-5 of NMFS 2011a). These analyses take into account the probable implementation constraints for each action (see Table 5-6 of NMFS 2011a). In addition, the module identifies a need to determine near-term implementation priorities by developing a 5-year implementation plan that provides specificity and certainty regarding near-term actions. For many actions, additional assessment is needed to determine implementation priorities and specific benefits to Lower Columbia River salmon and steelhead.

Developing implementation priorities for estuarine habitat actions should include establishment of milestones or expected trends in improved habitat condition in high-priority intertidal areas, which are particularly important for ocean-type salmon (i.e., fall Chinook and chum salmon). Less is known about the habitat needs of chum salmon than those of other ESUs addressed in this recovery plan, and the management unit plans call for habitat assessments to learn more on this subject. Yet what is known points to overlapping habitat needs with fall Chinook salmon, especially for rearing habitat. A topic to be investigated is whether Coast- and Cascade-stratum chum salmon populations, like fall Chinook salmon, make heavy use of the tidal portions of tributaries at their confluence with the mainstem Columbia. The Washington management unit plan notes that lower tidal reaches of streams were not typically assigned a high priority for habitat actions in the EDT-based watershed assessments, but these areas have been identified as critical rearing areas for both fall Chinook and chum salmon (LCFRB 2010a).

4.3 Hydropower

The Columbia Basin has more than 450 dams, which are managed for hydropower, flood control, and other uses. Together these dams provide active storage of 42 million acre-feet of water, with dams in Canada accounting for about half of the total storage (Northwest Power and Conservation Council 2001, as cited in NMFS 2011a). Within the United States, 14 multi-purpose hydropower projects operate as a coordinated system in the Columbia Basin. Bonneville Dam is the only mainstem hydropower facility within the geographic range of Lower Columbia River salmon and steelhead, but flow management operations at large storage reservoirs in the interior of the Columbia Basin (Grand Coulee, Dworshak, etc.) affect habitat in the lower Columbia River mainstem and estuary, and, potentially, the plume. In addition, significant tributary hydropower dams are located on the Cowlitz and Lewis rivers in Washington and the Willamette, Clackamas, and Sandy rivers in Oregon. Condit Dam, on the White Salmon River, was breached in October 2011 and completely removed in September 2012.[10] The impacts of hydropower facility construction and operation on Lower Columbia salmon and

[10] Powerdale Dam, on the Hood River, was removed in 2010.

steelhead occur both locally (at, above, and immediately below dams) and downstream, in the Columbia River estuary and, potentially, the plume.

4.3.1 Hydropower Limiting Factors and Threats

Hydropower limiting factors and threats can be categorized as those related to reservoirs and structures (including passage and habitat access impacts) and those related to flow modifications. These are described briefly below.

4.3.1.1 Reservoir-Related or Structural Impacts

Dam construction on the lower Columbia River and its tributaries has caused habitat loss by converting riverine habitat to large impoundments of slow-moving water and flooding upriver deltas, wetlands, and floodplains (ODFW 2010).

The impoundment of water in large storage reservoirs in the interior Columbia Basin and operations at mainstem hydropower projects in the lower Columbia Basin has contributed to increased water temperatures during the late summer and fall in the Columbia River, including the lower Columbia River mainstem and estuary. Even when elevated temperatures do not cause direct mortality, they can cause adverse physiological and behavioral effects and may enhance conditions for warm-water fish that prey on juvenile salmonids (NMFS 2011a).

Impoundments also alter food webs and enhance opportunities for some predators. In Bonneville Reservoir and just downstream of Bonneville Dam, a variety of fish species—northern pikeminnow, walleye, smallmouth bass, and salmonids—prey on juvenile salmon and steelhead. In addition, adult spring Chinook salmon and steelhead attempting to pass above Bonneville Dam are subject to predation by seals and sea lions that congregate at the dam (U.S. Army Corps of Engineers 2011a). For more on predation, see Section 4.6.1.1.

In addition, water can become supersaturated with atmospheric gases (primarily nitrogen) when spilled over high dams. These high concentrations of gases are absorbed into a fish's bloodstream during respiration. When the gas comes out of solution, bubbles may form and subject the fish to gas bubble disease, which can cause direct mortality or increase susceptibility to disease or predation (LCFRB 2010a). Dam operations have been modified to reduce what once were high dissolved gas levels, but some salmonid mortality continues to be associated with exceptionally high river flows (NMFS 2000a).

Impaired Fish Passage in the Columbia River Mainstem

Bonneville Dam on the Columbia River mainstem acts as a partial migration barrier to Lower Columbia River salmon and steelhead populations that originate above the dam—specifically, Upper Gorge, Hood River, and White Salmon populations. Both downstream-migrating juveniles and upstream-migrating adults experience delay, injury, and mortality while trying to pass the dam.

Although fish ladders provide for upstream passage of adult salmon and steelhead, historically—and during the baseline period for this recovery plan—they have not been completely effective (LCFRB 2010a). More recently in the lower Columbia River mainstem, average survival rates of adults at Bonneville Dam have been estimated at approximately 99 percent for spring Chinook salmon and steelhead and 97 percent for fall Chinook, coho, and chum salmon (NMFS 2008a).

Downstream fish passage at Bonneville Dam is complex, with two passage routes at each of two powerhouses, plus an unattached spillway. Outmigrating juveniles experience different mortality rates depending on whether passage occurs via turbines, spill, or a fish bypass system. NMFS estimates that recent average survival of juveniles from Lower Columbia River ESUs at Bonneville Dam is between 90 and 95 percent, depending on species (NMFS 2008a).

Impaired Fish Passage in Tributaries

Tributary dams create fish passage barriers that limit habitat connectivity and access to spawning and rearing habitats for some Lower Columbia River salmon and steelhead. As with Bonneville Dam, tributary dams can cause mortality of out-migrating juveniles, delay migration of returning adult salmon and steelhead, and hinder or totally block access to historical spawning areas above the dam. Within the lower Columbia recovery planning subdomain, major hydropower systems on the Cowlitz and Lewis rivers in Washington are responsible for the greatest share of blocked habitat access. Tributary dams also restrict fish passage in the Clackamas, Sandy, and White Salmon watersheds.[11] (Although dams are responsible for the greatest share of blocked habitat, inadequate culverts make up the vast majority of all barriers [LCFRB 2010a]; see Section 4.1.1.)

4.3.1.2 Flow-Related Impacts

Before development of the hydropower system, Columbia River flows were characterized by high spring runoff from snowmelt and regular winter and spring floods. Today, the interception and retention of spring freshets in multiple dams and their use for irrigation, reservoir storage, and other purposes cause flow volumes to the Columbia River estuary to be more uniform throughout the year than they were historically (see Figure 4-1). Over the last century, annual mean flow in the Columbia River estuary has declined, the volume of the spring freshet has dropped by 44 percent, and the timing of the freshet has shifted to 14 to 30 days earlier in the year (Jay and Kukulka 2003). Although changes in flow entering the estuary are due to a combination of factors, including water withdrawals and the effects of climate change, the management unit plans and *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) identify mainstem dams as the primary contributor to flow alterations in the estuary.

[11] Powerdale Dam, on the Hood River, was removed in 2010. Condit Dam, on the White Salmon River, was breached in October 2011 and completely removed in 2012.

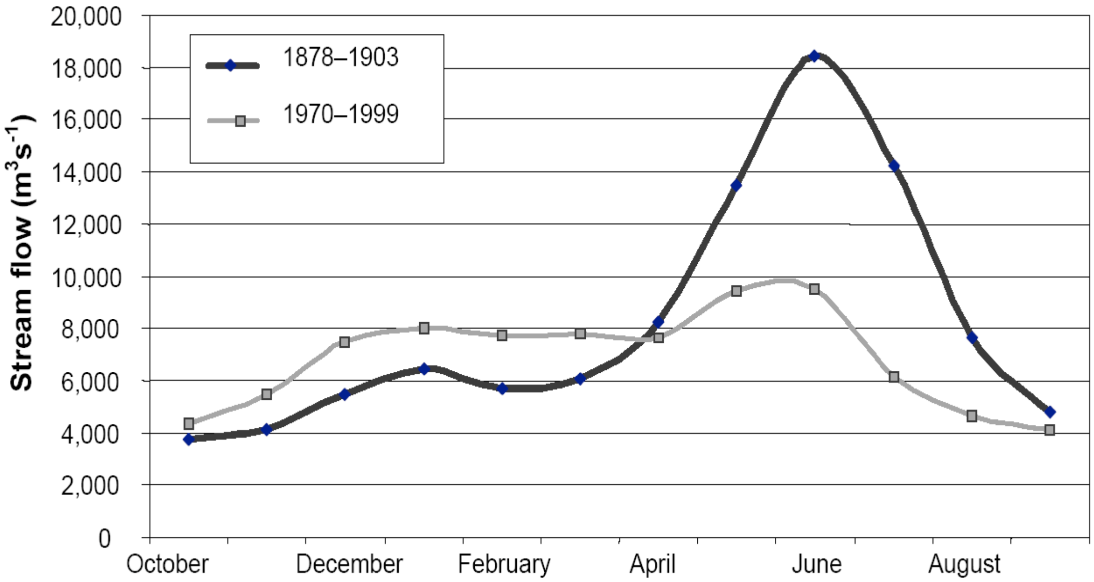

Figure 4-1. *Changes in Annual Columbia River Flow*
(Measured at Beaver Army Terminal, near Quincy, Oregon. Source: Bottom et al. 2005).

Flow alterations have disrupted habitat-forming processes such as the recruitment of large woody debris and sediment delivery to the Columbia River estuary. Historically, sediment was delivered to the estuary largely via spring freshets. That vehicle for sediment delivery has been curtailed, and today reservoirs commonly act to trap upstream supplies of fine sediments (NMFS 2011a). Since the late nineteenth century, sediment transport from the interior of the Columbia Basin to the Columbia River estuary has decreased approximately 60 percent (Jay and Kukulka 2003). This has altered deposition and erosion processes that shape estuarine habitat for salmonids.

Together with diking and the placement of dredged materials on or near the shore, flow alterations have also virtually eliminated the overbank flooding that once allowed juvenile salmonids to access large areas of off-channel habitat for refuge and rearing. Without periodic inundation—tidal, seasonal, or annual—much habitat that formerly was used by juvenile salmonids has disappeared or been transformed into different habitat types (NMFS 2011a).

By reducing wetland and foraging habitat, simplifying habitats, and altering sediment inputs, flow alterations have contributed to changes in the estuarine food web, particularly in detrital food sources. The current food web is based on decaying phytoplankton delivered from upstream reservoirs, instead of macrodetrital inputs from plants and animals originating from emergent forest and other wetland rearing areas in the estuary, as was the case historically. The switch from macrodetrital- to microdetrital-based food sources has lowered the productivity of the estuary (Bottom et al. 2005), provided different and possibly less favorable food sources to juvenile salmonids, and concentrated food sources within the estuarine turbidity maximum, in the middle region of the estuary (Bottom et al. 2005). This location is less accessible to ocean-type salmon, such as chum, that use peripheral habitats (LCFRB 2010a).

Both juvenile and adult migration behavior and travel rates are influenced by the changes in river flow. Artificial regulation of flow can stimulate or delay juvenile emigration or adult migration, thereby affecting the timing of juvenile arrival in the estuary and ocean (ODFW 2010, LCFRB 2010a) or adult arrival at spawning areas (LCFRB 2010a).

Rapid diurnal flow fluctuations can cause unintended and adverse redistribution of mainstem spawners, leave redds dewatered, or strand juveniles (LCFRB 2010a). Although daily flow fluctuations as a result of power production occurred in the past and resulted in dewatering of chum redds, a minimum flow now applies from November through April to reduce the potential for such dewatering.

4.3.2 Regional Hydropower Strategy

The regional hydropower strategy focuses on hydropower operations on the Columbia River mainstem and has three principal components: (1) improving passage survival at Bonneville Dam for Lower Columbia River populations that spawn above the dam, (2) addressing impacts in tributaries by implementing actions prescribed in Federal Energy Regulatory Commission agreements regarding operation of individual tributary dams, and (3) implementing mainstem flow management operations designed to benefit spring migrants from the interior of the Columbia Basin; NMFS expects that these flow management operations will also improve survival in the estuary and, potentially, the plume for all Lower Columbia River salmon and steelhead populations. Actions identified in the 2008 FCRPS Biological Opinion and its 2010 Supplement (NMFS 2008f and 2010a) will aid adults and juveniles from the Gorge populations in passing Bonneville Dam. Specific actions include structural improvements, changes in configuration and operations, and development and implementation of year-round fish passage plans for Bonneville Dam.[12] NMFS' estimates of recent survival of lower Columbia River species are shown in Table 4-4. NMFS expected that implementation of actions in the 2008 FCRPS Biological Opinion would improve juvenile salmon and steelhead survival at Bonneville Dam by less than ½ percent, and that the recent high level of adult survival would be maintained at the levels shown in Table 4-4 (NMFS 2008a and 2010a). Consequently, Oregon did not incorporate survival benefits from passage improvements at Bonneville into the hydropower threat reduction targets for Oregon populations above Bonneville.[13] The Washington management unit plan assumed that actions identified in the 2008 FCRPS Biological Opinion and its 2010 Supplement would aid adults and juveniles from all populations originating above Bonneville Dam. However, preliminary information indicates that survival gains for yearling Chinook and steelhead at Bonneville Dam are higher than expected, and that juvenile passage survivals are above 96 percent in both cases (U.S. Army Corps of Engineers 2011b).

In addition, for chum salmon, the regional hydropower strategy will focus on ensuring adequate flows in the Bonneville Dam tailrace and downstream habitats during chum salmon migration, spawning, incubation, and emergence. FCRPS Biological Opinion

---

[12] For more specificity, see the actions in the 2008 FCRPS Biological Opinion Reasonable and Prudent Alternative (NMFS 2008f).

[13] Hydropower-related threat reductions for Oregon populations above Bonneville Dam are associated with removal of Powerdale Dam on the Hood River.

actions will protect chum salmon spawning areas in the mainstem Columbia River in the area of the Ives Island complex and/or will provide access to Hamilton and Hardy creeks. These areas currently constitute significant spawning areas for the Lower Gorge population.

Table 4-4
Estimated Average Survival Rates of Lower Columbia Salmon and Steelhead Passing Bonneville Dam

	Average Survival Rate (%)	
	Juveniles 2002 – 2009	Adults 2002 – 2007
Coho salmon	95.1	96.9
Spring Chinook salmon	95.1	98.6
Fall Chinook salmon	95.1	96.9
Chum salmon	95.1	96.9
Steelhead	90.6	98.5

Source: NMFS (2008a) and (2010a).

In its management unit plan, Oregon incorporated four actions addressing impacts of the Columbia River hydropower system that are not included in the 2008 FCRPS Biological Opinion and its 2010 Supplement (NMFS 2008f and 2010a) but that Oregon maintains are needed to benefit Lower Columbia River salmon and steelhead:

- Action 1: Operate lower Columbia reservoirs at minimum operating pool during spring and summer as long as barge transport and irrigation needs are met.
- Action 2: Provide spill to total dissolved gas limits of water quality waivers or biological constraints at all dams, except maximize transportation at Snake River collector projects during lower (10^{th} percentile) flow years.
- Action 3: Draft storage reservoirs to meet Lower Columbia summer flow and velocity equivalent objectives on a seasonal and weekly basis.
- Action 4: Operate reservoirs at rule curves and seek additional flow augmentation volumes from Snake River and Canadian reservoirs to better meet spring and summer flow and velocity objectives.

The state of Oregon's position is that the FCRPS action agencies should conduct operations in addition to those incorporated in the 2008 FCRPS Biological Opinion and its 2010 Supplement to address the needs of ESA-listed salmon and steelhead. Oregon is a plaintiff in litigation against various federal agencies, including NMFS, challenging the adequacy of measures in the 2008 FCRPS Biological Opinion and its 2010 Supplement. NMFS does not agree with Oregon regarding the need for or likely efficacy of the additional actions that Oregon proposed in that litigation, including the items noted above; thus NMFS is not adopting as part of this recovery plan the additional actions proposed by Oregon.

In the Columbia River estuary, under the terms of the 2008 FCRPS Biological Opinion and its 2010 Supplement (NMFS 2008f and 2010a), the action agencies will implement an expanded estuary habitat program to address limiting factors that affect juvenile salmonids rearing in the estuary. These estuary habitat projects will increase the amount of juvenile salmonid shallow-water habitat and benefit all ESA-listed ESUs. The 2008 FCRPS Biological Opinion and its 2010 Supplement incorporate a relative survival improvement estimate of 9.0 percent for ocean-type ESUs (including Lower Columbia River fall Chinook and Columbia River chum salmon) to be derived from habitat improvements, and an estimate of 5.7 percent for stream-type ESUs (including Lower Columbia River coho salmon, spring Chinook salmon, and steelhead). In addition, the Biological Opinion projects that actions to reduce predation in the estuary will increase survival by additional amounts, as shown in Table 4-5.

Table 4-5
Projected Survival Improvements for Lower Columbia Salmon and Steelhead from Actions to Reduce Predation in the Estuary

	Survival Improvement (%)
Coho salmon	8.8
Spring Chinook salmon	3.1
Fall Chinook salmon	1.7
Chum salmon	1.0
Steelhead	4.4

Source: NMFS (2008f and 2010a).

As noted in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a), actions in the 2008 FCRPS Biological Opinion and its 2010 Supplement that relate to estuarine habitat, predation, and flow are contributing to implementation of actions called for in the module; however, these Biological Opinion actions are projected to yield only a portion of the total survival improvements that the estuary module hypothesizes are possible in those categories. Thus, the module identifies habitat, predation, and flow actions that are larger in scope than the actions that are required under the 2008 FCRPS Biological Opinion and its 2010 Supplement.

For information on stratum-level hydropower strategies, see Sections 6.6.4, 7.4.3.4, 7.5.3.4, 7.6.3.2, 8.6.4, and 9.6.3.

4.4 Hatcheries

For more than a century, fish managers have used hatcheries in the Lower Columbia River to produce fish for harvest. Although some early hatchery programs supplemented already large naturally spawning populations, most were developed to compensate for declining numbers of naturally spawned salmon and steelhead, which were experiencing the detrimental effects of habitat loss (particularly related to hydropower dams) (LCFRB 2010a). Today, salmon and steelhead production in the lower Columbia region is dominated by hatchery-origin fish (ODFW 2010, LCFRB 2010a).

Although the actual number of artificial production programs changes annually based on funding and broodstock availability, in 2011 there were more than 80 separate artificial production programs in the lower Columbia region. Almost all of these programs produce fish for harvest; a few produce fish for reintroduction purposes or to supplement severely depressed natural populations. Most Lower Columbia programs produce either coho or Chinook salmon, while a smaller number produce steelhead, and four programs produce chum salmon (Turner, personal communication 2011).[14]

As shown in Table 4-6, artificial production programs release millions of fall Chinook salmon, spring Chinook salmon, coho salmon, chum salmon, and steelhead into lower Columbia River subbasins each year, although Lower Columbia production has been reduced substantially over the past 15 years. In addition to these releases, hatchery fish released elsewhere in the Columbia Basin migrate through the lower Columbia River as juveniles and adults.

Table 4-6

Hatchery Releases of Salmon and Steelhead in the Lower Columbia River, 2011

LCR Release	By ODFW	By WDFW	By USFWS	Total
Fall Chinook*	11,991,500	14,800,000	17,034,500	43,826,000
Spring Chinook**	1,225,000	2,940,400	1,714,000	5,879,400
Coho	5,404,000	6,689,000	643,900	12,746,900
Summer Steelhead	255,000	1,066,100	0	1,321,100
Winter Steelhead	510,000	1,234,300	111,500	1,855,800
Chum	0	307,000	0	307,000
All releases				65,936,200

* Fall Chinook includes tules, upriver brights, and Select Area brights.

**Excludes Clackamas hatchery spring Chinook salmon, which are in the Upper Willamette spring Chinook ESU.

Source: Turner, personal communication (2011).

Annual returns of adult hatchery-origin fish are large relative to returns of adult fish produced naturally in the Columbia Basin. For example, from 2000 to 2010, the number of adult Lower Columbia River hatchery-origin fall Chinook salmon returning annually to the Columbia River ranged from 27,000 to 156,400, while natural-origin Lower Columbia River fall Chinook salmon returns numbered between 4,300 and 26,000 fish (Joint Columbia River Management Staff 2011). From 2000 to 2008, annual coho salmon returns ranged from 318,600 to more than 1.1 million, with almost all being hatchery-origin fish (NMFS 2008b).[15]

[14] Only three of these chum salmon hatchery programs are part of the ESU; NMFS has not yet evaluated the fourth, which the Oregon Department of Fish and Wildlife initiated in 2010, for inclusion in the ESU.

[15] Over this same time period, the geometric mean number of natural-origin spawners for the two largest coho salmon populations totaled less than 3,000 (http://www.nwfsc.noaa.gov/trt/trt_documents/lcolumbia_coho.pdf).

At the time many hatchery programs were developed, little was known about the impacts of hatchery fish on natural populations. Instead, it was generally believed that hatchery fish could be substituted for naturally spawning fish without lasting consequences; there was little understanding of the negative impacts hatchery fish could have on naturally spawning populations and of the need to protect naturally spawning populations and their habitats.

Today scientists and managers understand that hatchery programs have the potential both to benefit and to harm Lower Columbia River salmon and steelhead. The weight of available scientific evidence indicates that any artificial breeding and rearing will result in some degree of genetic change and fitness reduction in hatchery fish, and in the progeny of hatchery-origin fish that spawn naturally, relative to desired levels of diversity and productivity for natural populations. Hatchery fish thus pose a threat to the rebuilding and recovery of natural populations when they interbreed with fish from natural populations. That risk is outweighed in certain circumstances, such as when the near-term demographic risks of extinction outweigh longer term risks to population diversity and productivity. The extent and duration of genetic change and fitness loss and the near- and long-term implications and consequences for different species, for species with multiple life-history types, and under different hatchery practices and protocols remains unclear and should be the subject of further scientific investigation. NMFS believes that in certain circumstances, hatchery intervention is an appropriate tool to help avert salmon and steelhead extinction in the near term and to accelerate the recolonization of habitat. Otherwise, managers should limit interactions between hatchery- and natural-origin fish during the transition to hatchery practices consistent with recovery of listed populations, treaty fishing rights, and other applicable laws and policies.

4.4.1 Hatchery Limiting Factors and Threats

4.4.1.1 Genetic Effects

Hatchery practices such as broodstock collection and spawning protocols can cause genetic changes in hatchery fish. When hatchery-origin fish spawn with natural-origin fish, these genetic changes can be transmitted to the naturally produced fish; the larger the proportion of hatchery-origin spawners, the larger the genetic effects to the natural population. These genetic effects can be summarized as follows (NMFS 2011c):

- Loss of within-population diversity. Loss of within-population genetic diversity is a loss in the amount or type of genetic variability in a population, which can be caused by genetic drift and inbreeding depression. Genetic drift typically results from using small numbers of broodstock fish, having an unbalanced sex ratio in the broodstock, or pooling gametes from many adults during spawning. Inbreeding depression is a reduction in fitness caused by mating related individuals (Busack and Currens 1995, NMFS 2011c). The smaller the population, the higher the probability of inbreeding.

- Outbreeding effects. Outbreeding effects refer to changes in fitness and diversity caused by gene flow (i.e., interbreeding) in excess of natural rates among genetically distinct populations (NMFS 2011c). One outbreeding effect is loss of within-population diversity, which may have no immediate impact on fitness. Large-scale loss of diversity is called "genetic swamping" or homogenization. The other outbreeding effect is outbreeding depression, in which changes in diversity caused by gene flow result in loss of fitness. Decreased disease resistance (Currens et al. 1997) and diminished ability to avoid predators (Tymchuk et al. 2007) are demonstrated results of outbreeding depression.

- Domestication selection. Domestication selection is intentional or inadvertent change to the natural selection regime caused by hatchery culture, resulting in the fish being less well adapted in the wild. Traits such as fish size, timing of spawning, growth rate, and feeding behaviors are subject to domestication selection. Domestication selection can also include the relaxation of selection. For example, hatchery fish do not participate in mate-choice behaviors, and the ability to perform these behaviors effectively can diminish in hatchery populations. When naturally produced fish interbreed with hatchery-origin fish, the level of domestication selection that occurs to the total population is a function of the fraction of hatchery-origin fish on the spawning grounds and the composition of the hatchery broodstock (NMFS 2011c, Berejikian and Ford 2004).

High proportions of hatchery fish on the spawning grounds have been common for decades in many Lower Columbia River salmon and steelhead populations, including the vast majority of Chinook and coho salmon populations. The impacts are likely a mix of outbreeding effects and domestication selection. For example, homogenization already has occurred in natural-origin coho salmon, which are now genetically indistinguishable from hatchery fish (Flagg et al. 1995). Fitness impacts from domestication selection are difficult to quantify in the Lower Columbia River, but a recent review of the literature worldwide suggests that progeny of hatchery fish that spawn in the wild are less likely to survive and return as adults than the progeny of natural-origin spawners (Berejikian and Ford 2004). In addition, Chilcote et al. (2011) found a negative relationship between the reproductive performance in natural, anadromous populations of steelhead, coho salmon, and Chinook salmon and the proportion of hatchery fish in the spawning population, including populations in the Lower Columbia.

4.4.1.2 Competition (Density-Dependent Mortality) and Predation

Density dependence refers to changes in the productivity of a population that are a result of the size of the population (productivity here refers to the number of returning offspring per spawner). In a density-dependent process, the number of offspring produced per spawner is higher when there are few spawners but decreases to one offspring per spawner (i.e., replacement) when the number of spawners is at the habitat's carrying capacity. With salmon and steelhead, density-dependent mortality can occur at any stage in the animal's life cycle and may be exacerbated by the introduction of large numbers of hatchery fish released over a relatively short time (NMFS 2011a).

Some scientists suspect that closely spaced releases of hatchery fish from Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the Columbia River estuary. NMFS (2011) and LCFRB (2010a) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged this uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon in freshwater, estuarine, and nearshore ocean habitats.

In addition, hatchery fish can sometimes prey directly on naturally produced juveniles, particularly chum salmon (ODFW 2010). Chum salmon fry from all populations may experience predation by hatchery-origin coho salmon, steelhead, and Chinook salmon smolts, although differences in life history patterns may moderate effects and the significance of interactions is unknown.

4.4.1.3 Other Effects: Disease Transmission, Passage Blockages, Water Withdrawals, and Mixed Stock Harvest

Hatchery fish can be infected with pathogens or parasites and have the potential to spread these organisms to natural-origin fish, although disease transmission from hatchery to natural-origin fish does not appear to be widespread in the lower Columbia region (LCFRB 2010a). (For more on this topic, see Section 4.6.1.3.) Hatchery structures, such as weirs, ladders, and screens, can injure fish and block or delay the passage of naturally produced adults and juveniles and thus reduce population spatial structure. Water withdrawals for hatchery operations can reduce tributary flow and habitat quality. Lastly, when hatchery production stimulates harvest, the incidental mortality of naturally produced fish can increase.

4.4.2 Regional Hatchery Strategy

For most Lower Columbia River ESUs, the general goals of the hatchery strategies developed by local recovery planners, and the basic approaches they recommend for achieving those goals, are similar. These goals and approaches are summarized below. Although these strategies are especially relevant for Lower Columbia River coho, spring and fall Chinook salmon, and Lower Columbia River steelhead (which have been subject to the most hatchery influence), they also are relevant to Columbia River chum salmon and late-fall Chinook salmon to the extent that hatcheries have created or may create limiting factors for these fish. Although the overall hatchery strategy will be applied consistently throughout the domain, management unit planners have or will establish specific targets for reductions in hatchery impacts at the population level and specific actions for achieving those targets; consequently, the specifics of how the regional hatchery strategy is applied will differ among populations and among hatchery programs.

The overall goals of the hatchery recovery strategies for the Lower Columbia ESUs are to (1) reduce hatchery impacts on natural-origin populations as appropriate for each population, (2) ensure that some populations have no in-subbasin hatchery releases and are isolated from stray out-of-subbasin hatchery fish, (3) use hatchery stocks in the short term for reintroduction or supplementation programs to restore naturally spawning populations in some watersheds, and (4) ensure rigorous monitoring and evaluation to better understand existing population status and the effects of hatchery strategies on natural populations. The management unit plans include the additional societal goal of maintaining harvest opportunities created by hatchery fish. To accomplish these goals, hatchery programs will be managed in one of two general ways: as genetically integrated with or segregated from the natural populations they most directly influence.

In integrated programs, the intent is for the natural environment to drive the adaptation and fitness of a composite population of fish that spawns both in a hatchery and in the wild (i.e., to limit domestication). When hatcheries are used for conservation purposes (e.g., increasing the abundance of natural spawners, reintroducing fish into historically occupied habitats, or conserving genetic resources), integrated programs are the tool of choice because, by design, they allow a certain number of hatchery-origin fish to spawn in the wild. Integrated programs are also sometimes used to provide harvest opportunities, in which case the intent is to produce a desired set of fishery characteristics; however, there is still the need to reduce the effects of hatchery-origin fish spawning naturally. Integrated programs promote local adaptation and natural productivity through measures such as use of local broodstock, inclusion of naturally produced fish in the hatchery broodstock, and limits on the proportion of hatchery fish spawning in the wild.

In segregated programs, the intent is to maintain a hatchery population that is genetically isolated from and does not interact with the natural population. In contrast to integrated programs, segregated programs reduce domestication solely by minimizing spawning between natural-origin and hatchery-origin fish. The purpose of segregated programs is almost always to provide harvest opportunities. Risks posed to the natural population by the hatchery fish are reduced by minimizing interactions throughout the fishes' life cycles, including the proportion of hatchery-origin spawners (pHOS) on the spawning grounds. Managers control the proportion of hatchery-origin spawners through measures such as reducing overall production, shifting production to reduce straying into certain watersheds, changing production strategies to reduce straying (e.g., using different acclimation or release strategies), physically removing hatchery-origin fish (distinguishable by their clipped adipose fins) from natural spawning areas at weirs or other physical barriers, maintaining some wild fish sanctuaries (i.e., populations or substantial portions of subbasins where the pHOS target is very low), and improving habitat conditions to increase the number of natural-origin fish.

Theoretically the two approaches can be equally effective at limiting domestication impacts. Guidelines exist for applying both approaches to primary, contributing, and stabilizing populations (see Appendix A of Hatchery Scientific Review Group 2009.). The risks posed by a particular program are based not on the program type but on the gene flow levels involved (i.e., the proportion of natural-origin broodstock and the proportion of hatchery-origin spawners). Chilcote et al. (2011) evaluated the effects of hatchery programs on 89 steelhead, coho, and Chinook salmon populations and concluded that the proportion of hatchery-origin fish on the spawning grounds (pHOS) was negatively correlated with population productivity; furthermore, there seemed to be no difference in the impact of integrated and segregated programs on productivity. The authors concluded that, under most circumstances, ensuring that hatchery-origin fish are segregated from natural-origin fish on the spawning grounds (i.e., reducing pHOS) may be the best long-term conservation strategy regardless of brood type. A note about Chilcote et al.'s integrated-segregated comparison is that integrated programs complying with modern gene flow guidelines for reducing domestication are still uncommon and typically quite new, so a more detailed assessment and finer scale research of truly integrated hatchery programs is needed.

In addition to managing potential genetic effects of hatchery-origin fish on natural-origin fish, another important management consideration for both integrated and segregated programs is potential ecological effects, such as competition for food or space between hatchery-origin and natural-origin fish. Therefore controlling pHOS and managing juvenile release levels to minimize detrimental interactions are important considerations in both integrated and segregated programs.

Collectively, both Oregon and Washington will use both segregated and integrated programs, for fishery enhancement and to help recover natural populations above tributary dams that have blocked access to historical habitat and in other areas where the abundance of natural-origin fish is very low and hatchery supplementation can reduce extinction risk in the short term. Managers will limit the proportion of hatchery-origin fish spawning naturally by using measures such as reducing overall production, changing production strategies to reduce straying (e.g., using different acclimation or release strategies), and physically removing hatchery-origin fish (distinguishable by their clipped adipose fins) from natural spawning areas at weirs or other physical barriers. Managing the genetic and ecological risks posed by hatchery fish with the demographic risks of low natural abundance and productivity is an important aspect of the strategy—one that is characterized by many uncertainties. Decisions about whether to use artificial propagation to help conserve populations must take into consideration the benefits to the population and ESU versus the risks.

In both states, efforts to reduce hatchery impacts will be targeted at achieving a level of hatchery influence appropriate to each population, based on its target status. For example, for populations targeted for a high probability of persistence, Oregon has established a target of no more than 10 percent hatchery-origin spawners in natural spawning areas (ODFW 2010). Washington will establish similar targets in the Conservation and Sustainable Fisheries Plan being developed by the Washington Department of Fish and Wildlife.

The management unit plans also call for continuing existing programs to mark all hatchery-produced coho salmon with an adipose fin clip and for coded wire tagging enough fish from each hatchery to allow identification of the hatchery program of origin (ODFW 2010). The latter strategy will allow rearing and release strategies to be modified where needed to further reduce straying. Another element of the hatchery strategy will be to continue best management practices such as juvenile release strategies that minimize impacts to natural populations.

There are critical uncertainties associated with the approaches described above. For integrated programs, the primary uncertainties include the availability of sufficient numbers of naturally produced fish for incorporation into the hatchery broodstock and the validity of assumptions concerning the natural fitness of hatchery-origin fish produced using natural broodstock. (For example, for a population with very low natural-origin abundance, what are the tradeoffs of introducing natural-origin fish into hatchery broodstock versus waiting until natural production has increased?) For both integrated and segregated programs, a primary uncertainty concerns the effectiveness of measures such as weirs, acclimation, or release sites in achieving desired reductions in pHOS. A key unknown for all hatchery reforms is how quickly natural population diversity and productivity will respond to limiting the numbers of hatchery fish on the spawning grounds, and the extent to which limiting hatchery fish on the spawning grounds will affect the short-term demographic risks to the natural population by reducing the total number of spawners.

NMFS and other recovery planning entities will work with hatchery managers to develop more detail about how and when the strategies described above will be implemented, including detail about how strategies will reduce the proportion of hatchery fish in naturally spawning populations in a manner that addresses short-term demographic risks while promoting progress toward recovery objectives. A near-term priority is for state and federal hatchery program managers, working with NMFS and other recovery planning entities, to develop detailed schedules for implementation of hatchery strategies that address these questions and that lay out plans for transitioning from existing hatchery management to practices consistent with recovery of listed populations, treaty fishing rights, and other applicable laws and policies.[16] Through reduction of hatchery impacts, long-term priorities include achieving the recovery targets for each population and providing harvest opportunities.

NMFS expects that in general these "transition schedules" will reflect a plan to determine the extent to which naturally produced adults are returning to a population's habitat, as well as whether the intent for each population is to use hatchery supplementation. Use of hatchery supplementation should be considered an experimental strategy and not applied everywhere (that is, for some populations, the strategy should be to let the population restart based on stray spawners from nearby populations, an approach that has been demonstrated to work in the Scappoose and Clatskanie coho salmon populations). The schedules should also reflect an experimental design that will implement and evaluate several short-term recovery strategies to evaluate how different levels of natural and hatchery-origin fish on the spawning grounds affect progress toward recovery. The schedules should also address whether the long-term strategy for the use of hatchery fish is to isolate hatchery fish from the natural spawning population or to develop an integrated hatchery/natural population.

For information on stratum-level hatchery strategies, see Sections 6.6.6, 7.4.3.6, 7.5.3.6, 7.6.3.4, 8.6.6, and 9.6.5.

4.5 Harvest

Because of their wide-ranging migrations, anadromous salmonids are exposed to a variety of freshwater and ocean fisheries. Lower Columbia River salmonids are caught

[16] In 2011, hatchery managers developed transition schedules for Lower Columbia River fall Chinook populations designated in this recovery plan as primary (see "Task E" at http://www.nwr.noaa.gov/Salmon-Recovery-Planning/Recovery-Domains/Willamette-Lower-Columbia/LC/BO-tasks.cfm).

in commercial, recreational, and tribal fisheries along the West Coast of the United States and Canada as well as in the mainstem Columbia River and its tributaries. These various fisheries focus on different stocks and populations, taking fish to meet commercial, recreational, and tribal harvest allocations (see Table 4-7). A given fishery may be selective for fin-clipped hatchery fish or non-selective.

In the early part of the 20th century, nearly all commercial salmon fisheries in the Pacific Northwest operated in fresh water, where they harvested only mature salmon. Ocean fisheries became more important in the late 1950s as more restrictions were imposed on freshwater and coastal fisheries. Ocean harvest of salmon peaked in the 1970s and 1980s, after which commercial and recreational harvest of Columbia River salmon and steelhead declined. Harvest on Lower Columbia River tule fall Chinook salmon has been reduced from rates that averaged 69 percent during the years 1983 to 1993 (and that at one time exceeded 80 percent) to an average of 48 percent in the years since listing (NMFS 2008c). Tule fall Chinook salmon harvest rates recently have been further reduced, to 38 percent in 2009 and 2010 and 37 percent in 2011. Lower Columbia River spring Chinook salmon harvest averaged 51 percent during the years prior to listing (1980 to 1993) and has been reduced to around 20 percent since listing (NMFS 2008c). Harvest rates on Lower Columbia River coho salmon in the mid-1990s ranged from 75 to 90 percent, but since 2005, when NMFS listed this ESU, rates have averaged 16 percent. Before the mid-1970s, harvest impacts on Lower Columbia River steelhead were 70 percent or more. These impacts were reduced in 1975 when commercial harvest of steelhead in non-treaty fisheries was prohibited. Through implementation of mass marking and selective harvest, these rates were further reduced in the late 1980s and are now 10 percent or less. Columbia River chum salmon are not significantly affected by either direct or indirect harvest mortality (although historically harvest impacts were in the 90 percent range).

Table 4-7
Fisheries Affecting Lower Columbia ESUs

Area	Fishery Type	Targeted LCR ESU
Canada, Southeast Alaska (ocean)	Commercial troll and net Recreational fishing	Chinook (fall and spring) Coho
U.S. West Coast (ocean)	Commercial troll Treaty Indian commercial troll Recreational	Chinook (fall and spring) Coho
Lower Columbia River Mainstem	Commercial net; includes Select Area fisheries on fish returning to off-channel areas from net pen and hatchery releases in those places	Chinook (fall and spring) Coho
Lower Columbia River Mainstem	Recreational; includes Select Areas	Chinook (fall and spring) Coho Steelhead
Columbia River Mainstem above Bonneville (Zone 6a)	Treaty Indian set net fishing, both commercial and ceremonial and subsistence Recreational	Steelhead Chinook (fall and spring)
Oregon and Washington Tributaries	Recreational	Steelhead Coho Chinook (fall and spring)

Table 4-8 summarizes average harvest rates for natural- and hatchery-origin Lower Columbia River salmon and steelhead since the time of listing, along with the higher rates that generally occurred throughout the 1980s and early 1990s. Estimates of harvest impacts on a given ESU or run component can vary widely depending on the ESU, run component, and fisheries in question, the methods used, and the purpose of a given estimate. For example, estimates may be derived from coded-wire tags or through use of fishery models or other methods, depending on available information. Estimates may be for all fisheries or just those in the ocean or fresh water. In some cases, generalizations are sufficient to communicate the general magnitude of harvest impacts; in other cases, it is important to specify the source and methods used to derive a given estimate. The values in Table 4-8 rely where possible on published reports that contain specific estimates and explanations of how they were derived. These estimates may differ slightly from estimates in the management unit plans (which, in turn, may differ from each other). For purposes of indicating harvest impacts in general, all of these estimates are acceptable.

Table 4-8
Recent (Since Listing) Estimated Harvest Rates on Lower Columbia River Salmon and Steelhead Compared to Historical Highs

Stock	Natural-origin Fish (% harvested)	Hatchery-origin Fish (% harvested)	Historical High (Natural-origin Fish) (% harvested)
Spring Chinook[1]	20	34	51
Fall Chinook (Tule)[2]	48	48	69
Fall Chinook (Bright)[3]	36	NA	54
Chum[4]	1.6	1.6	NA
Coho[5]	16	NA	82
Steelhead (winter)[6]	4.1	NA	70
Steelhead (summer)[7]	6.7	NA	70

[1] 20 percent = average since listing (1999-2006), derived assuming that freshwater exploitation rates were 2 percent as a result of selective fisheries and constraints on upriver spring Chinook salmon); 34 percent = average since listing (1999-2006); 51 percent = average for the years 1980-1993 (NMFS 2008c).
[2] 48 percent = average since listing (1999-2006); 69 percent = average for the years 1983-1993 (NMFS 2008c).
[3] 36 percent = average since listing (1999-2006); 54 percent = average for the years 1979-1993 (NMFS 2008c).
[4] Source: NMFS 2008c. Although a specific estimate of historical harvest rates is not available, harvest on chum salmon was high through the 1950s but has been limited since the 1960s to a few hundred fish per year, at most (Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife 2002).
[5] 16 percent = average since listing (2005-2007); 82 percent = average for the years 1970-1993 (NMFS 2008c).
[6] 4.1 percent = average for the years 2001-2007 (NMFS 2008c); 70 percent = generalization from LCFRB (2010a).
[7] 6.7 percent = average for the years 1998-2007 (NMFS 2008c); 70 percent = generalization from LCFRB (2010a).

Fisheries affecting Lower Columbia River salmon and steelhead are managed by a number of regional and international organizations and agreements, including the Pacific Salmon Commission (which implements the Pacific Salmon Treaty between the United States and Canada), the Pacific Fishery Management Council, state fishery regulations in Oregon and Washington, the Columbia River Compact, and management agreements negotiated between the parties to *U.S. v. Oregon*. In addition, federal statutes such as the ESA and Magnuson-Stevens Fisheries Conservation and Management Act influence harvest management decisions. Fishery managers continually review population abundance and marine survival conditions, and adjust harvest rates and timing to minimize impacts to natural-origin stocks. They generally try to manage fisheries using a combination of gear, timing, area, and mark-selective regulations to optimize the harvest of hatchery-origin fish and strong natural stocks and protect weaker natural-origin stocks. Because of these fishing regulations and other actions, harvest rates for hatchery-produced Chinook salmon, coho salmon, and steelhead are higher than for natural-origin fish of the same species.

Both the Oregon and Washington management unit plans provide detailed information on the fisheries that affect Lower Columbia River salmon and steelhead and the organizations, agreements, and statutes that guide harvest management decisions (see

LCFRB 2010a pp. 3-62 through 3-69 and 3-70 through 3-75 and ODFW 2010 pp. 91 and 94).

4.5.1 Harvest Limiting Factors and Threats

Harvest affects the viability of Lower Columbia River salmon and steelhead populations by causing mortality to naturally produced adult fish, influencing population traits, and reducing nutrients in freshwater ecosystems.

4.5.1.1 Harvest Mortality

Harvest mortality can be either direct or indirect. Direct harvest mortality is associated with fisheries that target specific stocks. This includes both single-stock (terminal) and mixed-stock (intercept) fisheries. Single-stock fisheries are the most effective method for targeting a specific stock and commonly occur in terminal harvest areas where one stock is known to be present. In mixed-stock fisheries, the management challenge is to harvest from mixed populations having various available surpluses (sometimes including populations with no surplus) as the populations move through the fishery area at various rates and abundances. Harvest of a specific stock in the mix can be achieved through management decisions (e.g., fishery openings that use time and area to target stocks when and where they are abundant relative to other stocks), fishery adaptations (e.g., gear designed to target specific stock/species), or fishery regulations (e.g., prohibitions against retaining certain species).

Indirect mortality includes mortality of fish harvested incidentally to the targeted species or stock, fish that die after being captured by fishing gear but not landed, and fish that die after being caught and released. Despite the various methods used to target a specific stock, incidental bycatch—the harvest of nontargeted stocks—still occurs, largely because various stocks intermingle. Most fisheries have specific reporting requirements and limits for incidental bycatch that are intended to lessen the harvest impacts to non-targeted stocks. For the Columbia River, federal, state, and tribal harvest managers set specific incidental harvest percentages for protected stocks and manage fisheries so as not to exceed these limits. They also employ catch and release regulations that allow anglers to retain hatchery-origin salmon and steelhead but require them to release natural-origin fish. Mortality occurs as a result of catch and release because fish experience injury and trauma when they are caught and released, though the degree to which this occurs varies depending on the gear, timing and location of the fishery, and angler knowledge and skill.

4.5.1.2 Selection for Size, Age, Sex, Distribution, or Timing

Harvest may selectively remove fish based on size, age, sex, distribution, or run timing, depending on the gear, timing, and location of the fishery. Such selection can affect the reproductive success, genetics, structure, and biodiversity of populations. Gear or run timing selectivity may influence population productivity by removing older, larger individuals, too many individuals of one sex, or the larger females carrying the most eggs. Fishing-influenced changes in the average sizes and ages of salmon populations have been well documented (Ricker 1981). Body size is related to redd digging success (Beacham and Murray 1987) and/or fecundity, and larger fish usually carry more eggs

(Sandercock 1991). When too many individuals with high reproductive potential are removed, the population's productivity is reduced. A fishery might also disproportionately harvest the early portion of a run because of market- or industry-driven needs, or because of the timing of hatchery fish runs. Run timing is heritable (Garrison and Rosentreter 1981), so when fish that run at a certain time are selectively removed, the run timing of the entire population can shift. There is evidence that this may have occurred in Lower Columbia River coho salmon, with hatchery practices being a contributing factor (Cramer and Cramer 1994). However, it is likely that the reductions in coho salmon harvest in recent years have addressed concerns regarding selective effects of harvest because selective pressure is proportional to the magnitude of harvest impact. (For information on harvest-related limiting factors and recovery strategies specific to coho salmon, see Sections 6.4.4 and 6.6.5, respectively.)

4.5.1.3 Nutrient Supply and Carrying Capacity

Adult salmon carcasses in streambeds promote primary production, and their flesh and eggs are directly consumed by aquatic insects (Wipfli et al. 1999) and rearing fish (Bilby et al. 1996). This creates a biological feedback loop that benefits future salmon production. The chronic depression of salmon biomass to freshwater ecosystems may be contributing to reduced carrying capacity for salmon (Cederholm et al. 1999, Knudsen 2002). By reducing the number of spawners, harvest plays a role in diminishing the amount of nutrients provided to the system.

4.5.2 Regional Harvest Strategy

As noted above and described in more detail in Chapters 6 through 9, harvest managers have implemented substantial reductions in harvest for Lower Columbia River Chinook salmon, coho salmon, and steelhead since around the time NMFS listed these species under the ESA. Local recovery planners believe that for spring Chinook salmon, steelhead, and chum salmon, current harvest impacts are generally consistent with long-term recovery goals, at least in the near term. For these species the management unit plans recommend ancillary and precautionary measures to ensure that harvest does not adversely affect conservation and recovery in the future. For spring Chinook salmon, the Washington management unit plan notes that in the near term, harvest rates may need to be lower in some years to reduce the risks of critically low escapements during poor ocean conditions and to protect local populations. For fall Chinook and coho salmon, efforts will focus on (1) refinements in harvest management (including abundance-based management) to reduce risk to naturally produced fish, and (2) continued review of overall harvest rates.

Although the harvest management requirements of each ESU are unique and must be addressed separately, the management unit recovery plans rely on several principles and general approaches that harvest managers will employ to address recovery needs related to harvest impacts on Lower Columbia River salmon and steelhead. In general, the harvest strategy focuses on refining harvest management and reducing impacts where needed so that the target status of each population can be attained within an acceptable time frame, while still maintaining harvest opportunities that target hatchery-produced fish.

To accomplish these overall objectives, the management unit plans call for the use of six general approaches as appropriate and feasible (see Chapters 6 through 9 for details):

- **Abundance-based harvest management**: In abundance-based harvest management, managers base annual harvest decisions on the predicted adult returns for that year. In some cases the management unit plans call for (1) refining the existing harvest matrix to ensure that it adequately accounts for weaker components of the ESU or reflects changes in natural production as recovery actions are implemented, or (2) developing methods to predict the abundance of natural-origin fish so that abundance-driven harvest principles can be effectively applied.

- **Weak stock management principles**: In using weak stock management principles, harvest managers consider the impact of harvest rates on the abundance and productivity of weaker populations or population groupings in the ESU. For fall Chinook salmon harvest management, until recently harvest rates were established based on an indicator stock that was relatively healthy, because it was one of the few for which data on natural-origin returns were available. In response to actions outlined in the management unit recovery plans, managers have been exploring ways to incorporate additional, and weaker, stocks into those used to evaluate harvest impacts on the ESU.

- **Mark-selective harvest:** By marking hatchery fish and focusing harvest on them, managers can maintain harvest opportunity and increase harvest of hatchery-origin fish while limiting impacts to natural-origin fish. The harvest recovery strategy includes actions to broaden the use of mark-selective fishing methods, including, in some cases, the development of new gear and methods for commercial fishing.

- **Filling information needs**: Filling information needs will allow harvest managers to make management decisions that better protect natural-origin fish. Needs include, for example, better information on natural-origin and hatchery-origin spawner escapement, better estimates of natural population productivity, and better estimates of catch-and-release mortality rates in commercial and recreational fisheries. For coho salmon, there is an additional need to improve estimates of harvest impacts for natural-origin fish in ocean and Columbia River mainstem fisheries, because of the complexities of coho salmon's protracted run timing and the mix of natural-origin and unmarked hatchery-origin fish.

- **Ancillary and precautionary actions:** For some species or runs (steelhead and chum salmon), recovery planners believe that current harvest impacts are generally consistent with long-term recovery goals, at least in the near term. For these species they recommend ancillary and precautionary measures to ensure that harvest does not adversely affect conservation and recovery in the future.

- **Adaptive management:** As recovery proceeds and populations that now have little natural production begin to exhibit appreciable natural production, the management unit plans note that managers will need to reevaluate the impacts of harvest on the recovering populations and possibly readjust harvest management.

The management unit plans include the societal goal of maintaining harvest opportunities created by hatchery fish and have prioritized ESA recovery strategies that allow for continued harvest opportunities while working toward recovery; these strategies have been incorporated into the recovery plan. In addition, as part of their broad sense goals, the management unit plans envision eventual harvest of naturally produced salmon and steelhead from healthy, self-sustaining populations.[17]

In terms of recommended harvest rates, Oregon management unit planners did not recommend specific annual harvest rates; instead, in its analyses it used modeled, long-term average harvest rates for each species and assumed that harvest actions such as abundance-based, weak-stock management and mark-selective commercial fisheries would be implemented. The Washington management unit plan recommends a phased harvest strategy involving lower near-term rates to reduce population risks until habitat improvements are achieved. Modeling in the Washington management unit plan shows scenarios in which harvest rates would be managed for benchmarks in each of three 12-year implementation periods. The benchmark range is a target to be met within the designated period and to assess progress toward recovery. Generally the modeling projects that harvest rates eventually would increase as the benefits of other recovery actions were realized and natural production improved. These modeling results are planning targets and not predictions of future harvest rates; managers will establish future harvest rates based on observed indicators in Lower Columbia River salmon and steelhead populations.

In addition to these general approaches outlined above, NMFS will ensure that best available science continues to be used to determine harvest rates that, when combined with other threat reduction strategies, are likely to achieve positive growth rates and move populations to their target status over the long term. In ESA evaluations of hatchery and harvest actions, NMFS expects to analyze the combinations of effects of multiple actions when appropriate. For example, when harvest levels being evaluated are supported by hatchery production, the ecological, genetic, and other effects of hatchery production on both the juvenile and adult life stages also need to be considered as part of the harvest impact analysis.

4.6 Ecological Interactions

4.6.1 Limiting Factors and Threats Related to Ecological Interactions

Anthropogenic changes to habitat in the lower Columbia River region have altered the relationships between salmonids and other fish and wildlife species, leaving Lower Columbia River salmon and steelhead more vulnerable to predation by piscivorous fish,

[17] Currently, targeted harvest on naturally produced North Fork Lewis late-fall Chinook salmon is occurring when returns are above the escapement goal. The baseline persistence probability of this population, which has remained largely uninfluenced by hatchery production and has not experienced the population bottlenecks common among tule fall Chinook salmon populations, is estimated to be high.

birds, and pinnipeds (i.e., seals and sea lions) and subject to competition with introduced fish species and possibly hatchery-origin fish for limited food and habitat.

4.6.1.1 Predation

Significant numbers of salmon and steelhead are lost to fish, avian, and pinniped predators during migration and residency in the lower Columbia River and estuary (Northwest Power and Conservation Council 2004a). Although predation on salmon and steelhead has always occurred, predation rates in the lower Columbia River and estuary are believed to be higher now than they were historically because of anthropogenic changes in physical habitat that have increased predator abundance, predation effectiveness, or both. In addition, when hatchery-origin fish are present in large numbers, they can attract avian and fish predators of salmonids and spur predatory behavior that results in mortality of natural-origin juveniles. In the Columbia Basin this typically occurs at reservoir heads, at the face of dams, and at turbine spillway and bypass discharge areas (LCFRB 2010a). Researchers have also hypothesized that it is possible that a mass of hatchery-origin fish migrating through an area could also overwhelm predators, providing a beneficial, protective effect to co-occurring naturally produced fish (Fresh and Schroder 1987, Fritts and Pearsons 2008).

Dams, pile dikes, and other in-water structures in the lower Columbia River and estuary have created slack-water refuges and micro-habitats preferred by the northern pikeminnow, a native fish that feeds on juvenile salmonids. A bounty program on pikeminnow instituted in 1990 has reduced predation by 25 percent (Friesen and Ward 1999, NMFS 2000b). Still, pikeminnow in the lower Columbia mainstem have been estimated to consume up to 9.7 million juvenile salmon per year (Beamesderfer et al. 1996). Introduced fish such as walleye, smallmouth bass, and catfish also prey on juvenile salmonids in the estuary and mainstem, although in smaller numbers than pikeminnow; these warm-water species may benefit from the elevated water temperatures in Bonneville Reservoir and the Columbia River estuary.

Human alterations of the Columbia River estuary have contributed to increased predation by native birds, specifically Caspian terns, double-crested cormorants, and various gull species. Piscivorous birds congregate near dams and in the estuary around man-made islands and consume large numbers of emigrating juvenile salmon and steelhead (Roby et al. 1998). Populations of terns and cormorants in the estuary have increased significantly, in part because the deposition of dredged materials has created high-quality habitat for terns (Bottom et al. 2005). These habitats include Rice Island (at River Mile [RM] 21), which terns used for nesting from 1984 to 2000, and East Sand Island (RM 5), which has been an active nesting site since 1986. Double-crested cormorants are attracted to the estuary in part because of its tens of thousands of pilings, pile dikes, and other structures that provide perching opportunities. The loss of habitat elsewhere in the world has contributed to Caspian terns and double-crested cormorants relocating to the Columbia River estuary, which now has the world's largest nesting colonies of these species. In addition to being more numerous than they were historically, terns and cormorants in the estuary may be more effective in their predation because decreased fine sediment inputs to the estuary have reduced the turbidity that otherwise would help shield juvenile salmonids from predators.

The increased numbers of terns and cormorants have translated into measurable predation impacts on juvenile salmonids (Bonneville Power Administration, U.S. Bureau of Reclamation, and U.S. Army Corps of Engineers 2004). In 2006, Caspian terns and double-crested cormorants each were estimated to consume approximately 3.6 million juvenile salmon and steelhead (Collis and Roby 2006). How many of these juveniles are from the Lower Columbia River salmon ESU or steelhead DPS is unknown. However, evidence suggests that the steelhead DPS is likely to be affected by predation more than the other ESUs. Species-specific estimates of predation by Caspian terns from 1988 to 2000 were consistently highest for steelhead (9.4 to 12.7 percent), followed by coho salmon (3.6 to 4.1 percent), with the lowest rates observed in yearling Chinook salmon (1.6 to 2.9 percent) (Ryan et al. 2003).

Pinniped predation on adult spring Chinook salmon and winter steelhead in the Columbia River estuary continues to increase. On the West Coast, the total abundance of California sea lions is approximately 250,000; Stellar sea lions total about 31,000, and Pacific harbor seals total about 25,000 (Griffin 2006). Each spring about 1,000 Stellar sea lion males, 3,000 Pacific harbor seals, and 800 California sea lions take up residence in the lower estuary (Griffin 2006). Approximately 1,000 sea lions and harbor seals enter the freshwater portion of the estuary; of these, approximately 80 animals (primarily California sea lions) congregate at Bonneville Dam. The U.S. Army Corps of Engineers estimates that annual adult mortality at Bonneville Dam because of pinnipeds (primarily California sea lions) ranged from 0.4 percent (2002) to 4.2 percent (2007) during the study period ending in 2011 (U.S. Army Corps of Engineers 2011a).[18] Other, radio-telemetry-based studies suggest that annual pinniped predation on spring Chinook salmon and winter steelhead at Bonneville Dam may be as high as 8.5 percent and 20 percent, respectively (NMFS 2008c, Appendix G). There is a need for reliable estimates of the mortality caused by pinnipeds throughout the entire estuary and plume.

4.6.1.2 Competition

Habitat loss and alteration and releases of large numbers of hatchery fish have the potential to increase competition among salmonids and between salmonids and other fish species for food and habitat. In the case of salmon and steelhead, competition can occur in the tributaries, estuary, or ocean.

Competition among Salmonids

Competition is a natural process that helped shape the abundance of salmon and steelhead throughout their evolutionary history (Fresh 1997). The pressures of natural selection on salmon and steelhead promoted development of an array of life history strategies, involving differences in migration timing and habitat usage, so that populations could avoid competing for limited spatial and food resources (Quinn 2007, Naish et al. 2008) and, ultimately, maximize their marine survival.

At current levels of natural production it is unlikely that competition among salmonids is a limiting factor in the tributaries of the lower Columbia region. Even when hatchery

---

[18] Estimated consumption of adult salmonids ranged from a low of 1,010 in 2002 to a high of 6,081 in 2010; the percent of run consumed varied among reporting years in part because of changes in run size.

fish are released to tributaries in large numbers, releases usually are timed so that the juveniles are ready to migrate. It is more likely that competition between hatchery-origin fish and natural-origin fish is occurring in the Columbia River estuary, where food resources are limited and juvenile salmon and steelhead become concentrated on their way to the ocean (Fresh 1997).

Over the last century, habitat loss in the Columbia River estuary[19] has simplified Chinook salmon life history diversity there and concentrated the remaining salmon in more limited and fragmented regions (Bottom et al. 2005)—a process that may have increased competition. However, the impact of habitat loss on the Columbia River estuary's capacity to support juvenile salmon is unknown (Bottom et al. 2005).

Another unknown is the cumulative impact of hatchery-origin salmon and steelhead on natural-origin salmon and steelhead. When hatchery-origin fall Chinook subyearlings overlap spatially and temporally with natural-origin fall Chinook and chum salmon in the Columbia River estuary, they may compete directly for limited resources of food and space (Berejikian et al 2009), especially if the hatchery fish are released within a relatively short period or are larger than their naturally produced counterparts (NMFS 2011a, ODFW 2010). The competitive advantage that larger size or greater numbers imparts may result in so-called density-dependent mortality among Lower Columbia River salmon and steelhead (ODFW 2010) or compromise growth in natural-origin fall Chinook salmon juveniles, such that it takes longer to reach a critical size threshold above which mortality from predation will be reduced (Allee 2011). However, so little is known about the ecological interactions of hatchery- and natural-origin fish in the Columbia River estuary that it is difficult to conclude that competition for limited resources is occurring (Flagg et al. 2000). NMFS' Northwest Fisheries Science Center currently is investigating this topic. For more information see Appendix F.

Competition between Salmonids and Other Species

The new microdetritus-based food web in the estuary has benefited zooplanktivores, including American shad (*Alosa sapidissima*) (Sherwood et al. 1990). Shad were introduced to the Columbia River system in 1885, and their populations have grown substantially since then (Welander 1940, Lampman 1946), with up to 4 million adults returning to the estuary each year (Northwest Power and Conservation Council 2004a as cited in NMFS 2011a). The shad diet overlaps with that of subyearling salmonids in the Columbia River estuary, and juvenile shad and subyearling salmonids use similar heavily vegetated backwater habitats (McCabe et al. 1983). By their sheer numbers, shad represent a threat to trophic relationships in the Columbia River (NMFS 2011a). Other exotic fish species such as introduced walleye and catfish also have been able to capitalize on degraded conditions in the upper reaches of the estuary and altered food web dynamics through predation and competition for food resources (Northwest Power and Conservation Council 2004a).

---

[19] Diking and filling have reduced the surface area of the estuary by approximately 20 percent compared to historical levels, and approximately 43 percent of the tidal marshes and 77 percent of tidal swamps that existed in the Columbia River estuary before 1870 have been lost (Fresh 2005). In the Skagit River system in Washington, scientists have linked comparable habitat losses (i.e., 75 percent loss of tidal delta habitat) with density-dependent mortality of Skagit River fall Chinook (Beamer et al. 2005).

4.6.1.3 Disease Transfer

Salmon and steelhead can be infected by a variety of bacterial, viral, fungal, and microparasitic pathogens. Numerous diseases can result from pathogens that occur naturally in the wild or that may be transmitted to natural-origin fish via infected hatchery-origin fish. Disease transmission from hatchery-origin fish to natural-origin fish does not appear to be widespread in the lower Columbia region (LCFRB 2010a). To reduce the likelihood of disease transmission from hatchery salmonids to naturally produced fish, hatchery managers have established practices for monitoring fish health and sanitation and ensuring that hatchery fish are reared and released in healthy condition.[20]

4.6.2 Regional Ecological Interactions Strategy

The regional ecological interactions strategy involves reducing predation on all Lower Columbia River salmon and steelhead populations by redistributing Caspian terns and cormorants, increasing the pikeminnow bounty program in the Columbia River mainstem, and reducing marine mammal predation at Bonneville Dam using non-lethal or lethal measures. Managing predation by sea lions at Bonneville Dam is expected to benefit Gorge-stratum populations of Lower Columbia River salmon and steelhead ESUs. Pikeminnow are the focus of piscivorous predator reduction efforts because they are much more abundant in the region than introduced fish predators such as bass, walleye, and channel catfish (NMFS 2011a, LCFRB 2010a).

To reduce the risk of adverse ecological interactions between hatchery-origin and naturally produced salmon and steelhead, the Oregon and Washington management unit plans propose a combination of critical uncertainties research and near-term precautionary measures. Research needs include determining the degree of temporal and spatial overlap of hatchery- and natural-origin fish in the Columbia River estuary, the effect of competition on natural-origin fish, and the impact of predation of hatchery-origin fish on naturally produced fish. Near-term measures focus on restoring estuary habitat for fall Chinook and chum salmon and managing hatchery releases to minimize the risk of competition in the tributaries and Columbia River estuary (i.e., do not release hatchery-origin fish into the tributary rearing areas of natural-origin fish, coordinate releases to keep large numbers of hatchery-origin fish from accumulating in the estuary, and time releases so that hatchery-origin juveniles are at the optimal age and size to emigrate rapidly downstream and exit the estuary quickly, thus limiting interactions with natural-origin fish).

In addition, Allee (2011; see Appendix F) recommends research, modeling, and expert panel workshops to identify and evaluate potential methods of reducing the ecological interactions between hatchery-origin and natural-origin fish in the Columbia River estuary and thus lowering the risk of such interactions to natural-origin fish. These activities would focus on increasing scientific understanding of the habitat needs of hatchery-origin and natural-origin fish, habitats in the estuary, and risk to natural-origin

[20] For example, see Pacific Northwest Fish Health Protection Committee 1989, Integrated Hatchery Operations Team 1995, Washington Department of Fish and Wildlife 1996, Washington Department of Fish and Wildlife and Western Washington Treaty Indian Tribes 1998, U.S. Fish and Wildlife Service 1995, and U.S. Fish and Wildlife Service 2004.

fish in different habitats. Allee also supports recommendations by the Hatchery Scientific Review Group (HSRG) (2009) that would reduce the risk of negative cumulative impacts of hatchery-origin fish on naturally produced salmon and steelhead. For example, the HSRG recommends limiting hatchery production to the minimum needed to meet the systemwide harvest and conservation goals of the various managers, taking into account the carrying capacity of the mainstem, estuary and ocean; working with agencies and tribes to maximize survival of hatchery-origin fish consistent with conservation goals; and monitoring, evaluating, and adaptively managing hatchery programs to become more effective in meeting goals for conservation and harvest (Allee 2011).

4.6.3 Effects of Recovery Actions on Other Species

Recovery actions for listed Lower Columbia River salmon and steelhead have the potential to affect other species, both positively and negatively. These effects would most likely be manifested either through changes in habitat or through changes in predator/prey relations and interspecies competition resulting from shifts in the abundance and spatial distribution of LCR salmon and steelhead. In addition, one possible effect as salmon and steelhead recover and productivity improves is the increased delivery of marine-derived nutrients to inland ecosystems; these nutrients support other, non-salmonid species, including terrestrial species.

The species that share habitat or interact with LCR salmon and steelhead as predators or prey are numerous, as are the potential effects to those species from recovery actions. It is not possible to discuss them in detail in this plan. Nevertheless, in implementation, it will be useful and at times imperative to consider the effects of salmon recovery actions on other species. The National Environmental Policy Act requires federal agencies to evaluate such impacts for federal actions that significantly affect the environment. For species listed under the ESA, section 7(A)(2) of the ESA requires federal agencies to ensure that any actions they authorize, fund, or carry out are not likely to jeopardize the continued existence or adversely modify critical habitat of a listed species.

Generally, habitat-related recovery actions for Lower Columbia River salmon and steelhead would be likely to benefit many other species that share those habitats. For instance, the overall goals of the habitat recovery strategy to protect and restore functioning habitats and watershed processes are likely to benefit all native aquatic and riparian species, and it may be possible to specifically design protection and restoration projects in ways that benefit additional native species. For instance, culverts can be designed to pass not only salmon and steelhead but also lamprey, which do not have the jumping abilities of salmon and steelhead. Riparian habitat restoration projects can benefit not only aquatic but wildlife species, such as by providing micro-topographic features that would allow refuge from flooding.

Overall, NMFS expects that implementation of habitat protection and restoration actions for LCR salmon and steelhead would have concomitant benefits to many other native species and that adverse impacts would be rare. However, it is important that project developers consider such impacts. For example, dewatering of streams during instream restoration work can have adverse impacts on other aquatic species, and projects that create new equilibriums of species composition can shift predator/prey relationships in ways that could be adverse to a species. It is especially important that, during implementation of this recovery plan, entities consider potential impacts of habitat projects on other federally or state protected species or species of concern. Design of recovery actions involving large-scale changes in habitat, such as actions to reduce Caspian tern and cormorant nesting habitat or large scale changes from freshwater to saltwater marsh habitat should consider impacts to target and non-target species.

A potential adverse impact of hatchery recovery actions on other species could occur through changes in numbers of hatchery fish produced. It is possible that hatchery production locally or throughout the Lower Columbia would be decreased as part of a recovery strategy. Although other recovery actions are aimed at increasing numbers of natural-origin salmon and steelhead, total salmon and steelhead production could be temporarily or permanently less than it is at present. Lower total production would mean less availability of salmon as predators or prey. In addition, the use of weirs at hatcheries to prevent hatchery-origin fish from spawning naturally could affect other species' habitat access.

Changes in harvest management could affect other species through shifts in predator/prey relationships and through impacts to species affected as bycatch in salmon fisheries. In addition, efforts to control predation on salmon by species such as marine mammals and birds could potentially affect the predator species.

Table 4-9 lists other federally listed aquatic species that could be affected by salmon recovery actions described in this plan. These species and the potential for salmon recovery actions to affect them are discussed briefly below.

Table 4-9
Federally Listed Fish and Wildlife Species in the Lower Columbia Recovery Planning Area

Species	Range in Lower Columbia River Basin	Federal Listing Status	Type of Interaction with Salmon and Steelhead
Bull trout *(Salvelinus confluentus)*	Lewis and Clackamas subbasins, Lower Columbia River mainstem	Federally threatened	Predator of salmon and steelhead
Eulachon *(Thaleichthys pacificus)*	Lower Columbia River and tributaries	Southern DPS Federally threatened	Freshwater prey of salmon and steelhead
Green Sturgeon (*Acipenser medirostris*)	Columbia River estuary	Southern DPS Federally threatened	Bycatch in salmon fisheries
Southern resident killer whale	Occasionally forage on salmon in the mouth of the Columbia River	Federally endangered	Saltwater predator of salmon
Steller sea lion	Forage on salmon along lower Columbia River and estuary	Federally threatened	Predator of salmon

Adapted from NMFS (2010c), Tables 3-9 and 3-29.

4.6.3.1 Bull Trout

Bull trout exhibit both resident and migratory forms and require complex habitat characterized by cold water and a variety of pools, riffles, water depths, and velocities. Bull trout occur from the Northwest Territories of Canada south to northern Nevada. Historically they were found in about 60 percent of the Columbia Basin, but their distribution and abundance in the basin have declined significantly (Natural Resources Conservation Service 2006, U.S. Fish and Wildlife Service 2010).

In 1999, bull trout were listed as a threatened species under the ESA (64 *Federal Register* 58909). Oregon has also listed them as a sensitive species. In 2002, the U.S. Fish and Wildlife Service published a draft recovery plan for bull trout. Twenty-two recovery units support bull trout listed in the Columbia Basin, three of which—the Willamette, Lower Columbia, and Hood River—overlap with the area addressed by this plan (U.S. Fish and Wildlife Service 1998, 2010).

Bull trout, salmon, and steelhead can occur in similar habitat types; however, bull trout are more sensitive than salmon and steelhead to increased water temperatures, poor water quality, habitat conditions, and low-flow conditions; thus, they more often occur in higher elevations with less disturbed habitats. Bull trout also require colder water temperatures than other salmon and trout, so they are more likely to occur in headwater streams where temperatures tend to be cooler. Because bull trout feed primarily on fish as subadults and adults, they can be a substantial predator of young salmon and steelhead. Juvenile bull trout feed on similar prey as salmon and steelhead (Natural Resources Conservation Service 2006; U.S. Fish and Wildlife Service 2008, 2010).

The primary interaction between bull trout and salmon and steelhead is that bull trout, as subadults and adults, prey on juvenile salmon and steelhead.[21] Overall changes in abundance of salmon and steelhead or bull trout could shift predator-prey relations. In addition, because bull trout use similar aquatic habitats as salmon and steelhead, the species can compete for food resources and space. In general, actions to protect and improve salmon habitat would also likely benefit bull trout.

4.6.3.2 Eulachon

The eulachon (also known as Columbia River smelt) is a small anadromous fish that occurs in the eastern North Pacific Ocean. Eulachon spend most of their lives in salt water but return to fresh water to spawn at 3 to 5 years of age. Juvenile eulachon rear in shallow to moderately deep nearshore marine areas. The Columbia River and its tributaries are believed to support the largest eulachon run in the world (NMFS 2008g). Eulachon regularly spawn in the mainstem Columbia River (up to Bonneville Dam), in Skamokawa Creek, and in the Cowlitz, Grays, Elochoman, Kalama, Lewis, and Sandy rivers (NMFS 2010b).

The southern eulachon DPS (i.e., populations spawning in rivers from the Nass River in British Columbia south to the Mad River in California) is listed as a threatened species under the ESA and is a Washington State species of concern.

Newly hatched and juvenile eulachon are a prey species for salmon and steelhead (although predation of eulachon by salmon and steelhead has not been cited as a reason for eulachon declines). In addition, spawned-out and decomposing eulachon contribute to the nutrient cycle of freshwater streams (NMFS 2010c).

4.6.3.3 Green Sturgeon

The green sturgeon is a long-lived, slow-growing anadromous fish that ranges from Alaska to Mexico. Juvenile green sturgeon rear and feed in both fresh and estuarine waters for 1 to 4 years before dispersing into marine waters. They spend 6 to 10 years at sea before returning to fresh water to spawn for the first time. Adults spawn multiple times and spend 2 to 4 years at sea between spawning events (71 *Federal Register* 17757). Green sturgeon feed on benthic invertebrates and small fish; salmon and steelhead have not been documented as part of their diet (NMFS 2005b and 2009b).

The southern green sturgeon DPS, which occurs in freshwater rivers and coastal estuaries and bays along the west coast of North America, including estuaries of Oregon and Washington and the lower Columbia River, is listed as a threatened species under the ESA (71 *Federal Register* 17757). The DPS aggregates in the Columbia River estuary and Washington estuaries in the late summer (NMFS 2009b).

Interactions among green sturgeon and salmon and steelhead are limited to the Columbia River estuary and Pacific Ocean marine waters. Green sturgeon are caught as bycatch in salmon and steelhead fisheries (NMFS 2009b).

---

[21] Bull trout also prey on other fish species (e.g., non-native trout); this may reduce predation by those species on juvenile salmon and steelhead.

4.6.3.4 Southern Resident Killer Whale

The southern resident killer whale stock has been observed in ocean waters of Washington and Oregon and near the mouth of the Columbia River during winter and early spring months (Ford et al. 2000, Wiles 2004, Zamon et al. 2007, NMFS 2008h, and NMFS 2008i). As of July 2011, the total estimated population of southern resident killer whales was 88 individuals (Center for Whale Research). Southern resident killer whales are ESA-listed as endangered and are also protected under the Marine Mammal Protection Act.

Southern resident killer whales consume a variety of fish and one species of squid, but salmon—Chinook salmon in particular—are their preferred prey (NMFS 2008i). Although the prey base of southern resident killer whales that forage near the mouth of the Columbia River is unknown, prey of southern resident killer whales that forage elsewhere in the Pacific Northwest has been recorded. Sampling in diet studies of southern resident killer whales has been conducted primarily during spring, summer, and fall months in inland waters off Washington and British Columbia (Ford and Ellis 2006, Hanson et al. 2007, and Hanson et al. 2010a). In inland waters from May to September, the southern residents' diet consists of a high percent of Chinook salmon, with on overall average of 88 percent of their diet consisting of Chinook salmon (Hanson et al. 2010a). Other salmonids eaten include steelhead (5 percent), coho salmon (3 percent), sockeye salmon (2 percent), and chum salmon (less than 1 percent). Ford and Ellis (2006) found that killer whales captured older (i.e., larger) than average Chinook salmon.

Other results indicated that, during fall months in inland waters, southern resident killer whales foraging within Puget Sound shift their diet to primarily chum salmon (Hanson et al. 2007). Although southern resident killer whales are thought to feed on salmon and steelhead year-round, their diet from January through April is poorly understood; during this period they range in ocean waters from British Columbia to central California (Krahn et al. 2002, Krahn et al. 2007, Ford and Ellis 2006, NMFS 2008h).

The preference of southern resident killer whales for Chinook salmon in inland waters, even when other species are more abundant, combined with information indicating that these whales consume salmon year-round, makes it reasonable to expect that southern resident killer whales prefer Chinook salmon when available in coastal waters. Sightings of resident killer whales off Westport, Washington, and in the mouth of the Columbia River may coincide with the spring Chinook salmon run in the Columbia River (Krahn et al. 2004, Zamon et al. 2007, NMFS 2008i). There are direct observations of two southern resident killer whale predation events in coastal waters; in both cases, the prey species was identified as Columbia River Chinook salmon (Hanson et al. 2010b). Chemical analyses also indicate the importance of salmon in the year-round diet of southern resident killer whales (Krahn et al. 2002; Krahn et al. 2007). Furthermore, Ford et al. (2009) found that southern resident killer whale survival rates correlated directly with the availability of Chinook salmon.

Based on recent estimates assuming a diet of only Chinook salmon, the southern resident killer whale stock requires, in total, approximately 289,000 to 347,000 Chinook salmon annually (Noren 2010), but the extent to which they depend on specific salmon runs is not known. At different times of the year, southern resident killer whales may consume Chinook salmon that originate in the Fraser River, Puget Sound, Washington and Oregon coastal streams, the Columbia River, and central California streams (Hanson et al. 2010a), but data are insufficient to identify the proportion of different stocks in the year-round southern resident killer whale diet.

There is no evidence that southern resident killer whales distinguish between hatchery-origin and natural-origin salmon (Hanson et al. 2010a). Salmon production from Columbia River hatcheries may have partially compensated for declines in many natural-origin salmon populations to the benefit of resident killer whales (NMFS 2008i). The contribution of all salmon and steelhead from the Columbia Basin to the prey available to the whales in the ocean is substantial.

4.6.3.5 Steller Sea Lion

The eastern stock of Steller sea lions is resident year-round on the coasts of Oregon and Washington, and from the mouth of the Columbia River up to Bonneville Dam (NMFS 2008i and 2008c). No Steller sea lion rookeries (i.e., mating areas) exist near the Columbia River, but individuals use the South Jetty at the mouth of the river as a haul-out site year-round (Jeffries et al. 2000). Numbers vary seasonally, with peak counts of approximately 1,000 individuals during fall and winter months (NMFS 2008h). The eastern stock of Steller sea lions is listed as threatened under the ESA and is protected under Marine Mammal Protection Act.

Steller sea lions forage opportunistically on a wide variety of fishes in response to seasonal abundance. Foraging studies in the lower Columbia River and at Pacific Northwest coastal sites describe a variety of Steller sea lion prey species, including Pacific whiting, rockfish, eulachon, Pacific hake, anchovy, Pacific herring, staghorn sculpin, salmonids, octopus, and lamprey (Jeffries 1984, NMFS 2008c).

The extent to which eastern stock Steller sea lions depend on salmon in the lower Columbia River and nearby coastal waters is unknown, although some Steller sea lions exploit salmon at Bonneville Dam (NMFS 2008k). Salmon remains were found in 25 percent of the scat samples obtained in 2007 at Bonneville Dam. Surface observation at Bonneville Dam suggests that Steller sea lions in the Columbia River rely more on sturgeon than on salmon and steelhead (NMFS 2008h and 2008k and Stansell et al. 2011). However, predation by Steller sea lions on salmon elsewhere by (e.g., south Oregon coast) (NMFS 1997) appears to have increased since the 1980s and Steller sea lions have been observed preying on salmon smolts and adults (NMFS 1996).

4.7 Climate Change

4.7.1 Climate Change Limiting Factors and Threats

Likely changes in temperature, precipitation, wind patterns, ocean acidification, and sea level height have implications for survival of Lower Columbia River salmon and steelhead in their freshwater, estuarine, and marine habitats.

4.7.1.1 Information Sources

Recent descriptions of expected changes in Pacific Northwest climate that are relevant to listed salmon and steelhead include the U.S. Global Change Research Program's national climate change impacts assessment (Karl et al. 2009), the *Washington Climate Change Impacts Assessment* (Climate Impacts Group 2009), and the *Oregon Climate Change Assessment Report* (Oregon Climate Change Research Institute 2010).[22] These assessments are based on empirical observations and climate model projections. The regional climate assessments include projections from the Intergovernmental Panel on Climate Change's (IPCC) global climate models (Intergovernmental Panel on Climate Change 2007b), which were downscaled to reflect regional terrestrial and aquatic conditions (e.g., Salathe 2005) and ocean conditions (e.g., Stock et al. 2011). A new IPCC global climate assessment and a new national climate assessment, which will include updated analyses for the Pacific Northwest, are currently under way, with new climate projections expected by 2014.

Trends and projections of ocean acidification are reviewed in chapters of the Oregon and Washington climate assessments or subsequent publications of those chapters (Mote et al. 2010, Ruggiero et al. 2010, Huppert et al. 2009), based on primary research such as Feely et al. (2008).

Mote et al. (2008) and Ruggiero et al. (2010) described observed sea level height changes along the Pacific coast and reviewed literature projecting sea level changes in the Pacific Northwest. The West Coast Governors Alliance, along with the U.S. Geological Survey, NOAA, and the U.S. Army Corps of Engineers, have sponsored a study that the National Academies of Science will complete by 2013 that will provide sea level rise estimates for California, Oregon, and Washington for the years 2030, 2050, and 2100.[23] Various localized studies of projected sea level height changes are also available (e.g., Glick et al. 2007).

Recent reviews of the effects of climate change on the biology of salmon and steelhead in the Columbia Basin and the California Current region[24] include the Independent Scientific Advisory Board (ISAB) (2007a), the Oregon and Washington climate assessments (Huppert et al. 2009, Mantua et al. 2009 and 2010, and Hixon et al. 2010), NMFS (2010a), Ford (2011), and Crozier (2011). Crozier (2011, Section 9.3) includes a review of what is currently known regarding effects of ocean acidification on salmon and steelhead. In addition to these reviews, the NMFS Northwest Fisheries Science Center will be producing annual updates describing new information regarding effects of climate change relevant to salmon and steelhead as part of the FCRPS Adaptive Management Implementation Plan.

---

[22] These documents are highlighted because they are recent comprehensive reviews of observed and expected climate change impacts in the United States and Pacific Northwest. Numerous other primary literature publications are available, many of which are cited in these reports. Additionally, NMFS annually reviews and summarizes scientific literature relevant to the effects of climate change on Pacific salmon and steelhead. The review of 2009 literature is included as Chapter 2.2.1 of NMFS (2010a); Crozier (2011) reviews 2010 literature.

[23] See http://www8.nationalacademies.org/cp/projectview.aspx?key=49290.

[24] The California current is a Pacific Ocean current that moves south along the western coast of North America, beginning off southern British Columbia and ending off southern Baja, California.

The following text summarizes expected climate change effects on listed Lower Columbia River salmon and steelhead, based on the above sources.

4.7.1.2 Effects of Climate Change on LCR Salmon and Steelhead

Freshwater Environment

Climate records show that the Pacific Northwest has warmed about 1.0 °C since 1900, or about 50 percent more than the global average warming over the same period. The warming rate for the Pacific Northwest over the next century is projected to be in the range of 0.1 to 0.6 °C per decade. Although total precipitation changes are predicted to be minor (+ 1 to 2 percent), increasing air temperature will alter snowpack, stream flow timing and volume, and water temperature in the Columbia Basin. Climate experts predict the following physical changes to rivers and streams in the basin:

- More precipitation falling as rain rather than snow (as a result of warmer temperatures)
- Diminished snowpack and alterations in stream flow volume and timing
- A trend toward loss of snowmelt-dominant and transient subbasins
- Continued increases in summer and fall water temperatures

More winter flooding is expected in transient and rainfall-dominated subbasins. Transient subbasins are those where stream flow is strongly influenced both by direct runoff from rainfall and by springtime snowmelt because surface temperatures in winter typically fluctuate around the freezing point. Over the course of a given winter, precipitation in transient subbasins frequently fluctuates between snow and rain, depending on relatively small changes in air temperature (Mantua et al. 2009).

Historically transient subbasins, such as those in which Gorge and some Cascade populations spawn and rear, will experience lower late-summer flows. For example, Figure 4-2 shows the expected patterns of stream flow in the White Salmon River, the Kalama River, and the Columbia River at Bonneville Dam in the 2020s, 2040s, and 2080s. The White Salmon River is a transient subbasin that currently exhibits a November-December peak hydrograph caused by rain and an April-May peak that is associated with melting snow. In future years the April-May snowmelt-driven peak is expected to be much lower or possibly nonexistent. As a more rainfall-driven river, the Kalama currently does not exhibit a distinct spring peak. Future flows are expected to increase in the winter and decrease in the spring, but the general rainfall-driven pattern will continue. The hydrograph for the mainstem Columbia River at Bonneville Dam is strongly influenced by spring snowmelt in Canada and the western Rocky Mountains. In the future, the spring freshet is expected to occur earlier, with fall and winter flows increasing and summer and early fall flows decreasing.

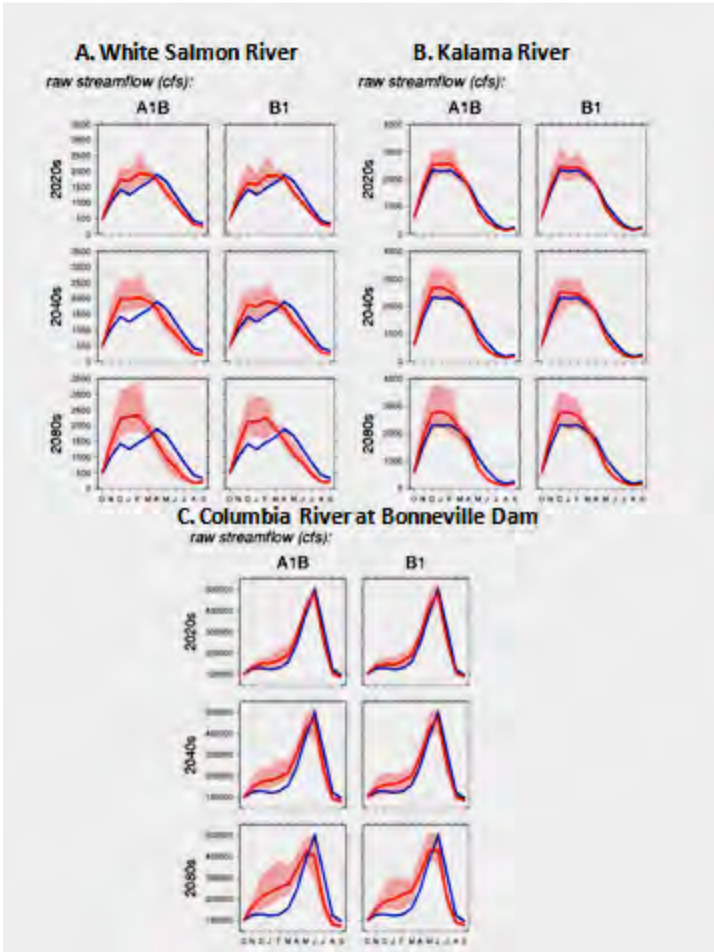

Figure 4-2. Projected Average Monthly Stream Flow (cfs) for the White Salmon and Kalama Rivers and the Mainstem Columbia River at Bonneville Dam[25]

(Note: Blue = historical average stream flow; red = projected stream flow for the 2020s, 2040s, and 2080s; shading = range of simulation results)

The predicted trend toward loss of snowmelt-dominant and transient subbasins will be most pronounced for some Gorge and Cascade subbasins with high-elevation headwaters that currently experience a spring freshet from melting snow. The hydrographs of most subbasins in the Lower Columbia domain are currently rainfall-dominated and will continue to be so as climate changes (Figure 4-3).

25 Projections are made under two IPCC (2007) anthropogenic aerosol and greenhouse gas emission scenarios: A1B corresponds to "moderate" and B1 corresponds to "low" emissions during the 21st century (Stock et al. 2011). Figures are from the University of Washington Climate Impacts Group and are available at: http://www.hydro.washington.edu/2860/products/sites.

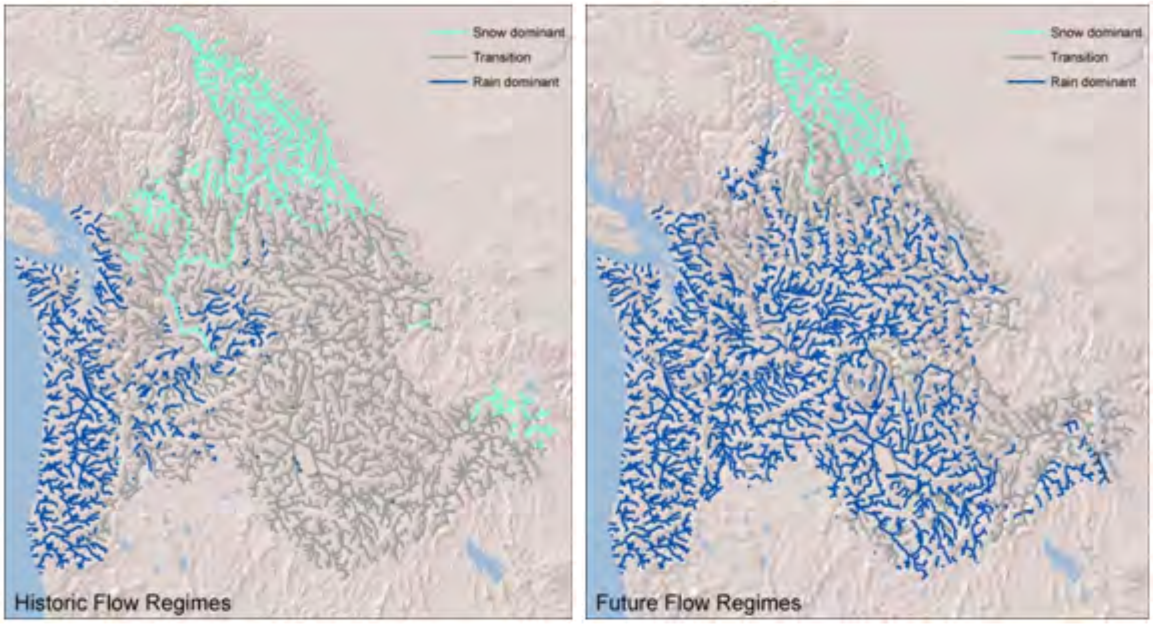

Figure 4-3. *Preliminary Maps of Predicted Hydrologic Regime for 1970-1999 and 2070-2099*[26]
Source: University of Washington Climate Impacts Group (www.hydro.washington.edu/2860/).

In the state of Washington, summer and fall water temperatures will continue to rise, with an increase of less than 1 °C expected by the 2020s but an increase of 2 to 8 °C predicted by the 2080s. By the 2080s, the number of Washington subbasins with a maximum weekly water temperature that exceeds 21.5 °C is expected to double, and thermal barriers greater than 21 °C are expected to increase in duration from 1 to 5 weeks in the 1980s to 10 to 12 weeks in the 2080s.

The changes in air temperatures, river temperatures, and river flows in the Pacific Northwest are expected to cause changes in salmon and steelhead distribution, behavior, growth, and survival. Although the magnitude and timing of these changes currently are poorly understood and specific effects are likely to vary among populations, the following effects on listed salmon and steelhead in fresh water are likely:

- Winter flooding in transient and rainfall-dominated subbasins may scour redds, reducing egg survival.
- Warmer water temperatures during incubation may result in earlier fry emergence, which could be either beneficial or detrimental, depending on location and prey availability.
- Reduced summer and fall flows may reduce the quality and quantity of juvenile rearing habitat, strand fish, or make fish more susceptible to predation and disease.

[26] Uses emission scenario A1B and global climate model CGCM3.1(T47), based on classification of annual hydrographs as in Beechie et al. (2006).

- Reduced flows and higher temperatures in late summer and fall may decrease parr-smolt survival.
- Warmer temperatures will increase metabolism, which may either increase or decrease juvenile growth rates and survival, depending on availability of food.
- Overwintering survival may be reduced if increased flooding reduces suitable habitat.
- Timing of smolt migration may be altered such that there is a mismatch with ocean conditions and predators.
- Higher temperatures during adult migration may lead to increased mortality or reduced spawning success as a result of lethal temperatures, delay, increased fallback for Gorge populations at Bonneville Dam, or increased susceptibility to disease and pathogens.

The degree to which phenotypic or genetic adaptations may partially offset these effects is being studied but currently is poorly understood.

Estuarine Environment

Climate change will also affect salmon and steelhead in the estuarine and marine environments. Effects of climate change on salmon and steelhead in estuaries include the following:

- Warmer waters in shallow rearing habitat may alter growth, disease susceptibility, and direct lethal or sublethal effects.
- Higher winter freshwater flows and higher sea level elevation may increase sediment deposition and wave damage, possibly reducing the quality of rearing habitat.
- Lower freshwater flows in late spring and summer may lead to upstream extension of the salt wedge, possibly influencing the distribution of salmonid prey and predators.
- Increased temperature of freshwater inflows and seasonal expansion of freshwater habitats may extend the range of non-native, warm-water species that are normally found only in fresh water.

In all of these cases, the specific effects on salmon and steelhead abundance, productivity, spatial distribution and diversity are poorly understood.

Marine Environment

Effects of climate change in marine environments include increased ocean temperature, increased stratification of the water column, changes in the intensity and timing of coastal upwelling, and ocean acidification. Hypotheses differ regarding whether coastal upwelling will decrease or intensify, but even if it intensifies, the increased stratification of the water column may reduce the ability of upwelling to bring nutrient-rich water to the surface. There are also indications in climate models that future conditions in the North Pacific region will trend toward conditions that are typical of the warm phases of the Pacific Decadal Oscillation, but the models in general do not reliably reproduce the oscillation patterns. Hypoxic conditions observed along the continental shelf in recent years appear to be related to shifts in upwelling and wind patterns that may be related to climate change.

Climate-related changes in the marine environment are expected to alter primary and secondary productivity, the structure of marine communities, and, in turn, the growth, productivity, survival, and migrations of salmonids, although the degree of impact on listed salmonids currently is poorly understood. A mismatch between earlier smolt migrations (because of earlier peak spring freshwater flows and decreased incubation period) and altered upwelling may reduce marine survival rates. Ocean warming also may change migration patterns, increasing distances to feeding areas.

In addition, rising atmospheric carbon dioxide concentrations drive changes in seawater chemistry, increasing the acidification of seawater and thus reducing the availability of carbonate for shell-forming invertebrates, including some that are prey items for juvenile salmonids. This process of acidification is under way, has been well documented along the Pacific coast of the United States, and is predicted to accelerate with increasing greenhouse gas emissions.

Ocean acidification has the potential to reduce survival of many marine organisms, including salmon and steelhead. However, because there is currently a paucity of research directly related to the effects of ocean acidification on salmon and steelhead and their prey, potential effects are uncertain. Laboratory studies on salmonid prey taxa have generally indicated negative effects of increased acidification, but how this translates to the population dynamics of salmonid prey and the survival of salmon and steelhead is uncertain. Modeling studies that explore the ecological impacts of ocean acidification and other impacts of climate change concluded that salmon landings in the Pacific Northwest and Alaska are likely to be reduced.

Summary of Likely Impacts of Climate Change

NMFS' 2010 5-year status report for salmon and steelhead in the Pacific Northwest (Ford 2011) includes a summary of likely effects of climate changes on Pacific Northwest salmon and steelhead. Table 4-10, which is reproduced from Table 79 of Ford (2011), summarizes the main climate change effects and indicates the certainty of their occurrence and their expected magnitude. Table 4-10 addresses all listed salmon and steelhead in the Pacific Northwest, so some effects, such as some terrestrial climate effects on forest and riparian structure, are more relevant to interior Columbia Basin species. Ford (2011) point out that we need to consider the cumulative impacts of climate change across the salmon life cycle and across multiple generations. Because these climate effects are multiplicative across the life cycle and across generations, small effects at individual life stages can result in large changes in the overall dynamics of populations. This means that the mostly negative effects predicted for individual life history stages will most likely result in a substantially negative overall effect of climate change on Pacific Northwest salmonids over the next few decades.

Table 4-10
Summary of Expected Climate Effects on Pacific Northwest ESUs

Habitat	Physical Change	Processes Affecting Salmon	Effect on Pacific Northwest Salmonid ESUs	Certainty
Terrestrial	Warmer, drier summers	Increased fires, increased tree stress, and disease will affect large woody debris, sediment supplies, and riparian zone structure	- - to 0 Largest effects likely to be felt in Interior Columbia populations, particularly in areas at lower and middle elevations	Low
	Reduced snowpack, warmer winters	Increased growth of higher elevation forests will affect large woody debris, sediment processes, and riparian zone structure	0 to +	Low
Freshwater	Reduced summer flow	Less accessible summer rearing habitat	- - to - Effects most pronounced in areas that currently have low flow, particularly in Interior Columbia populations	Moderate
	Earlier peak flow	Potential migration timing mismatch	-- to 0 Largest effects in “transition” areas that move from a snowmelt-dominated hydrograph to a rain-driven hydrograph	Moderate
	Increased floods	Redd disruption, juvenile displacement, upstream migration	- - to 0 Largest effects in “transition” areas that move from a snowmelt-dominated hydrograph to a rain-driven hydrograph	Moderate
	Higher stream temperature	Thermal stress, restricted habitat availability, increased susceptibility to disease and parasites	- - to - Largest effects likely to occur in what currently are high-temperature areas of the Interior Columbia and low-elevation areas	Moderate

Habitat	Physical Change	Processes Affecting Salmon	Effect on Pacific Northwest Salmonid ESUs	Certainty
Estuarine	Higher sea level	Reduced availability of wetland habitats	-- to - Largest effects on ESUs with a life history highly dependent on relatively long-term rearing in estuarine and tidally influenced areas	High
	Higher water temperature	Thermal stress and increased susceptibility to disease and parasites	- - to – Largest effects on ESUs with highly estuarine-dependent life cycles and ESUs subject to stress at earlier life stages	Moderate
	Combined effects	Changing estuarine ecosystem composition and structure	- - to +	Low
Marine	Higher ocean temperature	Thermal stress, shifts in migration, susceptibility to disease and parasites	- - to - Effects likely to vary by ESU, depending on ocean distribution	Moderate
	Intensified upwelling	Increased nutrients (food supply), coastal cooling, and ecosystem shifts; increased offshore transport	0 to ++ Effects likely to vary by ESU and correspondence of outmigration with upwelling patterns	Moderate
	Delayed spring transition	Food timing mismatch with outmigrants, ecosystem shifts	- - to 0 Effects likely to vary by ESU depending on correspondence of outmigration with upwelling patterns	Moderate
	Increased acidity	Disruption of food supply, ecosystem shifts	- - to - Effects likely to vary by ESU, dependent upon age and size at outmigration and ocean distribution	Moderate
	Combined effects	Changing composition and structure of ecosystem, changing food supply and predation	- - to + Effects likely to vary by ESU depending on age and size at outmigration and ocean distribution	Low

Effect ratings are: + +, strongly positive; +, positive; 0, neutral; -, negative, - -, strongly negative. Certainty level combines the certainty of the physical change with the certainty of the effect.

Source: Table 79 of Ford (2011); Table 79 was adapted from Stout et al. (2010) and includes citations for the main sources of information relied on for each entry.

4.7.2 Regional Climate Change Strategy

4.7.2.1 Mitigation Strategy

The IPCC (Intergovernmental Panel on Climate Change 2007b) defines climate change mitigation as implementing policies and technological changes to reduce greenhouse gas (GHG) emissions and enhance greenhouse gas sinks. Reduction of greenhouse gas emissions is the most reliable solution to the adverse effects of climate change on listed Lower Columbia River salmon and steelhead over the long term. The climate change mitigation strategy for this recovery plan is for relevant entities to implement greenhouse gas reduction strategies. Possible mechanisms for doing so include the West Coast Governors' Global Warming Initiative (http://www.ef.org/westcoastclimate/) and the Oregon Global Warming Commission's recommendations (Oregon Department of Energy 2009). There is also a need to integrate these local strategies with mitigation strategies at larger spatial scales.

4.7.2.2 Adaptation Strategy

The IPCC (Intergovernmental Panel on Climate Change 2007c) defines climate change adaptation as adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Adaptation strategies that contain measures to reduce impacts of climate change on Pacific Northwest salmon and steelhead include the Northwest Power and Conservation Council's Independent Scientific Advisory Board (2007a) review, the interim *Washington State Integrated Climate Change Response Strategy* (Washington Department of Ecology 2011), the *Oregon Climate Change Adaptation Framework* (Oregon Department of Land Conservation and Development 2010), and the draft *National Fish, Wildlife, and Plants Climate Adaptation Strategy* (U.S. Fish and Wildlife Service et al. 2012).

These adaptation plans commonly include the following general elements:

- Conserve adequate habitat to support healthy fish populations and ecosystem functions in a changing climate.
- Manage species and habitats to protect ecosystem functions in a changing climate.
- Reduce stresses not caused by climate change.
- Support adaptive management through integrated observation and monitoring and improved decision support tools.

The ISAB's recommendations for incorporating climate change considerations into restoration and recovery planning and recommended actions for reducing climate change impacts on Columbia Basin salmon and steelhead are specifically targeted to salmon and steelhead populations in the Pacific Northwest (Independent Scientific Advisory Board 2007a). NMFS incorporates the ISAB's recommendations by reference into this recovery plan, including those displayed in Table 4-11, some of which have been slightly modified to specifically apply to recovery of Lower Columbia River species. The management unit plans contain actions that implement many of these strategies. There will be a need throughout implementation for additional evaluation of the extent to which the management unit plan actions have been tailored specifically to address climate change impacts in the Lower Columbia.

A number of the strategies in Table 4-11 are currently being implemented through the 2008 FCRPS Biological Opinion and its 2010 Supplement, the Northwest Power and Conservation Council's Fish and Wildlife Program, local recovery plans, and activities and research of other federal and non-federal agencies.

In addition, the management unit plans and estuary recovery plan module (NMFS 2011) identify climate change as a threat, incorporate general approaches to climate change, and present specific actions that are responsive to the general strategies outlined above.[27] Some of these actions overlap with tributary habitat actions or, in the case of the Oregon management unit plan, actions to reduce the impacts of human population growth. The following actions from ODFW (2010) are representative of management unit plan actions to reduce the impacts of climate change on salmon and steelhead:

- Develop recommendations for land management scenarios that address hydrograph changes that are due to climate change, impervious surfaces, and other factors that result in altered water runoff.
- Protect and restore riparian areas to improve water quality, provide long-term supplies of large wood to streams, and reduce impacts that alter other natural processes.
- Develop a methodology to assess and identify, and then protect, stream reaches and population strongholds that will be resilient/resistant to climate change impacts.
- Protect and restore headwater rivers and streams (salmon- and non-salmon-bearing) to protect the sources of cool, clean water and normative hydrologic conditions.
- Conduct a detailed climate change risk analysis for all populations and use this to help prioritize actions, or develop new ones, that are contained in the implementation schedule.
- Implement credible, science-based programs, policies, and rules that contribute collectively to protect fish and water resources.

These actions are examples only. For more information, see Table 7-3A of ODFW (2010) and p. 5-70 of LCFRB (2010a).

---

[27] In calculating target abundances, Oregon recovery planners included an additional 20 percent "buffer" to account for the impacts of future threats—both climate change and human population growth—and expect that targets and actions will be adjusted as more specific information on the impacts of climate change becomes available. Washington recovery planners did not incorporate the impact of climate change or human population growth into its calculations of target abundances. NMFS' view is that this difference in approach is not significant for the reasons explained in Section 5.2.2.

Table 4-11
Strategies and Representative Actions to Address Climate Change Impacts

Category	Strategy	Representative Actions
Planning Actions	Assess potential climate change impacts in each subbasin and develop a strategy to address these concerns as part of updates to subbasin and recovery plan. NMFS will help provide technical assistance to planners to help ensure that climate change is addressed thoroughly and consistently in subbasin and recovery plans.	
	Ensure that subbasin and recovery planners are aware of pertinent resources. As needed, NMFS and other entities will direct planners to tools and climate change projections that will aid them in assessing the subbasin impacts of climate change. Resources currently include: • Pacific Northwest Climate Impacts Consortium: http://pnwclimate.org/ • Northwest Climate Science Center: http://www.doi.gov/csc/northwest/index.cfm • University of Washington Climate Impacts Group: http://cses.washington.edu/cig/ • Oregon State University's Oregon Climate Change Research Institute: http://occri.net/ • NOAA's climate sciences program: http://www.climate.gov/ • North Pacific Landscape Conservation Cooperative: http://www.fws.gov/pacific/Climatechange/nplcc/	
	Establish reserves through the purchase of land or conservation easements in locations likely to be sensitive to climate change that have high ecological value. Landscape-scale considerations will be critical in the choice of reserve sites because habitat fragmentation and changes of habitat will influence the ability of such reserves to support particular biota in the future. (Independent Scientific Advisory Board 2007a summarizes some generally accepted guidelines for selection of reserves or protected areas that are specifically intended to preserve biodiversity in the face of changing climate.)	
Tributary Habitat	Minimize temperature increases in tributaries by implementing measures to retain shade along stream channels and augment summer flow	• Protect or restore riparian buffers, particularly in headwater tributaries that function as thermal refugia • Remove barriers to fish passage into thermal refugia
	Manage water withdrawals to maintain as high a summer flow as possible to help alleviate both elevated temperatures and low stream flows during summer and autumn	• Buy or lease water rights • Increase efficiency of diversions

Category	Strategy	Representative Actions
	Protect and restore wetlands, floodplains, or other landscape features that store water to provide some mitigation for declining summer flow	• Identify cool-water refugia (subbasins with extensive groundwater reservoirs) • Protect these groundwater systems and restore them where possible • May include tributaries functioning as cool-water refugia along the mainstem Columbia where migrating adults congregate • Maintain hydrological connectivity from headwaters to sea
Mainstem and Estuary Habitat	Reduce temperatures and create thermal refugia	• Remove dikes to open backwater, slough, and other off-channel habitat, thus increasing flow through these areas and encouraging increased hyporheic flow
Mainstem and Tributary Hydropower	Augment flow from cool or cold-water storage reservoirs to reduce water temperatures, or create cool-water refugia in mainstem reservoirs and the estuary	• Investigate increasing storage in existing reservoirs or adding new storage facilities,, but must be cautious with this strategy • Investigate the possibility of implementing a seasonal flow strategy that includes cool-water releases from storage reservoirs in Lower Columbia River tributaries in late summer
	Use methods to increase surface passage of juveniles at Bonneville and The Dalles dams to move fish quickly through warm forebays and past predators in the forebays.	• Use corner collector at Bonneville Dam
	Reduce water temperatures in adult fish ladders at Bonneville and The Dalles dams	• Use water drawn from lower cool strata of forebay • Cover ladders to provide shade
	Reduce the impact of higher fish predation rates caused by warming water temperature by reducing predator populations	• Reduce predation by introduced piscivorous species (e.g., smallmouth bass, walleye, and channel fish) in mainstem reservoirs and the estuary
Harvest	When setting annual quotas and harvest limits, conduct and use assessments that take into consideration the changing climate	• Reduce harvest during favorable climate conditions to allow stocks that are consistently below sustainable levels during poor phase ocean conditions to recover their numbers and recolonize areas of freshwater habitat • Use stock identification to target hatchery stocks or robust wild stocks, especially when ocean conditions are not favorable
Hatcheries	Reduce density-dependent interactions among hatchery- and natural-origin fish; such interactions can cause lower growth and survival at times when climate effects reduce ocean productivity	• Control juvenile migration by reducing hatchery releases or modifying release timing to reduce competition and ensure that ocean entry coincides with favorable ocean conditions • Consider changing systemwide habitat conditions in determining appropriate stocks for reintroduction programs

4.8 Human Population Growth

4.8.1 Limiting Factors and Threats Related to Human Population Growth

An estimated 5 million people live in the Columbia Basin, and the human population in the region is expected to increase significantly in coming years. By the end of the twenty-first century, between 40 million and 100 million people are predicted to be living in the Columbia Basin (National Research Council 2004). Some communities—both urban and rural—can expect their populations to double between 2000 and 2020; significant growth also is projected for unincorporated areas. In Oregon, particularly fast growth is predicted in Clackamas, Clatsop, Columbia, Hood River, and Multnomah counties—areas that support Lower Columbia River coho, Chinook, and steelhead and Columbia River chum salmon. The population of these counties is expected to increase by 41 percent from 2003 to 2040 (State of Oregon Office of Economic Analysis 2004). In Washington, the populations of Clark and Cowlitz counties are projected to grow by 65 and 53 percent, respectively, from 2000 to 2030 (Washington State Department of Transportation).

The Oregon management unit plan describes in general the expected future impacts of human population growth on Columbia Basin fish and wildlife populations, based on work by the Independent Scientific Advisory Board (ISAB) for the Northwest Power and Conservation Council, Columbia River Basin Indian tribes, and NMFS (Independent Scientific Advisory Board 2007b). The ISAB reached the following conclusions:

- Population growth will increase the demand for water, land, and forests that are key to fish and wildlife populations. This demand for resources will increase threats to and extinction risks for fish and wildlife.
- Changes in land use related primarily to increases in human population size and per-capita consumption rates will increase water use, affect land management and, ultimately, affect fish and wildlife habitat.
- Increased demand for residential land is accelerating the rate of conversion of forest and agricultural lands.
- The dominant ongoing pattern of settlement in the Columbia Basin is exurban sprawl—i.e., the building of new communities on the fringes of urban growth boundaries. Exurban sprawl causes loss, degradation, and fragmentation of habitat and increases infrastructure costs, social conflict, and harmful interactions among people and wildlife.
- Urbanization will increase the amount of impervious surfaces (pavement, roofs etc.) in watersheds, increasing surface runoff during storm events and reducing groundwater recharge and thus base flows.
- The effects of population growth will combine with those of climate change to increase pressure on fish and wildlife habitats.

- Demands for fresh water from surface and groundwater will increase. Climate change-related decreases in the snowpack at higher elevations will exacerbate this situation, especially during low-flow summer and fall seasons.
- Population-related factors external to the Columbia Basin, such as international trade, shipping, dredging, hazardous material transport, and airborne pollution, will affect fish and wildlife habitat in the basin. (See ODFW 2010, and Independent Scientific Advisory Board 2007b.)

4.8.2 Regional Strategy for Human Population Growth

The Oregon and White Salmon management unit plans identified both human population growth and climate change as future threats to lower Columbia salmon and steelhead. Although Oregon recovery planners believe that actions should be implemented now to prevent or mitigate for the future impacts of these threats (ODFW 2010), the magnitude of the impacts is unknown. Given this uncertainty, in developing improvement targets for Oregon populations, recovery planners added an additional 20 percent in abundance above that needed to achieve the WLC TRT criteria for stratum viability. This 20 percent conservation "buffer" is intended as a precautionary measure, to help mitigate for the impacts of both human population growth and climate change in the interim until the magnitude of these threats is better understood. Once the impacts of human population growth and climate change can be estimated more accurately, targets and actions in the Oregon management unit plan can be adjusted accordingly (ODFW 2010).

The Washington management unit plan did not identify future growth in the human population as a threat to lower Columbia salmonids or incorporate the impacts of future threats—either population growth or climate change—in its calculations of target abundance for recovery of its populations. Instead, managers and scientists expect to use the adaptive management process to refine strategies, measures, and actions as the Washington management unit plan is implemented, based on the observed response to initial recovery efforts. Effective adaptive management will require that initial actions be of a magnitude sufficient to produce a measurable response, and that monitoring be sufficient to detect a response (LCFRB 2010a).

All three management unit plans include actions or strategies that will lessen the impacts of human population growth. The Oregon management unit plan identifies specific actions as mitigation for this threat, while the Washington management unit plan incorporates mitigation measures into larger scale principles and strategies that are intended to address six major categories of threats to lower Columbia salmon and steelhead. Representative actions and strategies from the Oregon and Washington management unit plans are shown in Table 4-12. The White Salmon management unit plan includes broader scale strategies that, although not linked specifically to human population growth, will help mitigate this threat; examples include protecting the highest quality habitats through acquisition and conservation, conserving rare and unique functioning habitats, consistently applying best management practices and existing laws to protect and conserve natural ecological processes, and providing public outreach to educate river uses and others (NMFS 2011).

Table 4-12
Representative Actions and Strategies to Mitigate for Human Population Growth

Oregon Management Unit Plan	Washington Management Unit Plan
• Prevent impacts from future development in the 100-year floodplain—i.e., impacts on wetlands and vegetation, stormwater effects, and the net impacts of new dikes, levees, and floodwalls. Mechanisms to prevent impacts in the 100-year floodplain include updating floodplain maps and incorporating them into land use planning, providing FEMA funding for land acquisition in the floodplain, developing new regulations, and enhancing efforts to enforce existing land use regulations, laws, and ordinances. • Encourage the Oregon Division of State Lands to (1) require avoidance and minimization of impacts to waters of the state in priority areas identified in the Oregon management unit plan, (2) work with landowners to design projects that avoid and minimize impacts to wetlands and other waters of the state, (3) explore opportunities to target compensatory mitigation towards areas that have high intrinsic potential for salmon and/or have been identified as priority areas for restoration, and (4) explore conservation easements for state-owned lands with high value for salmon recovery. • Protect existing high-quality or intact habitat, including riparian areas and off-channel habitat in the Columbia River estuary; actively purchase off-channel estuarine habitats in urban and rural settings. • Encourage and provide incentives for local, state, and federal regulatory entities to maintain, improve, and enforce habitat protections throughout the lower Columbia region. • Provide more resources and incentives to small (non-metropolitan) communities so they have the infrastructure to better manage runoff from impervious surfaces. • Educate landowners about the benefits of protecting and stewarding intact ecosystems and the costs of degraded systems. • Remove or modify over-water structures to provide beneficial habitats. • Reduce the stranding of juvenile salmonids on estuarine beaches as a result of ship wakes. • Reduce salmonid exposure to toxic contaminants: implement pesticide and fertilizer best management practices; identify and reduce industrial, commercial, and public sources of pollutants; and restore or mitigate contaminated sites in the Columbia River estuary. • Implement stormwater best management practices in cities and towns.	• Consider salmon recovery needs up front in the comprehensive land use planning process, along with other social, infrastructure, and service needs. • Protect habitat conditions and watershed functions through land use planning that guides population growth and development—i.e., plan growth and development to avoid sensitive areas (wetlands, riparian zones, floodplains, unstable geology, etc.), encourage the use of low-impact development methods and materials, and apply mitigation measures to offset potential impacts • Protect and restore instream flows through water rights closures, purchase or lease of existing water rights, relinquishment of existing unused water rights, enforcement of water withdrawal regulations, and implementation of water conservation, use efficiency, and water re-use measures to decrease consumption. • Protect and restore runoff processes, in part by limiting additional watershed imperviousness, managing stormwater runoff, and protecting and restoring wetlands in developed and developing areas. • Protect and restore water quality, in part by reducing fecal coliform bacteria levels and inputs of chemical contaminants from developed lands. This involves managing industrial point sources of pollution, eliminating urban and rural sewage discharge to streams, and treating storm runoff before it is discharged to streams. • Manage recreation to protect and restore sensitive areas, such as by rehabilitating damaged terrain, limiting use, and managing human waste. • Maintain and/or establish adequate resources, priorities, regulatory frameworks, and coordination mechanisms for effective enforcement of land and water use regulations for the protection and restoration of habitats significant to fish and wildlife resources. This involves establishing cooperative enforcement partnerships among agencies, public, land owners, and industry and establishing priorities to emphasize protection in key areas and facilities where recovery efforts are focused.

For more detail on mitigating for the growing human population in the Columbia Basin, see the Oregon and Washington management unit plants (ODFW 2010 pp. 100-101, 226-239; LCFRB 2010a Chapter 5, S.S10, S.M1, S.M3, S.M12, S.M13, S.M15, and 2.M16).

4.9 Summary

No single factor, threat, or threat category accounts for the declines in the species addressed in this recovery plan; instead, the status of Lower Columbia River salmon and steelhead and Columbia River chum salmon is the result of the cumulative impact of multiple limiting factors and threats. Although this chapter and the recovery analyses that follow highlight major recovery topics, factors, and actions, recovery of the Lower Columbia species will be accomplished through improvements in every general threat category. Even small increments of improvement will play an important role. When the need for improvement for most ESUs is so large, the contribution of no population or threat reduction can be discounted.

5. Overall Approach to Species Recovery Analyses

This chapter describes the management unit recovery planners' overall analytical approach to species recovery and summarizes the key analyses that formed the basis of their recovery strategies. Where relevant, the chapter describes differences in approaches and discusses the implications of those differences. For more detailed information on these methodologies, see the management unit plans (LCFRB 2010a, ODFW 2010, NMFS 2013). The chapters that follow describe the results of these analyses as applied to each Lower Columbia River ESU or DPS.

In general, the management unit recovery planners did the following:

1. Evaluated the baseline status of their respective populations using techniques based on those recommended by the WLC TRT (McElhany et al. 2003, McElhany et al. 2004, McElhany et al. 2006) and demonstrated in McElhany et al. (2007).[1]

2. Identified limiting factors for each Lower Columbia River salmon and steelhead population.

3. For each population, quantified the estimated baseline impacts of six categories of threats—tributary habitat, estuary habitat, hydropower, harvest, hatcheries, and ecological interactions or predation—that were useful as an organizing construct for grouping limiting factors.

4. Established a target status for each population, taking into consideration (1) each population's potential for improvement, in view of available habitat and historical production, (2) the degree of improvement needed in each stratum to meet WLC TRT guidelines for a viable ESU, and (3) for some ESUs, the desire to accommodate objectives such as maintaining opportunities to harvest hatchery-origin fish. Management unit recovery planners used the term "conservation gap" to refer to the difference between the baseline and target status for each population.

5. Calculated the population-specific improvements in abundance and productivity and, in some cases, spatial structure and diversity that would be needed to achieve each population's target status (i.e., to close the conservation gap).[2]

6. Identified a "threat reduction scenario" for each population, meaning a specific combination of reductions in threats that would lead to that population achieving its target status.

[1] McElhany et al. (2007) was a collaborative effort by NMFS Northwest Fisheries Science Center staff, ODFW staff, and a consultant working for the Lower Columbia Fish Recovery Board to refine the approach to population status assessment.

[2] The Oregon management unit plan contains explicit targets for spatial structure and diversity; in the Washington management unit plan, spatial structure and diversity improvements are implicit in the abundance and productivity targets.

7. Identified and scaled recovery strategies and actions to reduce threats by the targeted amount in each category. Management unit planners identified recovery strategies and actions through meetings and workshops with stakeholders, including representatives of implementing and affected entities.

8. Considered the probable effects of actions, established benchmarks for implementation, and identified critical uncertainties and research, monitoring, and evaluation needs for each species for incorporation into an adaptive management framework (see Chapter 10 of this plan).

9. Developed implementation frameworks that address organizational structures, prioritization methods, systems for tracking implementation, coordination needs and approaches, and stakeholder involvement (see Chapter 11of this plan).

The following text further describes the analytical framework used by the management unit recovery planners.

5.1 Baseline Population Status

Management unit recovery planners assessed each population's status based on methods described in technical reports developed by the WLC TRT and demonstrated in McElhany et al. (2007). (For a description of these reports, see Section 2.5.2). For each population, management unit recovery planners evaluated and scored the four VSP attributes of productivity/abundance, spatial structure, and diversity individually and then integrated the VSP attribute scores to yield an overall population score; this overall score reflects the population's baseline probability of persistence, as shown in Table 5-1. For information on specific benchmarks and scoring techniques, see McElhany et al. (2003, 2004, 2006, and 2007, primarily the latter two documents), pp. 50 through 75 of ODFW (2010), and pp. 4-11 through 4-18 of LCFRB (2010a).

Readers should note that in the management unit plans, Oregon described its populations in terms of extinction risk, while Washington described its populations in terms of persistence probability. This is a difference in terminology only, as persistence probability is simply the inverse of extinction risk status (e.g., high persistence probability is the equivalent of low extinction risk, as shown in Table 5-1). This ESU-level plan presents the status of all populations in terms of persistence probability (this is consistent with the language of the WLC TRT technical documents) but uses "extinction risk" in some contexts when that term is more illuminating.

Table 5-1
Population Scores and Corresponding Probability of Persistence (or Extinction)

Score*	Probability of Persistence**	Population Status	Probability of Extinction **	Extinction Risk
0	0 – 40%	Very low (VL)	60 – 100%	Extinct or at very high risk of extinction (VH)
1	40 – 75%	Low (L)	25 – 60%	Relatively high risk of extinction (H)
2	75 – 95%	Medium (M)	5 – 25%	Moderate risk of extinction (M)
3	95 – 99%	High (H)	1 – 5%	Low/negligible risk of extinction (L)
4	> 99%	Very high (VH)	< 1%	Very low risk of extinction (VL)

* Population scores between whole numbers are rounded. For example, a score of 2.75 would be rounded up to 3; a score of 2.45 would be rounded down to 2.

** Probability over a 100-year time frame.

Source: McElhany et al. (2006).

5.1.1 Oregon Approach to Assessing Baseline Status

Oregon recovery planners established a "baseline period" from which to assess population status based on the most recent data available at the time of their assessment—generally up through 2006-2008 for modeling of abundance and productivity and through 2004 for assessment of other VSP parameters and threat assessments (ODFW 2010).

Consistent with the WLC TRT's approach (described in McElhany et al. 2003 and 2006 and demonstrated in McElhany et al. 2007), the four VSP parameters of productivity/abundance, spatial structure, and diversity were the foundation of the status assessment for Oregon populations. Oregon recovery planners also used the WLC TRT's scoring method—i.e., total score = 2/3 A&P + 1/6 spatial + 1/6 diversity (see McElhany et al. 2007)—to derive a composite score for each population. As in McElhany et al. (2007), Oregon recovery planners based scoring of the abundance/productivity attribute on population viability modeling and used a mix of quantitative and qualitative metrics to score the spatial structure and diversity attributes.

To reflect the uncertainty associated with both the data and the assessment methods, and consistent with McElhany et al. (2007), Oregon recovery planners presented results as a distribution of possible extinction risk scores, displayed graphically as a diamond shape (see Figure 5-1), rather than as a single score. The widest point of the diamond reflects the most likely extinction risk category, while the upper and lower points correspond to the extremes of possible extinction risk values. The height of the diamond represents the degree of uncertainty about the assessment. During later steps in their recovery analyses, Oregon recovery planners used the extinction risk category at the diamond's widest point as the baseline extinction risk.

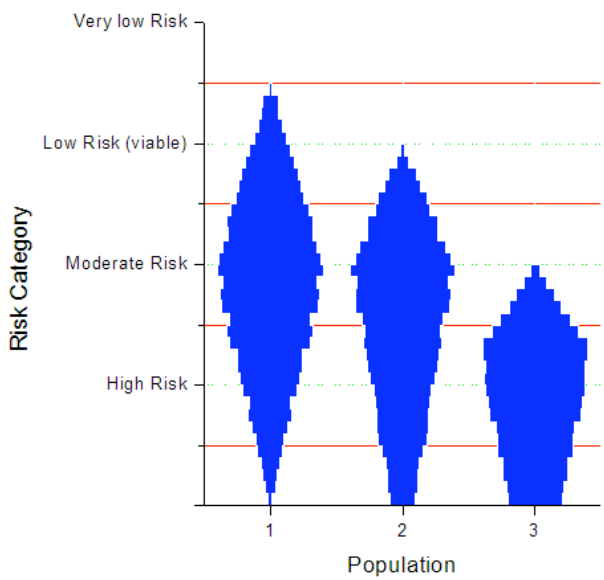

Figure 5-1. *Sample "Diamond Graph" Showing Populations with Different Distributions of Extinction Risk (Inverse of Persistence Probability***)**

5.1.2 Washington Approach to Assessing Baseline Status

Washington recovery planners evaluated population status circa 1999—around the time when most Lower Columbia River salmon and steelhead were listed under the ESA (LCFRB 2010a)—and did not use time series information after the baseline period in any quantitative analysis; they considered spatial structure and diversity conditions as of 1999). The Washington recovery planners chose this point because it ensures that the baseline assessments reflect the conditions that led to the initial ESA listings and that must be addressed through recovery actions.

As in Oregon, the four VSP parameters of productivity/abundance, spatial structure, and diversity were the foundation of the Washington status assessments. However, instead of deriving an overall population score using the WLC TRT's formula (total population status score = 2/3 A&P + 1/6 spatial structure + 1/6 diversity), Washington recovery planners assessed population status by (1) scoring the abundance/productivity, diversity, and spatial structure attributes for each population (see Table 4-4 in LCFRB 2010a) and then (2) designating the lowest of the individual attribute scores as the overall population status. The Washington recovery planners considered this "lowest attribute" approach intuitively simpler, less subjective, and more effective in capturing spatial structure and diversity concerns.

A consultant to the Lower Columbia Fish Recovery Board developed abundance/productivity scores for each Washington population using a quantitative population viability analysis that uses a stochastic stock-recruitment model. This approach is similar to the risk analyses in McElhany et al. (2007) and the Oregon management unit plan. Scores for spatial structure and diversity that go into the overall population status scores were based on qualitative analyses and expert judgment using criteria established by a technical work group and based on guidance established by the WLC TRT (McElhany et al. 2003).

The Washington management unit plan notes that there is significant uncertainty in the population status assessments—on the order of at least one point in the population score. The uncertainty is a consequence of the limited data and limited understanding of the relationships between population attributes and persistence probability (LCFRB 2010a).

5.1.3 White Salmon Approach to Assessing Baseline Status

For baseline population status, the White Salmon recovery planners used status assessments completed by the WLC TRT in 2004 (McElhany et al. 2004), the most current assessment of the White Salmon populations available at the time of plan development. The 2004 evaluation involved individual WLC TRT members ranking the VSP attributes based on best available information and professional judgment and providing an estimate of "data quality" based on their assessment of the overall amount of information available for each attribute. Overall population viability was determined using the WLC TRT's formula for a weighted average of the VSP attributes (McElhany et al. 2004).

5.1.4 Differences in Status Assessment Methods

The population assessment methods used by Oregon, Washington, and White Salmon recovery planners were similar to each other and consistent with the approach outlined in McElhany et al. (2000), but they differed in specific application, such as selection of the baseline period and integration of VSP attribute scores to yield an overall population score (see Table 5-2). As a result, the status assessments in the different plans are not necessarily directly comparable. However, the actual results of the assessments are generally in agreement on the relatively poor status of most populations. This suggests that the fundamental similarities of the approaches outweigh their differences, which appear to have relatively little effect on overall conclusions about population status. NMFS' view is that the status assessment methods used by the WLC TRT, McElhany et al. (2007), and the management unit plans all are scientifically sound, are based on the best information available, and provide a credible assessment of population status and a solid foundation for additional assessments and identification of initial recovery actions.

As described in more detail in Section 5.10, NMFS is required to complete reviews of the status of listed salmon and steelhead every 5 years. The most recent reviews, which were completed in 2011, used the same VSP concept that the management unit planners used and reached conclusions about population status similar to those in the management unit plans (76 *Federal Register* 50448). As new methods for status assessment are developed and new and better data become available, NMFS will employ the improved techniques in future 5-year reviews and recovery plan updates.

Table 5-2
Key Differences in Status Assessment Methodologies

Element	Oregon	Washington	White Salmon
Baseline period	Modeled baseline abundance assuming environmental conditions similar to those through 2006-2008	Used circa 1999 (i.e., ESA listing dates) as the baseline period	Used 2004 as the baseline period
Population score	Used weighted average of VSP attribute scores to determine population score	Used lowest VSP attribute score to determine population score	Used weighted average of VSP attribute scores,* tempered by professional judgment
Uncertainty	Expressed uncertainty graphically, using diamond shapes and reduced extinction risk thresholds to account for uncertainty	Stated that population score may be off by one or more points	Scored the quality of the data for each VSP attribute

* McElhany et al. (2004), which was the source of the status assessments for the White Salmon populations, used a slightly different list of VSP attributes than did the Oregon and Washington recovery planners—namely, productivity, juvenile outmigrants, diversity, habitat, and spatial structure. The WLC TRT later refined the VSP parameters to abundance, productivity, spatial structure, and diversity.

5.2 Target Status

5.2.1 Recovery Scenario

Through an iterative process, management unit recovery planners collaborated to reach agreement on a target status for each population that either was consistent with the WLC TRT's stratum and ESU/DPS viability criteria or that would contribute to comparable ESU/DPS risk levels. Where a population's target status was inconsistent with the WLC TRT's stratum or ESU/DPS criteria, the management unit plans documented the basis for the divergence. In this ESU-level recovery plan and the management unit plans, the target viability statuses are referred to collectively as the "recovery scenario" for the ESU or DPS (see Table 3-1 for the actual scenarios). Recovery planners also designated each population as "primary," "contributing," or "stabilizing" to reflect its expected level of contribution to recovery of the ESU or DPS (see Section 3.1.3 for a description of these designations).

5.2.2 Conservation Gaps

The difference between a population's baseline status and its target status reflects the magnitude of improvement needed to close the "conservation gap." Oregon and Washington management unit recovery planners estimated the abundance, productivity, spatial structure, and diversity improvements that would be necessary for each population to achieve its target status.[3] They quantified gaps in abundance and

---

[3] Washington management unit recovery planners quantified the conservation gap for the White Salmon populations as part of their conservation gap analysis (see LCFRB 2010a). The White Salmon management unit plan (NMFS 2013) does not include this gap analysis. Instead, the plan presents a baseline status for

productivity using the same stochastic population viability analysis models used to estimate baseline risk status and treated gaps in spatial structure and diversity qualitatively because of a lack of rigorous quantitative analytical methods and criteria for these parameters.[4] For more on information on how management unit recovery planners calculated population-specific conservation gaps in terms of the VSP parameters, see pp. 58 to 78 of ODFW (2010) and pp. 4-28 through 4-30 of LCFRB (2010a).

Although population-specific gap analyses are subject to a significant level of uncertainty that is difficult to quantify, management unit planners and NMFS consider the results of these analyses useful in conveying the order of magnitude of improvements that need to be addressed through recovery strategies and actions.

Quantification of population-specific gaps in abundance and productivity is one area where Oregon and Washington recovery planners took slightly different approaches in their analyses. In calculating the abundance and productivity improvements needed to achieve each population's target status, Oregon recovery planners built in two numerical "buffers": one to account for expected future threats (i.e., climate change and human population growth in the region), and one to serve as a "safety factor," to compensate for scientific uncertainty and possible measurement errors. In contrast, Washington recovery planners based their calculations of needed abundance and productivity improvements on known baseline conditions and expect to respond to future threats and account for scientific uncertainty through adaptive management.

A result of this difference in approach to future threats and scientific uncertainty is that the numerical estimates of abundance and productivity needed to fill the conservation gaps for Oregon populations are bigger than those for corresponding gaps for the Washington populations. NMFS' view is that this difference in approach is not significant because (1) management unit recovery planners did not do quantitative modeling of the probable effects of recommended recovery actions, and (2) both states will rely on adaptive management as actions are implemented and conditions in the region change.

5.3 Limiting Factors and Threats

NMFS defines limiting factors as various biological, physical, or chemical conditions (such as high water temperatures) and the associated ecological processes and interactions that limit a species' viability[5]; NMFS defines threats as human activities or natural events that cause or contribute to limiting factors. For example, the limiting factor of high water temperature could be caused by any number of threats, either alone

---

each population (based on McElhany et al. 2004) and a target status for each population (based on LCFRB 2010a).

[4] The Oregon management unit plan contains explicit targets for spatial structure and diversity; in the Washington management unit plan, spatial structure and diversity improvements are implicit in the abundance and productivity targets.

[5] In this recovery plan, the term "limiting factors" is used to indicate the full range of factors that are believed to be impairing the viability of salmon and steelhead and not to indicate the single factor that is most limiting. Some NMFS scientists are now using the term "ecological concerns" instead of "limiting factors" to connote this full range of factors affecting viability.

or in combination, such as warm water discharged to a stream, loss of bank vegetation that otherwise would shade the stream, low stream flow, or climate change. Threats can be caused by past or present actions or events. Understanding threats allows recovery planners to identify actions that will change the actual activities or events that cause a limiting factor, thus reducing the limiting factor itself.

The management unit recovery planners identified population-specific limiting factors and threats that are contributing to the threatened status of Lower Columbia River ESUs through review and synthesis of published and unpublished literature, supplemented by EDT modeling (for Washington populations) and professional judgment (for Oregon and White Salmon populations). Each management unit plan presents limiting factors for all populations within its planning area (see, for example, Table 5-1 of ODFW 2010), with impacts falling into six associated threat categories: tributary habitat, estuary habitat, hydropower, harvest, hatcheries, and predation (or ecological interactions, in the Washington management unit plan). The management unit plans describe limiting factors and threats in relation to the biological needs of the species and across the full spectrum of conditions that affect salmon and steelhead throughout their life cycle. Because data linking limiting factors to specific effects on population risk status are generally lacking, each management unit plan presents the limiting factors as hypotheses to be tested through action implementation and monitoring of results, with adaptive management as needed.

Oregon recovery planners used a multi-step process to identify limiting factors and threats. Using available published and unpublished information and professional judgment, an expert panel developed an initial set of population-level limiting factors and threats by life stage (juvenile or adult) and categorized them as having either a key or secondary impact on population status.[6] The Oregon recovery planning team and the Oregon Lower Columbia River stakeholder team then worked iteratively to review the initial set of limiting factors and threats and modify them based on additional information and deliberation. For additional discussion of the expert panel process and detailed results for each population, see Chapter 5 of ODFW (2010).

Washington recovery planners based their descriptions of limiting factors and threats on review and synthesis of published and unpublished literature for the listed species in the lower Columbia region. They also used Ecosystem Diagnosis and Treatment (EDT) modeling to identify primary and secondary habitat limiting factors by juvenile and adult life stages at the population and stream reach scale. Detailed results of the EDT modeling are presented in Volume II of the LCFRB plan and are reflected in the population-level limiting factors reported in this ESU-level recovery plan (see Section 5.4 and Appendix H).

White Salmon recovery planners identified limiting factors and threats based on a substantial body of research, local field data and observations, and the opinions of regional experts (NMFS 2013).

---

[6] For discussion of the thresholds used to determine whether a factor was key or secondary, see Section 5.1.4 of ODFW (2010).

5.4 NMFS Limiting Factors Crosswalk

Each of the management unit plans use somewhat different terms to describe limiting factors and threats, and in some cases, the plans characterize limiting factors and threats at different levels of specificity. To facilitate the use of a common parlance in discussing limiting factors in all salmon and steelhead recovery plans, the NMFS Northwest Fisheries Science Center developed a standardized set of limiting factors (also known as ecological concerns) that affect salmon and steelhead (Hamm 2012). NMFS refers to this standardized list of limiting factors as a "data dictionary" and intends to use it to track and report on recovery plan limiting factors and actions regionwide. For this recovery plan, NMFS developed a set of limiting factor "crosswalk" tables that correlate each management unit plan's population-specific limiting factor information with the terms used in the data dictionary. Appendixes G and H present the data dictionary and crosswalk tables, respectively.

The crosswalk tables indicate the limiting factors (i.e., the "ecological concerns" in the data dictionary) that affect each population, as well as the life stage affected, the degree of impact (primary or secondary), the location of the impact (in tributaries or in the Columbia River estuary and plume), and, in certain cases, whether there is uncertainty regarding the accuracy of the data. NMFS used the crosswalk tables in Appendix H to derive the summaries of stratum- and ESU-level limiting factors and threats in Chapters 6 through 9 of this ESU recovery plan.

Appendix H explains the methodology that NMFS used to develop the limiting factor crosswalks. Briefly, the limiting factors identified in the Oregon management unit plan tracked quite readily to the subcategories of ecological concerns in the Northwest Fisheries Science Center data dictionary. For Washington populations, it was necessary for NMFS staff and an independent contractor to examine the EDT results, draw information from various parts of the Washington management unit plan, and confer with Lower Columbia Fish Recovery Board staff and the board's consultant to distinguish between primary and secondary limiting factors.

5.5 Baseline Threat Impacts

Once management unit recovery planners had identified population-specific limiting factors, they estimated the baseline mortality impacts to each population caused by six categories of threats—tributary habitat, estuary habitat, hydropower, harvest, hatcheries, and predation (or ecological interactions, in the Washington management unit plan)—that also proved useful as an organizing construct for grouping limiting factors. Only potentially manageable impacts were considered. In estimating impacts, management unit recovery planners evaluated each threat category independently (i.e., impacts reflect the mortality of fish exposed to that particular category of threats, whether or not they are exposed to threats in the other categories). The estimates of baseline threat impacts have high levels of uncertainty and in many cases should be considered working hypotheses that are testable as part of recovery plan implementation. Despite this uncertainty, it is the expert judgment of NMFS and management unit scientists that, based on the best available information at this time, the baseline threat impacts provide a reasonable estimate of the relative magnitude of different sources of anthropogenic mortality on each population and serve as an adequate basis for designing initial recovery actions. As more and better information is collected, it will be applied to recovery efforts in an adaptive management framework.

Management unit recovery planners used the population-specific baseline threat impacts when (1) evaluating the effects of possible reductions in each threat category (see Tables 6-6, 7-6, 7-8, 7-10, 8-4, and 9-7), and (2) scaling actions to achieve the target status for each population (see Section 5.7, "Recovery Strategies and Actions").

5.5.1 Oregon Approach to Quantifying Baseline Threat Impacts

Oregon recovery planners estimated the baseline impacts of threats as summarized below:

- Hydropower impacts: Estimated dam passage mortality among juveniles and adults based on estimates in the 2008 FCRPS Biological Opinion (NMFS 2008f) or FERC relicensing documents, and in some cases professional judgment. Excluded non-passage impacts such as habitat blockage, habitat inundation, and flow modification in the Columbia River estuary.

- Harvest impacts: Calculated average fishery exploitation rates for a reference period that extends loosely from 1994 to 2004 (ODFW 2010 p. 72-74 and Table 4-8, p. 73).

- Hatchery impacts: Estimated hatchery impacts as mortality resulting from the reduced overall population productivity of natural-origin fish; assumed that mortality corresponds to the proportion of hatchery fish in natural spawning populations (except for Chinook salmon populations, where hatchery impact rates were assumed to be one-half the rates at which hatchery fish were found on natural spawning grounds; see pp. 156 to 158 of ODFW 2010). This approach reflects a concern for both the genetic and ecological effects of hatcheries and excludes the benefits of conservation hatchery programs.

- Predation impacts: Estimated overall predation rates based on information in the literature and then adjusted those rates downward to exclude non-anthropogenic predation.

- Estuary habitat impacts: Derived estimates of baseline mortality from estimates of total juvenile mortality in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). Adjusted the module estimates downward assuming that 70 percent of subyearling migrant mortality and 35 percent of yearling migrant mortality in the estuary is anthropogenic. Further adjusted the estimates downward to subtract estimated mortality that is due to predation on juveniles.

- Tributary habitat impacts: Estimated the baseline mortality associated with estuary habitat degradation, hydropower, harvest, hatcheries, and predation and assigned all remaining mortality (relative to the difference between the baseline modeled abundance and estimated historical abundance) to tributary habitat impacts.

Throughout the Oregon management unit plan, ocean conditions were considered to be part of the environmental, variable baseline and thus not a discrete threat. However, the Oregon management unit plan notes that anthropogenic impacts in the ocean and other locations may be increasing, and that past assumptions about natural variability may not hold true in the future. Oregon recovery planners increased the size of the abundance and productivity gap by 20 percent in part to account for effects of future climate change, including changes in ocean conditions.

Oregon recovery planners did not quantify baseline and target threat impacts for chum salmon populations because data were inadequate to do so.

For more detailed information on how Oregon recovery planners estimated baseline threat impacts, see Section 6.2.1 of ODFW (2010).

5.5.2 Washington Approach to Quantifying Baseline Threat Impacts

Washington recovery planners estimated the baseline impact of threats as summarized below:

- Hydropower impacts: Estimated impacts from dam passage mortality, habitat loss caused by inundation, and loss of access to historical production areas because of the presence of large, impassable tributary and mainstem dams; excluded indirect hydropower impacts. Inferred the production potential of inaccessible habitat from EDT results. Estimated mainstem hydropower impacts based on the *Recovery Plan Module: Mainstem Columbia River Hydropower Projects* (NMFS 2008a).

- Harvest impacts: Used baseline fishery impacts rates from a reference period in the late 1990s; rates included harvest and indirect mortality and generally reflected the maximum estimated impacts.

- Hatchery impacts: Estimated hatchery impacts as mortality resulting from reduced overall population productivity of natural-origin fish; assumed that mortality is a function of the proportion and productivity of hatchery-origin fish that are spawning naturally. Inferred estimates of the relative fitness of hatchery- and natural-origin spawners from Columbia River Hatchery Scientific Review Group (HSRG) analyses. Limited hatchery impacts to not more than 50 percent per population, in accordance with HSRG assessments of the potential for genetic effects. Excluded impacts from interactions between hatchery- and natural-origin fish and the beneficial impacts of conservation hatchery programs.

- Ecological interactions: Estimated aggregate predation rates in the Columbia River mainstem and estuary by northern pikeminnow, marine mammals, Caspian terns, and cormorants, based on a combination of data, anecdotal information, and clearly articulated assumptions.

- Estuary habitat impacts: Derived estimates of baseline mortality from estimates of total juvenile mortality in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). Excluded predation mortality and assumed that manageable habitat mortality in the estuary was half of the non-predation-related total mortality.

- Tributary habitat impacts: Used EDT to derive estimates of the relative reduction in fish numbers resulting from changes in stream habitat conditions compared to a historical template.

Washington recovery planners did not quantify the effects of ocean conditions and long-term climate changes because of uncertainty about the magnitude and timing of their effects. However, the effects of normal variability in ocean conditions on annual fish survival were accounted for in the models that were used to evaluate population-level abundance and productivity and to establish abundance and productivity goals and threat reduction targets. The Washington management unit plan intends to address potential future changes in ocean and climate effects through adaptive management, prioritization of habitat restoration and protection actions, and setting recovery goals higher than necessary to achieve delisting (see Section 5.9 of LCFRB 2010a).

For more detailed information on how Washington recovery planners estimated baseline threat impacts, see Sections 3.7.2 through 3.7.4 of LCFRB (2010a).

5.5.3 White Salmon Approach to Quantifying Baseline Threat Impacts

The White Salmon management unit plan does not include an analysis of the baseline threat impacts. However, Washington recovery planners developed baseline threat impacts for the White Salmon populations to facilitate establishment of ESU-level recovery scenarios (see LCFRB 2010a). These threat impacts will be used to inform implementation and monitoring for the White Salmon management unit plan.

5.6 Threat Reduction Scenarios

Once management unit planners had quantified the baseline impacts of the six categories of threats (tributary habitat, estuary habitat, dams, harvest, hatcheries, and predation), they were able to evaluate the effects of possible reductions in each threat category. In this recovery plan, a given combination of threat reduction targets that would lead to a population achieving its target status is termed a threat reduction scenario. The scenario describes how much of a gain in population abundance and productivity is needed from recovery actions in each threat category to achieve a population's target status.

For each Oregon population, recovery planners developed and evaluated multiple threat reduction scenarios and then selected one. Washington recovery planners, on the other hand, developed a single threat reduction scenario for each population by assigning threat reduction targets to the six threat categories in proportion to the baseline impacts of each category. The different management unit plan approaches to developing threat reduction scenarios and population-specific threat reduction targets are summarized below. For more detail, see Section 4.5.2 of LCFRB (2010a) and Section 6.2.1 of ODFW (2010).

5.6.1 Oregon's Threat Reduction Scenarios

Oregon recovery planners evaluated how a number of different combinations of reductions in the six threat categories would affect each population's persistence probability. Evaluating multiple combinations of threat reductions across the six categories allowed the planning team and stakeholders to examine the tradeoffs among the various threat reduction options.

Oregon recovery planners evaluated the following threat reduction scenarios for each population:

- 20 percent reduction in each threat category's baseline rate
- Maximum harvest and hatchery (assumes essentially zero harvest, with a remaining 5 percent incidental impact rate, eliminating all LCR hatchery programs, and maintaining other threats at baseline levels)
- Maximum feasible reduction (assumes reductions in all threat categories that were considered feasible with current biological, social, political, and economic realities)
- Minimum tributary habitat (explores the minimum tributary habitat impact reduction required if reductions in other threat categories are maximized)
- Maintain into future (evaluates the threat reductions needed in each category to achieve a 20 percent increase in abundance to account for unknown future threats and maintain baseline risk status)
- Low extinction risk (evaluates the threat reductions needed to achieve low extinction risk, i.e., high persistence probability)
- Very low extinction risk (evaluates the threat reductions needed to achieve very low extinction risk, i.e., very high persistence probability)

The first four scenarios evaluated the persistence probability that would result from reducing two or more threat categories a given amount; the last three scenarios evaluated the threat reductions necessary to achieve a specific persistence probability.

Eventually, Oregon recovery planners selected a specific threat reduction scenario for each population based on factors such as feasibility, societal goals (including harvest opportunity, in some cases), and consistency with the WLC TRT's viability criteria. In addition, for the selected threat reduction scenario, Oregon assigned a level of confidence of whether the reductions could be achieved. In some cases the confidence was low. For more information on how Oregon developed its threat reduction scenarios, see Section 6.2.1 of ODFW (2010).

Once Oregon recovery planners had selected a threat reduction scenario, they used a simple, independent, threat impact model to apportion the needed abundance and productivity improvements (which had been calculated as part of the gap analysis) across the six threat categories, in accordance with the selected scenario.

5.6.2 Washington's Threat Reduction Scenarios and Interim Benchmarks

Washington recovery planners developed a single threat reduction scenario for each population, setting a target impact level for each threat category that reflects long-term future conditions when recovery objectives are achieved. To establish these threat reduction targets, planners distributed the needed abundance and productivity improvements across the threat categories in proportion to the baseline impacts of each category. This was a policy decision by the Lower Columbia Fish Recovery Board that will lead to each sector being responsible for reducing its impacts in proportion to its contribution to the total baseline impacts. Thus, sectors with small baseline impacts are responsible for effecting a smaller reduction than sectors with large baseline impacts.

Washington recovery planners calculated proportionate reductions in each threat category directly from the population productivity improvement targets identified in the conservation gap analysis. The resulting impact reduction targets provide guidance on the scale of threat-specific improvement that must be accomplished by threat-specific strategies and measures.

The Washington management unit plan's threat reduction targets do not explicitly consider the timing of recovery action implementation, or the potential lag time in the realization of benefits. Some threats respond quickly to actions aimed at reducing them, while others respond more slowly. For example, reductions in harvest translate into immediate increases in survival and abundance, while the benefits of hatchery and habitat measures typically take much longer to be realized. To address this problem and provide some immediate reductions in extinction risk (until the benefits of all recovery measures can be realized), the Washington management unit plan includes a schedule of interim threat reduction benchmarks that, for some threat categories, define relatively large reductions in impacts in the near term; specific values were determined based on a combination of biological benefits and implementation feasibility. The benchmarks also include a combination of action implementation, impact reduction, and biological improvement standards by which recovery plan implementation can be scheduled and evaluated. The interim benchmarks are presented in Tables 6-3, 6-4, 6-8, 6-11, and 6-14 of LCFRB (2010a).

5.6.3 White Salmon Threat Reduction Scenarios

The White Salmon management unit plan does not include an analysis of the relative impact of baseline threat categories or the reductions needed in each threat category to reach recovery targets. However, Washington recovery planners developed threat reduction scenarios for the White Salmon populations to facilitate establishment of ESU-level recovery scenarios (see LCFRB 2010a). With the removal of Condit Dam, these threat reduction scenarios will need to be reevaluated as new information about conditions in the White Salmon subbasin becomes available.

5.7 Recovery Strategies and Actions

The threat reduction targets provided a foundation from which management unit recovery planners could identify and scale recovery strategies and actions intended to reduce threats by the targeted amount in each category. The actions in the management unit plans address threats across the entire salmonid life cycle and include a balance of (1) actions intended to provide relatively immediate benefits, and (2) actions whose benefits are expected to be realized over a longer period of time. The management unit plans recommend both new activities and the continuation of existing programs that currently are benefiting Lower Columbia River ESUs (ODFW 2010, LCFRB 2010a). Actions identified in the management unit plans are intended to reduce threats in each category consistent with the conservation gaps and threat reduction targets described in Sections 5.2.2 and 5.6.

The Oregon and Washington management unit plans emphasize that recovery success will require not just local action but combined effort at the state, regional, national, and—in the case of harvest and hydropower—international level (ODFW 2010, LCFRB 2010a). Also, because there is a high degree of uncertainty about the biological response to actions and the level to which actions will need to be implemented to achieve the desired benefits, the plans consider proposed actions to some extent as hypotheses that will need to be tested. None of the management unit plans quantified the incremental benefit of any specific action; instead, actions were selected and scaled based on scientific judgment. (For a discussion of the sufficiency of recovery actions, see Section 5.8) All three management unit plans stress that adaptive management will play a central role in the recovery process, with research, monitoring, and evaluation activities providing crucial information on the effects of individual actions and overall progress toward recovery goals (ODFW 2010, LCFRB 2010a). (For more on research, monitoring, evaluation, and adaptive management, see Chapter 10.) Background information on recovery strategies and actions is presented in Section 5.1 of LCFRB (2010a) and 7.1 of ODFW (2010) and summarized below.

5.7.1 Oregon Approach to Developing Recovery Strategies and Actions

To develop recovery strategies and actions for Oregon populations, Oregon recovery planners began with the limiting factors and threats identified for each population by life stage and location. They then developed 14 overarching recovery strategies to provide an ecological context for identifying recovery actions (see Table 7-1 of ODFW 2010). Each strategy was associated with one or more of the six threat categories and was consistent with goals of biological diversity, ecological integrity, and ecological health (ODFW 2010).

Next, recovery planners developed recovery actions. The Oregon Lower Columbia River stakeholder team, which included state and federal agency staff and representatives of agricultural, commercial, conservation, recreational, forestry, and fishing interests, reviewed the recovery actions and provided additional input. The Oregon management unit plan includes actions that address all key or secondary limiting factors. For some habitat actions, Oregon recovery planners identified specific locations for implementation, using reach-scale assessments, other action plans, and professional judgment; for some locations, they identified a need for completion of reach-scale assessments so that recovery actions could be targeted to where they are most needed.

Recovery actions in the Oregon management unit plan are organized by species and population (see Tables 7-3B, 7-3C, 7-3D, and 7-3E of ODFW 2010), with specific locations noted separately (see Table 9-3 of ODFW 2010). The threat category that each action addresses is indicated. The plan also identifies actions that address threats common to all Lower Columbia River salmon and steelhead populations (see Table 7-3A of ODFW 2010) and actions that apply to a single ESU or run component at multiple locations.

The Oregon management unit plan recommends that priority be given to recovery actions that do the following:

- Benefit populations that must achieve high persistence probability
- Address a key limiting factor or large conservation gap
- Will protect or result in accessible and connected high-quality habitat
- Are in locations with high intrinsic potential[7]
- Protect threatened high-quality or highly productive habitat
- Provide resiliency against climate change

In addition, Oregon recovery planners suggested funding strategies and recommended quick action for populations targeted for high persistence probability, especially in the case of tributary habitat actions (ODFW 2010).

5.7.2 Washington Approach to Developing Recovery Strategies and Actions

Washington recovery planners developed an integrated regional strategy for recovery, a series of threat-specific strategies and measures, and corresponding working hypotheses regarding the facts and assumptions that the strategies and measures are based on. Measures provide initial recovery guidance. Some apply generally to most Lower Columbia River ESUs; others apply to a single species. Measures are categorized based on whether they are existing or new activities and whether they provide primarily protection or restoration benefits (LCFRB 2010a).

To develop the regional strategies and measures, Lower Columbia Fish Recovery Board staff conducted meetings and workshops attended by representatives from affected entities and implementing agencies. The strategies and measures are based on a combination of expected biological results and economic, political, social, and cultural considerations, with the expectation that they will be refined during implementation.

Habitat protection and restoration actions targeted to specific stream reaches are identified in a series of subbasin chapters that constitute Volume II of the Washington

[7] Analyses based on the relationship between certain landscape features (e.g., channel gradients or geology) and species' habitat preferences can form the basis of a consistent approach to evaluating habitat potential to support a particular species. These analyses can inform species conservation and habitat restoration activities. Intrinsic potential models use geospatial data to identify stream reaches with high, low, or no potential to host a particular species. The models rate habitat potential at the level of a stream reach but provide a method for estimating habitat quantity and quality across local or regional scales.

management unit plan (LCFRB 2010a). Washington recovery planners prioritized these actions based on subbasin and stream reach fish production values and habitat limiting factors in all current and historical anadromous production areas. This prioritization considered the needs of the multiple populations within each subbasin. Geographically specific management actions for tributary habitat were developed using EDT and a geographical information system (GIS)-based tool known as the Integrated Watershed Assessment (IWA), which is used to assess stream habitat conditions and watershed process impairments at the subwatershed scale (3,000 to 12,000 acres). For further descriptions of the EDT and IWA analyses, see Chapter 7 and Appendix E of LCFRB (2010a).

5.7.3 White Salmon Approach to Developing Recovery Strategies and Actions

Recovery strategies and actions in the White Salmon management unit plan fall into two categories: (1) those aimed at reintroducing naturally produced salmon and steelhead into historical habitat after the removal of Condit Dam and (2) those aimed at improving and increasing freshwater habitat for salmon and steelhead production in key reaches (NMFS 2013). Actions for reintroduction were developed by the White Salmon Working Group, which consisted of federal, state, and tribal fisheries managers and representatives of PacifiCorp (the operator of Condit Dam). For each ESU, the group developed and evaluated a number of reintroduction options and proposed one for implementation. Options are described in more detail in Section 6.1 and Appendix 1 of the White Salmon management unit plan (NMFS 2013).

As part of the White Salmon recovery planning process, NMFS worked with the White Salmon Working Group to review and analyze available information and define freshwater habitat strategies, actions, and priority reaches (NMFS 2013). The habitat strategies and actions include gathering additional information to use in prioritizing actions, protecting existing ecological processes and functioning habitats, restoring vegetation along stream reaches that exceed state standards for water temperature, restoring habitat in the reservoir footprint now that Condit Dam has been removed,[8] and improving habitat in upriver reaches in preparation for the time when reintroduced populations exceed the carrying capacity of the existing habitat.

The White Salmon management unit plan also briefly discusses hatchery, harvest, and hydropower-related strategies and actions (NMFS 2013).

5.8 Analysis of Actions

A question relevant to recovery planning is the level of effort that will be required to close the gap between baseline and target population status, and whether the actions identified in the recovery plan are sufficient to attain target status for each population. Because any analysis of such questions involves significant uncertainty, it is essential for any recovery plan to link hypotheses regarding level of effort and sufficiency of actions to rigorous research, monitoring, and adaptive management programs.

---

[8] Condit Dam was breached in October 2011 and completely removed in September 2012.

Management unit recovery planners addressed the question of the level of effort needed to close conservation gaps by identifying threat reduction targets in each major threat category. They addressed the question regarding sufficiency of actions through varying levels of analysis, depending on threat category, and by taking what the Washington management unit plan termed a "directional approach." The directional approach is based on the hypotheses that (1) the set of actions in this plan is sufficient to establish a trajectory toward recovery, (2) mechanistic analyses of the effects of actions are too uncertain to provide adequate confidence that any initial set of actions will be sufficient, and (3) modifications and refinements will be made as necessary within an adaptive management framework.

As described in the sections above, Oregon and Washington management unit planners did the following:

1. Quantified the abundance and productivity improvements—and in some cases the spatial structure and diversity improvements—needed for each population to move from its baseline persistence probability to its target persistence probability.

2. Quantified the baseline impact on population abundance and productivity for each of six major threat categories.

3. Quantified the amount by which each major threat impact would need to be reduced to close the gap between baseline and target status for each population.

4. Identified strategies and actions in each threat category that are intended to reduce the impact of each threat and improve abundance and productivity by the amount consistent with the target for each population.

Although the management unit planners hypothesized that actions would be sufficient to achieve the targeted threat reductions, the level of analysis carried out to confirm this varied by plan and by threat category. The different approaches in the Washington and Oregon management unit plans make it difficult to generalize; however, in general, the plans provide relatively detailed quantitative documentation for the expected benefits of harvest and hydropower actions. The potential benefits of hatchery, tributary habitat, and estuary habitat actions are assessed systematically but rely more heavily on extrapolations and general assumptions. In some cases, analysis of the sufficiency of actions in the management unit plans is based on professional judgment.

In addition, as part of developing recovery action cost estimates for habitat actions, Washington and Oregon management unit planners developed rough estimates of the number of stream miles that would need to be restored to achieve the habitat improvements targeted in the plans. (In Washington, estimates were for the number of stream miles that would need to be restored in each subbasin, while in Oregon the estimates were species-specific at the population scale; in both cases these estimates were rough and based on multiple assumptions.)

The management unit plans also incorporated monitoring and evaluation programs and an adaptive management framework for implementation to allow us to evaluate whether we are on course and to adjust as needed. This basic approach is useful in understanding the scale of actions that need to be implemented and in laying the groundwork for understanding and evaluating whether the actions have been effective.

The Washington management unit plan incorporates explicit interim benchmarks, defined as "reference points for planning and evaluating recovery progress over the duration of plan implementation," for action implementation, action effectiveness, and status improvements (see LCFRB 2010a, Section 6.1). The interim benchmarks provided in the Washington management unit plan reflect the incremental implementation strategies described in the plan and explicitly recognize the range in expected response times associated with different actions (e.g., adjustments to harvest rates versus restoring riparian habitats). The interim benchmarks are at 12-year intervals, corresponding to the adaptive management schedule called for in the plan (see LCFRB 2010a, Chapter 10).

The Oregon management unit plan (ODFW 2010) recognizes the importance of periodic assessments of plan performance, although it does not explicitly establish benchmarks equivalent to those in the Washington management unit plan. The adaptive management section of the Oregon management unit plan identifies the need for specific reviews of population status and plan performance at 5-year intervals and recognizes that such reviews would serve as the basis for considering major revisions to the plan on a 12-year cycle (see ODFW 2010, Chapter 9). Although the Oregon management unit plan does not include specific benchmarks, it does provide some general guidance on the expected timing of particular actions (including high-priority research, monitoring, and evaluation efforts) (see ODFW 2010, Section 9.3). This guidance includes specific time frames for full implementation of individual actions (see Table 9-3) and some general guidance on assessing implementation progress for tributary habitat actions ("Note that if the quantity of restoration action indicated in Table 9-2 is divided by the implementation schedule for that action in Section 9.1.3, an annual rate of restoration can be calculated. This can be compared to reported restoration projects and progress toward these habitat recovery action goals can be tracked").

5.9 Research, Monitoring, and Evaluation

Strategic research, monitoring, and evaluation (RME) programs that are designed to inform key questions and critical uncertainties and to feed information into an adaptive management framework are key components of salmon and steelhead recovery plans. The management unit plans contain or will contain specific RME plans for their areas. (See Chapter 8 of ODFW 2010 and Chapter 9 of LCFRB 2010a.) These RME plans are based on regional guidance for adaptive management and RME and will guide recovery planning RME efforts and funding in their respective areas, within a context of ongoing regional guidance and coordination. Chapter 10 of this plan describes RME in more detail.

As Chapter 10 also describes, a number of regional entities, including NMFS, are involved in research, monitoring, and evaluation for salmon and steelhead recovery. One component of the RME system for recovery planning is the NMFS 5-year reviews, which are described briefly below because of their relevance to the baseline population status completed by the management unit planners. The NMFS 5-year reviews are discussed in more detail in Chapter 10.

5.10 NMFS 2011 5-Year Reviews

Because the management unit plans evaluated baseline status several years ago, when the plans were in development, it is reasonable to ask whether the status of any population has changed since those assessments. Under ESA section 4(c)(2)(B), NMFS is required to conduct a review of listed species at least once every 5 years. Based on such reviews, NMFS determines whether any species should be removed from the list (i.e., delisted) or reclassified from endangered to threatened or from threatened to endangered. During these reviews, NMFS considers the best scientific and commercial data available. In 2011, NMFS published a 5-year review covering the period 2005-2010 that included review of the four species addressed by this recovery plan (76 *Federal Register* 50448). In the 2011 5-year review, NMFS generally relied on information through 2008 or 2009. Evaluation methods and information on species' status will continue to evolve and be updated over time. NMFS' next 5-year review will provide updated summaries of species' status based on best available information.

For the 2011 review, the NMFS Northwest Fisheries Science Center collected and analyzed new information about ESU and DPS viability, using the viable salmonid population concept developed by McElhany et al. (2000) (Ford 2011). NMFS Northwest Region salmon management biologists also reviewed the status of the ESA section 4(a)(1) listing factors (NMFS 2011b).

The updated 5-year review indicates that, although a number of populations in each ESU or DPS have high or medium persistence probability, not a single stratum in any of the ESUs or DPS is currently viable. Multiple populations in each stratum of each ESU or DPS will need improved status to meet the recovery criteria. Although little improvement in ESU or DPS viability has been observed over the last 5 years, there is also no new information to indicate that the extinction risk has increased. In addition, NMFS' analysis of ESA section 4(a)(1) factors indicates that the collective risk to the persistence of the Lower Columbia River Chinook, coho, and steelhead and Columbia River chum has not changed significantly since NMFS' final listing determination in 2006. The 2011 review emphasizes the importance of continuing to implement recovery actions that address the factors limiting population viability, as well as the importance of monitoring the effects of the actions over time.

6. Lower Columbia River Coho Salmon

6.1 Coho Salmon Biological Background

6.1.1 Coho Salmon Life History and Habitat

Lower Columbia River coho salmon (*Oncorhynchus kisutch*) are typically categorized into early- and late-returning stocks. Early-returning (Type S) adult coho salmon enter the Columbia River in mid-August and begin entering tributaries in early September, with peak spawning from mid-October to early November. Late-returning (Type N) coho salmon pass through the lower Columbia from late September through December and enter tributaries from October through January. Most spawning occurs from November to January, but some occurs as late as March (see Figure 6-1) (LCFRB 2010a). Migration and spawning timing of specific local populations may be mediated by factors such as latitude, migration distance, flows, water temperature, maturity, or migration obstacles (ODFW 2010). For example, coho salmon spawning in warmer tributaries spawn later than those spawning in colder tributaries (LCFRB 2010a).

Historically, coho salmon spawned in almost every accessible stream system in the lower Columbia River (LCFRB 2010a). Coho salmon generally occupy intermediate positions in tributaries, typically further upstream than chum or fall-run Chinook, but often downstream of steelhead or spring-run Chinook (ODFW 2010). Early-run fish usually spawn farther upstream within a basin than late-run fish. Coho salmon typically spawn in small to medium, low- to-moderate elevation streams from valley bottoms to stream headwaters. Coho salmon particularly favor small, rain-driven, lower elevation streams characterized by relatively low flows during late summer and early fall, and increased river flows and decreased water temperatures in winter (LCFRB 2010a). On their return, adult fish often mill near the river mouths or in lower river pools until the first fall freshets occur (LCFRB 2010a).

Coho salmon construct redds in gravel and small cobble substrate in pool tailouts, riffles, and glides, with sufficient flow depth for spawning activity (NMFS 2013). Eggs incubate over late fall and winter for about 45 to 140 days, depending on water temperature, with longer incubation in colder water. Fry may thus emerge from early spring to early summer (ODFW 2010). Hatching success depends on clean gravel that is not choked with sediment or subject to extensive scouring by floods (LCFRB 2010a).

Juveniles typically rear in freshwater for more than a year. After emergence, coho salmon fry move to shallow, low-velocity rearing areas, primarily along the stream edges and inside channels. Juvenile coho salmon favor pool habitat and often congregate in quiet backwaters, side channels, and small creeks with riparian cover and woody debris. Side-channel rearing areas are particularly critical for overwinter survival, which is a key regulator of freshwater productivity (LCFRB 2010a).

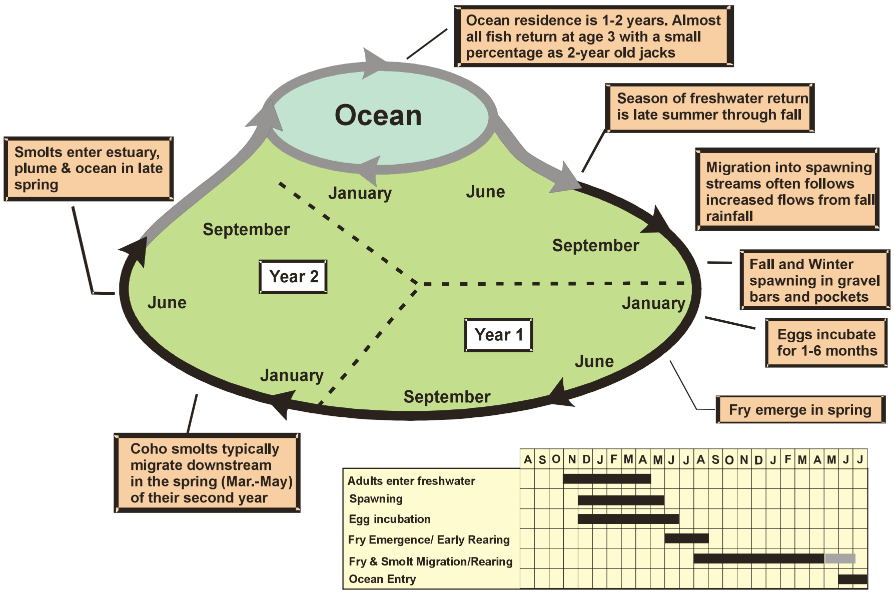

Figure 6-1. *Life Cycle of Lower Columbia River Coho Salmon*
(Source: LCFRB 2010a)

The key freshwater habitat needs of Lower Columbia River coho salmon at different life stages are shown in Table 6-1.

Table 6-1
Key Habitat for Coho Salmon, by Life Stage

Life Stage	Key Habitat Descriptions
Spawning	Riffles, tailouts, and the swifter areas in glides containing a mixture of gravel and cobble sizes with flow of sufficient depth for spawning activity
Incubation	As for spawning, but with sufficient flow for egg and alevin development and protection from high flow scour
Fry Colonization	Shallow, slow-velocity areas within the stream channel, including backwater areas, often associated with stream margins and back eddies and usually in relatively low-gradient reaches
Active Rearing	Relatively slow-water habitat types, often near velocity shears, often associated with relatively low-gradient stream channel reaches, including primary pools, backwaters, tailouts, glides, and beaver ponds
Inactive Rearing	Non-turbulent habitat types, particularly deeper water types within the main channel, but also including slower portions of large cobble riffles
Migrant	All habitat types having sufficient flow for free movement of juvenile migrants and adequate structure for protection from predators
Pre-Spawning Migrant	All habitat types having sufficient flow for free movement of sexually mature adult migrants
Pre-Spawning Holding	Relatively slow, deep-water habitat types typically associated with (or immediately adjacent to) the main channel

Source: Adapted from Northwest Power and Conservation Council (2004b) and McElhany (2010).

Most juvenile coho salmon migrate seaward as smolts in April to June, typically during their second year. Salmon that have stream-type life histories, such as coho, typically do not linger for extended periods in the Columbia River estuary, but the estuary is a critical habitat used for feeding during the physiological adjustment to salt water. Juvenile coho salmon are present in the Columbia River estuary from March to August (LCFRB 2010a).

Columbia River coho salmon typically range throughout the nearshore ocean over the continental shelf off of the Oregon and Washington coasts. Early-returning (Type S) coho salmon are typically found in ocean waters south of the Columbia River mouth. Late-returning (Type N) coho salmon are typically found in ocean waters north of the Columbia River mouth (LCFRB 2010a). Coho salmon grow relatively quickly in the ocean, reaching up to 6 kilograms after about 16 months of ocean rearing (ODFW 2010). Most coho salmon sexually mature at age three, except for a small percentage of males (called "jacks") who return to natal waters at age two, after only 5 to 7 months in the ocean (LCFRB 2010a). All coho salmon die after spawning. Weather-related upwelling patterns in the ocean and the short 3-year life cycle of this species cause highly variable population cycles (LCFRB 2010a).

6.1.2 Historical Distribution and Population Structure of LCR Coho Salmon

The Lower Columbia River coho salmon ESU historically consisted of a total of 24 independent populations (see Table 6-2). Because NMFS had not yet listed the ESU in 2003 when the WLC TRT designated core and genetic legacy populations for other ESUs, there are no such designations for Lower Columbia River coho salmon. However, the Clackamas and Sandy subbasins contain the only populations in the ESU that have clear records of continuous natural spawning (McElhany et al. 2007). Figure 6-2 shows the historical geographical distribution of Lower Columbia River coho salmon strata and populations.[1]

[1] Willamette Falls, on the Willamette River at Oregon City, Oregon, marked the historical upstream extent of coho salmon in the Willamette River. Coho salmon now spawn above Willamette Falls because a fish ladder constructed there in the late-nineteenth century allows them to pass the falls in low flow conditions that would have prevented their passage historically and because hatchery coho salmon were introduced above the falls. In its 2005 listing decision, NMFS noted that coho salmon spawning above Willamette Falls were not considered part of the Lower Columbia River coho ESU (70 *Federal Register* 37160).

Table 6-2
Historical LCR Coho Salmon Populations

Stratum	Historical Populations	Early or Late Stock*
Coast	Youngs Bay (OR)	Late
	Grays/Chinook (WA)	Late
	Big Creek (OR)	Late
	Elochoman/Skamokawa (WA)	Late
	Clatskanie (OR)	Late
	Mill/Abernathy/Germany (WA)	Late
	Scappoose (OR)	Late
Cascade	Lower Cowlitz (WA)	Late
	Upper Cowlitz (WA)	Early, late
	Cispus (WA)	Early, late
	Tilton (WA)	Early, late
	SF Toutle (WA)	Early, late
	NF Toutle NF (WA)	Early, late
	Coweeman (WA)	Late
	Kalama (WA)	Late
	NF Lewis (WA)	Early, late
	EF Lewis (WA)	Early, late
	Salmon Creek (WA)	Late
	Clackamas (OR)	Early, late
	Sandy (OR)	Early, late
	Washougal (WA)	Late
Gorge	Lower Gorge (WA & OR)	Late
	Upper Gorge/White Salmon (WA)	Late
	Upper Gorge/Hood (OR)	Early

* This represents the WLC TRT's understanding of the historical run timing for Lower Columbia River coho salmon (i.e., 10 early stocks and 23 late stocks).

Source: Myers et al. (2006).

Up through 2008, 25 artificial propagation programs produced coho salmon considered to be part of this ESU. In 2009, the Elochoman Type-S and Type-N programs were discontinued. In 2011, NMFS recommended that these two programs be removed from the ESU (76 *Federal Register* 50448, Jones 2011). Table 6-3 shows the 23 coho salmon hatchery programs that currently are included in the ESU. For a list of coho salmon hatchery programs not included in the ESU, see Jones (2011).

Table 6-3
*Artificial Propagation Programs Included in the LCR Coho Salmon ESU**

Washington Programs	Oregon Programs
Grays River	Big Creek Hatchery
Sea Resources Hatchery	Astoria High School (STEP)
Peterson Project	Warrenton High School (STEP)
Cathlamet High School FFA Type N	Eagle Creek National Fish Hatchery
Cowlitz Type N - Upper Cowlitz	Sandy Hatchery
Cowlitz Type N -Lower Cowlitz	Bonneville/Cascade/Oxbow complex
Cowlitz Game and Anglers Program	
Friends of the Cowlitz Program	
North Fork Toutle River Hatchery	
Kalama River Type S	
Kalama River Type N	
Lewis River Type S	
Lewis River Type N	
Washougal Type N	
Fish First Wild Coho Salmon	
Fish First Type N	
Syverson Project Type N	

* Hatchery programs that are listed as Type S or Type N in this table but that do not correspond to the run timings in Table 6-2 likely will be reevaluated for inclusion/exclusion in the ESU at some point in the future.
Source: 70 *Federal Register* 37178, 76 *Federal Register* 50448, and Jones (2011).

6.2 Baseline Population Status of LCR Coho Salmon

Out of the 24 populations that make up this ESU, 21 are considered to have a very low probability of persisting for the next 100 years (see Figure 6-2), and none is considered viable (LCFRB 2010a, ODFW 2010, Ford 2011).[2] All three strata in the ESU fall significantly short of the WLC TRT criteria for viability.

The very low persistence probability for most Lower Columbia River coho salmon populations is related to low abundance and productivity, loss of spatial structure, and reduced diversity. Although poor data quality prevents precise quantification, most populations are believed to have very low abundance of natural-origin spawners (50 fish or fewer, compared to historical abundances of thousands or tens of thousands); data

[2] As described in Section 2.6, the WLC TRT recommended methods for evaluating the status of Lower Columbia River salmon and steelhead populations. The TRT approach is based on evaluating the population parameters of abundance, productivity, spatial structure, and diversity and then integrating those assessments into an overall assessment of population persistence probability. As also described in Section 5.1, management unit recovery planners evaluated their respective populations' baseline status in a manner generally consistent with the WLC TRT's approach, with the baseline period being circa 1999 (for Washington populations) or 2006-2008 (for Oregon populations). Unless otherwise noted, NMFS and the management unit planners believe that those assessments accurately reflect the status of the population at that time; the assessments are the basis for the summaries presented here and are consistent with the conclusions of the Northwest Fisheries Science Center in its *Status Review Update for Pacific Salmon and Steelhead Listed under the Endangered Species Act* (Ford 2011). New information on population status will continue to accumulate over time and will be taken into account as needed to reflect the best available science regarding a population's status.

quality has been poor because of inadequate spawning surveys and, until recently, the presence of unmarked hatchery-origin spawners. [3] The spatial structure of some populations is constrained by migration barriers (such as tributary dams) and development in lowland areas. Low abundance, past stock transfers, other legacy hatchery effects, and ongoing hatchery straying may have reduced genetic diversity within and among coho salmon populations (LCFRB 2010a, ODFW 2010). It is likely that hatchery effects have also decreased population productivity.

Only in the Clackamas and Sandy subbasins is there a clear record of continuous natural spawning from the 1990s to the present. Spawner abundance for both these populations is, however, still well below long-term minimum abundance thresholds, although there was a generally positive trend from the 1990s through 2005 (Ford 2011). More recent spawning surveys indicate short-term increases in natural production in the Clatskanie, Scappoose, and Mill/Abernathy/Germany populations (ODFW 2010, Ford 2011). Although McElhany et al. (2007) and ODFW (2010) reached the same conclusions about the persistence probability of most Oregon coho salmon populations, conclusions for three Oregon populations (the Scappoose, Clackamas, and Sandy) did change as a result of considering additional years of data and adjusting the risk models used by Oregon in the assessments (ODFW 2010).[4]

The generally poor baseline population status of coho salmon reflects long-term trends: natural-origin coho salmon in the Columbia Basin have been in decline for the last 50 years (ODFW 2010).[5] For additional discussion of Lower Columbia River coho salmon population status, see the management unit plans (LCFRB 2010a, pp. 6-44 through 6-47; ODFW 2010, Chapter 4; and NMFS 2013, p. 4-2) and Ford (2011).

---

[3] Since 1997, all Lower Columbia River hatchery coho salmon have been marked, and both Oregon and Washington have begun efforts to identify and address data gaps for coho salmon. Unmarked, out-of-ESU coho salmon released in the Klickitat subbasin may stray into the Hood subbasin; these fish are expected to be marked in the near future.

[4] It is particularly notable that the Sandy coho salmon population was assigned a higher risk rating for abundance and productivity in the ODFW (2010) assessment than in the McElhany et al. (2007) assessment; however, although the abundance and productivity risk category changed, the relative gap between current abundance and target abundance did not change appreciatively.

[5] Coho populations upstream of Hood River have been extirpated (ODFW 2010).

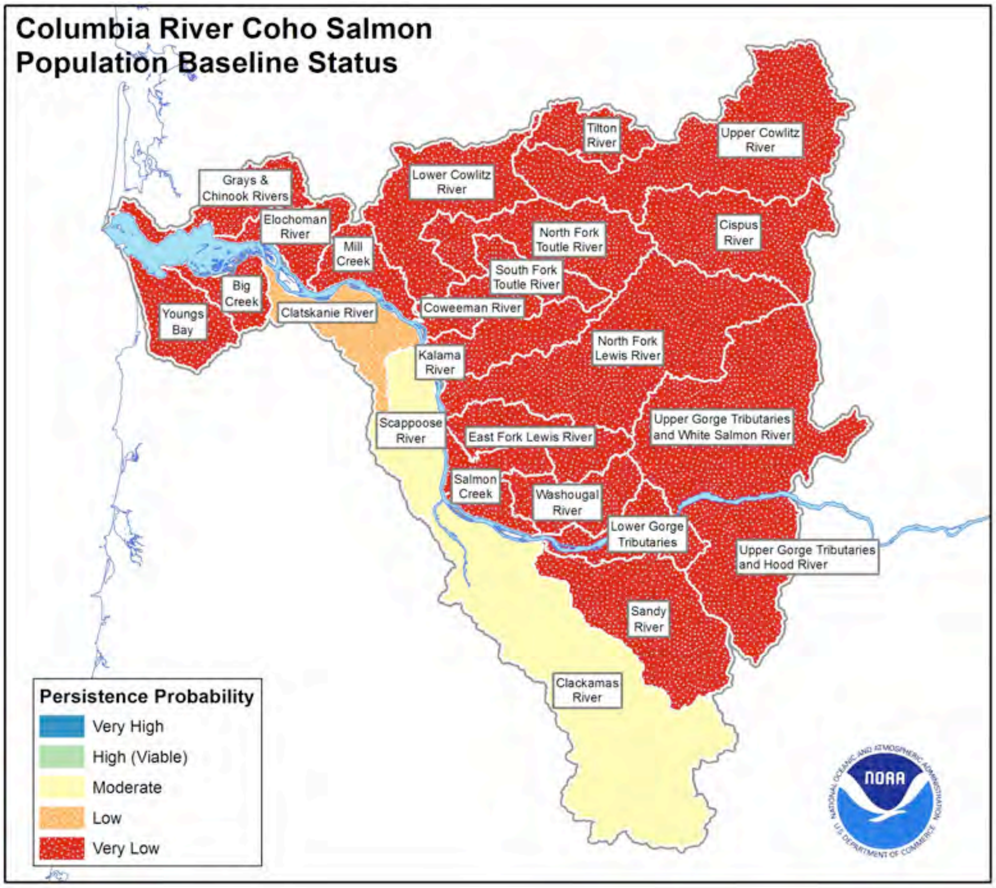

Figure 6-2. *Baseline Status of Historical LCR Coho Salmon Populations*

6.3 Target Status and Conservation Gaps for Coho Salmon Populations

Table 6-4 shows the baseline and target status for each Lower Columbia River coho salmon population, along with historical and target abundance. Local recovery planners coordinated with NMFS in making decisions about the target status for each population, taking into consideration opportunities for improvement in view of historical production, current habitat conditions and potential, and the desire to accommodate objectives such as maintaining harvest opportunities. (Note: the target statuses in Table 6-4 are the same as the persistence probabilities in the recovery scenario presented in Table 3-1 in Section 3.1.3.) As described in Section 5.1.4, although Oregon and Washington recovery planners used somewhat different methodologies to estimate baseline status and target abundance and productivity, NMFS and the management unit planners agree that the methodologies led to similar conclusions regarding the very low baseline status for most Lower Columbia River coho salmon populations.

Very large improvements are needed in the persistence probability of most coho salmon populations if the ESU is to achieve recovery. For example, 16 of the 24 historical populations are targeted for high or very high persistence probability. Of these, 14 have a low or very low baseline persistence probability. Some level of recovery effort will be needed for every population—even stabilizing populations that are expected to remain at their baseline status—to arrest or reverse long-tem declining trends. For most populations, meeting recovery objectives will require improvement in all VSP parameters: abundance, productivity, diversity, and spatial structure.

In the Coast stratum, four of seven populations are targeted for high or very high persistence probability. Two populations—Youngs Bay and Big Creek—are not targeted for improvements in their baseline persistence probability of very low. This decision represents a strategic choice to provide harvest opportunity through terminal fisheries targeting hatchery fish in these subbasins; consequently, the proportion of hatchery-origin spawners (pHOS) in these two populations is expected to remain high.

Of fourteen populations in the Cascade stratum, nine are targeted for high or very high persistence probability. The Kalama and Washougal populations are designated as contributing, in part so that fishery enhancement hatchery programs in those subbasins can continue to support harvest. The North Fork Lewis population is designated as contributing in part because of uncertainties regarding the success of reestablishing natural production above tributary dams. Two populations—Salmon Creek and the Tilton—are not targeted for improvements in their baseline persistence probability of very low. The Salmon Creek subbasin is highly urbanized. In the Tilton subbasin, habitat is of lower quality than in the Upper Cowlitz and Cispus subbasins.

All three of the Gorge stratum populations are targeted to move from very low to high persistence probability. However, the Oregon management unit plan notes that the feasibility of meeting abundance and productivity targets for the Upper Gorge/Hood River population (see Table 6-4) is very low. Challenges include the small amount of historical and current habitat (and thus the limited options for restoration); anthropogenic impacts that are unlikely to change in the near future (e.g., inundation of historical spawning habitat by Bonneville Reservoir and roads that restrict access to habitat); high uncertainty in the data and analyses for small populations[6]; and the possibly inaccurate designation of population structure for this stratum. The Oregon management unit plan states that most of these issues are related to the population structure designation and suggests re-evaluating the Gorge stratum population structure for all species (ODFW 2010). As discussed in Section 3.2.1, NMFS agrees that such an evaluation is needed.

If the scenario in Table 6-4 were achieved, it would exceed the WLC TRT's viability criteria, particularly in the Cascade stratum.[7] Exceeding the criteria in the Cascade stratum was intentional on the part of local recovery planners to compensate for uncertainties about the feasibility of meeting the WLC TRT's criteria in the Gorge stratum, in particular the questions raised by Oregon recovery planners about the

---

[6] In the method used by the WLC TRT and management unit planners to establish abundance goals, target abundance is based to some extent on the gap between current and historical abundance. If the historical abundance of the Upper Gorge/Hood coho population has been significantly overestimated, then the abundance needed to achieve its target status may also be overestimated (ODFW 2010).

[7] As discussed in Section 2.5.4, the TRT's criteria for high probability of stratum persistence require that two or more populations be viable and that, using the WLC TRT's scoring system, the average score for all populations in the stratum be 2.25 or higher. In the Cascade stratum, nine populations are targeted for high or very high persistence probability, and, using the WLC TRT's scoring system, the average score for all populations in the stratum would be 2.39.

feasibility of meeting the target status for the Upper Gorge/Hood population. (Delisting criteria for the Lower Columbia River coho ESU are described in Sections 3.2 and 6.7)

Figure 6-3 displays the population-level conservation gaps for Lower Columbia River coho salmon graphically. The conservation gap reflects the magnitude of improvement needed to move a population from its baseline status to the target status. For additional discussion of targets and conservation gaps for Lower Columbia River coho salmon populations, see the management unit plans (LCFRB 2010a, pp. 6-44 to 6-48; ODFW 2010, pp. 148, 169 to 177; and NMFS 2013, p. 3-12).

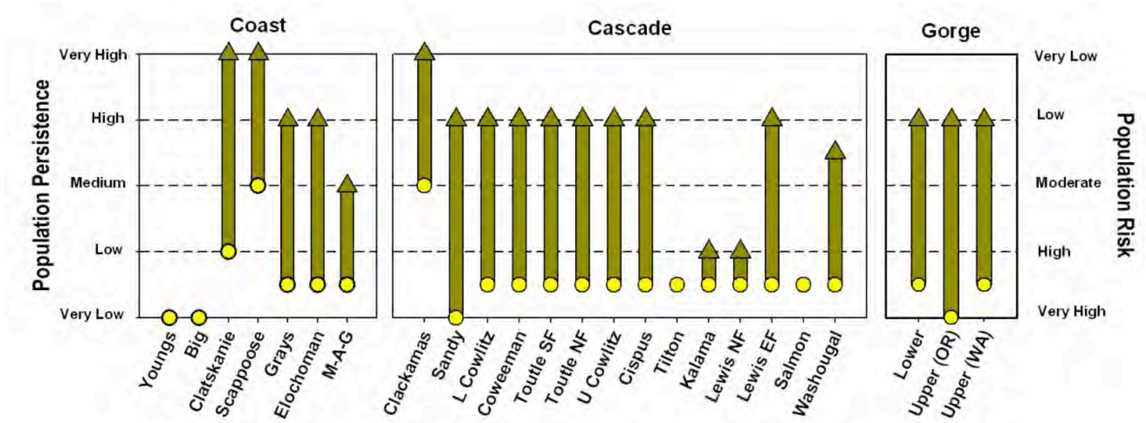

Figure 6-3. *Conservation Gaps for LCR Coho Salmon Populations: Difference between Baseline and Target Status*

Source: LCFRB 2010a.

Table 6-4

Baseline and Target Persistence Probability and Abundance of LCR Coho Salmon Populations

			Baseline Persistence Probability[8]					Abundance		
Stratum	**Population**	**Contribution**	**A&P**	**S**	**D**	**Net**	**Target Persistence Probability**	**Historical**	**Baseline[9]**	**Target**
Coast	Youngs Bay (OR)	Stabilizing	VL	VH	VL	VL	VL	18,588	4	7
	Grays/Chinook (WA)	Primary	VL	H	VL	VL	H	3,800	< 50	2,400
	Big Creek (OR)	Stabilizing	VL	H	L	VL	VL	10,830	8	12
	Elochoman/Skamokawa (WA)	Primary	VL	H	VL	VL	H	6,500	< 50	2,400
	Clatskanie (OR)	Primary	L	VH	M	L	VH	16,781	1,363	3,201
	Mill/Abernathy/Germany (WA)	Contributing	VL	H	L	VL	M	2,800	< 50	1,800
	Scappoose (OR)	Primary	M	H	M	M	VH	22,164	1,942	3,208
Cascade	Lower Cowlitz (WA)	Primary	VL	M	M	VL	H	18,000	500	3,700
	Upper Cowlitz (WA)	Primary	VL	M	L	VL	H	18,000	< 50	2,000
	Cispus (WA)	Primary	VL	M	L	VL	H	8,000	< 50	2,000
	Tilton (WA)	Stabilizing	VL	M	L	VL	VL	5,600	< 50	--
	SF Toutle (WA)	Primary	VL	H	M	VL	H	27,000	< 50	1,900
	NF Toutle (WA)	Primary	VL	M	L	VL	H		< 50	1,900
	Coweeman (WA)	Primary	VL	H	M	VL	H	5,000	< 50	1,200
	Kalama (WA)	Contributing	VL	H	L	VL	L	800	< 50	500
	NF Lewis (WA)	Contributing	VL	L	L	VL	L	40,000	200	500
	EF Lewis (WA)	Primary	VL	H	M	VL	H	3,000	< 50	2,000
	Salmon Creek (WA)	Stabilizing	VL	M	VL	VL	VL	-- [10]	< 50	--

[8] A&P = Abundance and productivity, S = spatial structure, and D = genetic and life history diversity. Net = overall persistence probability of the population. VL = very low, L = low, M = moderate, H = high, VH = very high.
[9] Baseline abundance was estimated as described in Section 5.1 and does not equal observed natural-origin spawner counts. The baseline is a modeled abundance that represents 100-year forward projections under conditions representative of a recent baseline period using a population viability analysis that is functionally equivalent to the risk analyses in McElhany et al. (2007). Projections generally assume conditions similar to those from 1974 to 2004. Oregon numbers reflect fishery reductions between the 1990s and about 2004, while Washington numbers reflect fishery impacts prevalent circa 1999.
[10] " – " indicates that no data are available from which to make a quantitative assessment.

Table 6-4

Baseline and Target Persistence Probability and Abundance of LCR Coho Salmon Populations

			Baseline Persistence Probability[8]					Abundance		
Stratum	**Population**	**Contribution**	**A&P**	**S**	**D**	**Net**	**Target Persistence Probability**	**Historical**	**Baseline[9]**	**Target**
	Clackamas (OR)	Primary	M	VH	H	M	VH	52,565	6,548	11,232
	Sandy (OR)	Primary	VL	H	M	VL	H	19,647	1,622	5,685
	Washougal (WA)	Contributing	VL	H	L	VL	M+	3,000	< 50	1,500
Gorge	Lower Gorge (WA & OR)	Primary	VL	M	VL	VL	H	--	< 50	1,900
	Upper Gorge/White Salmon (WA)	Primary	VL	M	VL	VL	H	--	< 50	1,900
	Upper Gorge/Hood (OR)	Primary	VL	VH	L	VL	H*	8,846	41	5,162

*Oregon's analysis indicates a low probability of meeting the delisting objective of high persistence probability for this population.

Source: LCFRB (2010a) and ODFW (2010).

6.4 Limiting Factors and Threats for LCR Coho Salmon

Lower Columbia River coho salmon have been—and continue to be—affected by habitat degradation, hydropower impacts, harvest, and hatchery production. The combined effects of these factors have reduced the persistence probability of all Lower Columbia River coho salmon populations.

Table 6-5 and the text that follows summarize baseline limiting factors and threats for Lower Columbia River coho salmon strata based on population-specific limiting factors and threats identified in the management unit plans. In cases where conditions have changed significantly since the management unit plans' analyses of limiting factors and threats (e.g., if harvest rates have dropped or a dam is no longer present), this is noted in the text. Unless otherwise noted, NMFS agrees that the management unit plans' identification of limiting factors provide a credible hypothesis for understanding population performance and identifying management actions.

Because the individual management unit plans used somewhat different terms in identifying limiting factors, NMFS has translated those terms into standardized and more general terminology taken from a NMFS "data dictionary" of possible ecological concerns that could affect salmon and steelhead (Hamm 2012; see Section 5.4). In addition, in Table 6-5 NMFS has rolled up the population-specific limiting factors (see Appendix H) to the stratum level—a process that has resulted in some loss of specificity.

In addition, each management unit plan used a different approach for identifying limiting factors and threats (see Section 5.3). One difference relevant to the crosswalk is that while the Oregon management unit plan identified primary and secondary limiting factors for each population in each threat category,[11] the Washington management unit plan categorized limiting factors in this way only for habitat-related limiting factors, and the White Salmon plan and the estuary module did not use the primary and secondary terminology. For the crosswalk and this table, NMFS assigned primary and secondary status to non-habitat limiting factors for Washington populations (based on the Washington management unit plan's quantification of threat impacts and the professional judgment of the Lower Columbia Fish Recovery Board's staff and consultants). For populations that historically spawned in the White Salmon subbasin, NMFS staff inferred primary and secondary designations based on discussion in the Washington and White Salmon management unit plans (LCFRB 2010a, NMFS 2013). It is likely that some apparent distinctions in results between Washington and Oregon populations are artifacts of differences in limiting factor assessment methodologies and not an actual difference in conditions or their effects on salmon and steelhead populations. In addition, there is not necessarily a bright line between primary and secondary limiting factor designations. Nevertheless, NMFS believes that the designations are useful, particularly for looking across ESUs and populations and identifying patterns (see Chapter 4).

The management unit plans provide more detail on limiting factors and threats affecting

[11] In the Oregon management unit plan, primary limiting factors are those that have the greatest impact and secondary limiting factors have a lesser but still significant impact.

each Lower Columbia River coho salmon population, including magnitude, spatial scale, and relative impact (see LCFRB 2010a, Chapter 3 and various sections of Volume II; ODFW 2010, pp. 102-115; and NMFS 2013, Chapter 5). For a regional perspective on limiting factors and threats that affect multiple salmon and steelhead ESUs, see Chapter 4 of this recovery plan. For a description of the data dictionary, the approach NMFS used to correlate management unit terms for limiting factors with the standardized NMFS terminology at the population scale, and the approach for rolling up from the population to the stratum scale, see Section 5.4 and Appendix H.

Management unit recovery planners in Oregon and Washington recognized that six major categories of manageable threats—tributary habitat, estuary habitat, hydropower, harvest, hatcheries, and predation—were useful as an organizing construct for grouping limiting factors, quantifying impacts on population productivity, and determining how much different categories of threats would need to be reduced to close the gap between baseline and target population status. Planners in both Washington and Oregon quantified the impacts of each of these major threat categories on population status, along with a reduction in each impact that would be consistent with achieving population target status. The results of that analysis are presented in Section 6.5 and provide a related but slightly different perspective on limiting factors. The threat reduction targets also allow actions to be scaled to achieve a specific impact reduction, and to be linked to monitoring and performance benchmarks.

Table 6-5

Baseline Limiting Factors and Threats Affecting LCR Coho Salmon: Stratum-Level Summary

Ecological Concern	Threat(s)	VSP Parameters Affected	Coast	Cascade	Gorge
Tributary Habitat Limiting Factors					
Habitat Quantity	Small dam (irrigation)	All			Secondary for Upper Gorge/Hood adults
Riparian Condition	Past and/or current land use practices	All	Primary for juveniles in all populations		
Channel Structure and Form	Past and/or current land use practices/ transportation corridor	All	Primary for juveniles in all populations		
Peripheral and Transitional Habitats: Side Channel and Wetland Conditions	Past and/or current land use practices/ transportation corridor	All	Primary for juveniles in all populations		
Peripheral and Transitional Habitats: Floodplain Conditions	Past and/or current land use practices/ transportation corridor	All	Primary for juveniles in all populations		

Table 6-5

Baseline Limiting Factors and Threats Affecting LCR Coho Salmon: Stratum-Level Summary

Ecological Concern	Threat(s)	VSP Parameters Affected	Coast	Cascade	Gorge
Sediment Conditions	Past and/or current land use practices/ transportation corridor	All	Primary for WA juveniles; secondary for OR juveniles[12]	Secondary for Clackamas, Sandy, Kalama, and Washougal juveniles; primary for juveniles in all other populations	Secondary for juveniles in all populations
Water Quality (Temperature)	Land uses that impair riparian function/decrease streamflow, dams	A,P,D	Secondary for juveniles in all populations		Secondary for Upper Gorge/White Salmon juveniles[13] and Upper Gorge/Hood juveniles
Water Quantity (Flow)	Dams, land use, irrigation, municipal, and hatchery withdrawals	All	Primary for Youngs Bay and Big Creek juveniles; secondary for juveniles in all other populations	Primary for Tilton, Kalama, and Washougal juveniles; secondary for juveniles in all other populations	Primary for Upper Gorge/Hood juveniles (irrigation withdrawals); secondary for juveniles in all other populations
Estuary Habitat Limiting Factors[14]					
Toxic Contaminants	Agricultural chemicals, urban and industrial practices	A,P,D	Secondary for juveniles in all populations		
Food[15]	Dam reservoirs	All	Secondary for juveniles in all populations		

[12] This distinction is likely an artifact of differences in limiting factor assessment methodologies between the two states and not an actual difference in sediment conditions in tributary streams or their effects on coho populations.

[13] For the Upper Gorge/White Salmon population, water temperature in the mainstem White Salmon River is at or near optimum levels for salmonids. Maximum temperature within the expected range of anadromous fish within the White Salmon subbasin meets Washington state water quality standards, with the exception of Rattlesnake Creek. Rattlesnake Creek is a significant habitat area where water temperature approaches lethal levels in some locations during some years (NMFS 2013).

[14] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the ESU, the estuarine limiting factors in this table and Section 6.4.2 reflect the determinations in the Oregon management unit plan, applied to all Lower Columbia River coho salmon populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

[15] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is

Table 6-5

Baseline Limiting Factors and Threats Affecting LCR Coho Salmon: Stratum-Level Summary

Ecological Concern	Threat(s)	VSP Parameters Affected	Coast	Cascade	Gorge
(Shift from macrodetrital- to microdetrital-based food web)					
Peripheral and Transitional Habitats: Estuary Condition	Past and/or current land use practices/transportation corridor, mainstem dams	All	Secondary for juveniles in all populations		
Channel Structure and Form	Past and/or current land use practices/ transportation corridor	All	Primary for juveniles in all populations		
Sediment Conditions	Past and/or current land use practices/transportation corridor, dams	All	Primary for juveniles in all populations		
Water Quality (Temperature)	Land uses that impair riparian function/decrease streamflow; dam reservoirs	A,P,D	Secondary for juveniles in all populations		
Water Quantity (Flow)	Columbia River mainstem dams	All	Primary for juveniles in all populations		
Hydropower Limiting Factors					
Habitat Quantity (Access)	Bonneville Dam	All			Secondary for Upper Gorge/White Salmon and Upper Gorge/Hood adults and juveniles
Habitat Quantity (Inundation)	Bonneville Dam	All			Secondary for Upper Gorge/Hood and Upper Gorge/White Salmon juveniles[16]
Habitat Quantity (Access)	Tributary Dams	All		Primary for Upper Cowlitz, North Fork Lewis, Cispus, and Tilton adults and juveniles; secondary for Clackamas juveniles	Primary for Upper Gorge/White Salmon adults and juveniles; secondary for Upper Gorge/Hood

unclear.

[16] The exact extent to which Bonneville Reservoir inundated habitats for any species is unknown. Some biologists have hypothesized impacts to coho salmon as a result of inundation. Based on spawning habitat preferences, it is likely that the impacts of inundation were greatest on fall Chinook and chum salmon.

Table 6-5
Baseline Limiting Factors and Threats Affecting LCR Coho Salmon: Stratum-Level Summary

Ecological Concern	Threat(s)	VSP Parameters Affected	Coast	Cascade	Gorge
					adults and juveniles
Harvest Limiting Factors					
Direct Mortality	Fisheries	A,D	Primary for adults in all populations		
Hatchery Limiting Factors					
Food[17]	Smolts from all Columbia Basin hatcheries competing for food and space in the estuary	All	Secondary for juveniles in all populations		
Population Diversity	Stray hatchery fish interbreeding with wild fish	A,P,D	Secondary for Clatskanie adults; primary for adults in all other populations except Scappoose	Secondary for Coweeman, Lewis(N&E), and Salmon Creek adults; primary for adults in all other populations except Sandy	Primary for adults in all populations
Predation Limiting Factors					
Direct Mortality	Land use	A,P,D	Secondary for juveniles in all populations		
Direct Mortality	Dams	A,P,D			Secondary for Upper Gorge/Hood and Upper Gorge/White Salmon adults

6.4.1 Tributary Habitat Limiting Factors

Impaired side channel and wetland conditions and degraded floodplain habitat have significant negative impacts on juvenile coho salmon throughout the ESU and are identified as primary limiting factors for all populations. Degraded riparian conditions also are a primary limiting factor for juveniles and adults of all populations within the ESU, as are channel structure and form issues. Extensive channelization, diking, wetland conversion, stream clearing, and, in some subbasins, gravel extraction have severed access to historically productive habitats, simplified many remaining tributary habitats, and weakened the watershed processes that once created healthy ecosystems. In

---

[17] Some scientists suspect that closely spaced releases of hatchery fish from all Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the estuary. NMFS (2011a) and LCFRB (2010a) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon and steelhead in freshwater, estuarine, and nearshore ocean habitats.

addition, the lack of large woody debris and appropriately sized gravel has significantly reduced the amount of suitable spawning and rearing habitat.

Sediment conditions (affecting egg to fry survival) are identified as a primary limiting factor for all Washington populations and a secondary limiting factor for the Oregon portion of the ESU.[18] The high density of forest and rural roads throughout the Lower Columbia subdomain leads to an abundance of fine sediment in tributary streams that covers spawning gravel and increases turbidity. Water quantity issues related to withdrawals or to land uses that alter hydrology have been identified as either primary or secondary for all coho salmon populations. In addition, water quality—specifically, elevated water temperature, generally brought about through land uses, lack of functional riparian habitat, and water withdrawals—is a secondary limiting factor for all populations except the Lower Gorge.[19]

In the Coast stratum, tributary habitat limiting factors are generally the same as those described for the ESU and are attributable largely to past and current land uses in Coast-stratum watersheds. Private and state forest land used for timber harvest predominates in the upper reaches of these watersheds, while lower reaches are mostly in agricultural and rural residential use and have been extensively modified by bank stabilization, levees, and tide gates. Water quantity issues related to withdrawals or to land uses that alter hydrology are identified as a primary limiting factor for winter parr in Youngs Bay and Big Creek and as secondary for all other Coast-stratum populations.

Habitat limiting factors in the Cascade stratum are generally the same as those described for the ESU. Altered hydrology and flow timing are identified as a primary limiting factor for the Tilton, Kalama, and Washougal populations and a secondary limiting factor for the other Cascade-stratum populations. Land uses that have led to these conditions include forest management and timber harvest, agriculture, urban and rural residential development, and gravel extraction. A mix of private, state, and federal forest land predominates in the upper mainstem and headwater tributaries of the Cascade subbasins, while the lower mainstem and tributary reaches of most subbasins are characterized by agricultural and rural residential land use, with some urban development, especially in the Salmon Creek and lower Clackamas subbasins. The Oregon management unit plan notes that in the Clackamas, high water temperatures are attributed in part to hydropower reservoirs.

A unique issue in the Cascade stratum is legacy effects in the Toutle subbasin of the 1980 Mount St. Helens eruption. The North Fork Toutle in particular was heavily affected by sedimentation from the eruption. A sediment retention structure was constructed on the North Fork Toutle in an attempt to prevent continued severe sedimentation of stream

[18] This distinction likely is an artifact of differences in limiting factor assessment methodologies between the two states and not an actual difference in sediment conditions in tributary streams or their effects on coho populations.

[19] For the Upper Gorge/White Salmon population, water temperature in the mainstem White Salmon River is at or near optimum levels for salmonids. Maximum temperature within the expected range of anadromous fish within the White Salmon subbasin meets Washington state water quality standards, with the exception of Rattlesnake Creek. Rattlesnake Creek is a significant habitat area where temperature approaches lethal levels in some locations during some years (NMFS 2013).

channels and associated flood conveyance, transportation, and habitat degradation problems. The structure currently blocks access to as many as 50 miles of habitat for anadromous fish. Although fish are transported around the structure via a trap and haul system, it remains a source of chronic fine sediment to the lower river; this reduces habitat quality and has interfered with fish collection at its base.

In the Gorge stratum, habitat limiting factors are generally the same as those described for the ESU and result largely from past and current land uses. A mix of private, state, and federal forest land predominates in the upper mainstem and headwater reaches of the Gorge subbasins, while the lower mainstem and tributary reaches are characterized by transportation and rural residential land uses, with some urban development. Water quantity issues caused by irrigation withdrawals are a primary limiting factor for the Upper Gorge/Hood population and a secondary limiting factor for the other populations. Highway and railroad transportation corridors run parallel to the Columbia River shoreline, traversing all creek drainages in ways that restrict access and disconnect upland and lowland habitat processes. For the Upper Gorge populations, inundation of historical habitat by Bonneville Reservoir also is a limiting factor.[20] In addition, Laurance Lake Dam, operated by the Middle Fork Irrigation District, blocks access to coho salmon habitat in the Hood subbasin and is identified as a secondary limiting factor.

Habitat within the White Salmon subbasin was altered by the removal of Condit Dam (breaching occurred in October 2011 and full removal in September 2012). Alterations include near-term negative effects from sediment release and scouring. Scientists and managers expect long-term positive effects as the result of restoration of natural flow regimes and sediment transport, but monitoring is needed to evaluate habitat and fish response to dam removal, and additional assessment of habitat limiting factors will be needed to refine understanding of limiting factors.

6.4.2 Estuary Habitat Limiting Factors[21]

As stream-type fish, coho salmon spend less time in the Columbia River estuary and plume than do ocean-type salmon such as fall Chinook, yet estuary habitat conditions nevertheless play an important role in the survival of coho salmon juveniles, particularly those displaying less dominant life history strategies. Water quantity issues related to altered hydrology and flow timing are identified as a primary limiting factor for all

[20] The exact extent to which Bonneville Reservoir inundated habitats for any species is unknown. Some biologists have hypothesized impacts to coho salmon as a result of inundation. Based on spawning habitat preferences, it is likely that the impacts of inundation were greatest on fall Chinook and chum salmon.
[21] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the ESU, the estuarine limiting factors in this section and in Table 6-5 reflect the determinations in the Oregon management unit plan, applied to all Lower Columbia River coho salmon populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

populations, as is impaired sediment and sand routing; these limiting factors are associated with hydroregulation at large storage reservoirs in the interior of the Columbia Basin, and, in the case of sediment issues, land uses both past and present. Much of the land surrounding the Columbia River estuary is in agricultural or rural residential use and has been extensively modified via dikes, levees, bank stabilization, and tide gates. Altered hydrology and sediment routing influence habitat-forming processes, the quantity and accessibility of habitats such as side channels and wetlands, the dynamics of the Columbia River plume, and the estuarine food web. Channel structure issues, in the form of reduced habitat complexity and diversity, also are a primary limiting factor for juveniles from all populations. Again, simplification of channel structure is related to conversion of land to other uses—agricultural, rural residential, and as a transportation corridor.

Lack of access to peripheral and transitional habitats, such as side channels and wetlands, is a secondary limiting factor for juveniles from all populations, with access being impaired by land uses—including the transportation corridor—and by flow alterations caused by mainstem dams. Other secondary limiting factors in the estuary that affect all coho salmon populations are exposure to toxic contaminants (from urban, industrial, and agricultural sources) and elevated late summer and fall water temperatures, which are related to (1) land use practices that impair riparian function or decrease streamflow, and (2) large hydropower reservoirs.[22] Altered food web dynamics involving a transition from a macrodetrital-based food web to a microdetrital-based food web also are considered a secondary limiting factor for all populations.[23] These changes in the estuarine food web are caused primarily by increased microdetrital inputs from hydropower reservoirs and the loss of wetland habitats through diking and filling.

6.4.3 Hydropower Limiting Factors

The severity of dam-related impacts on coho salmon populations varies throughout the ESU. Flow management operations at large storage reservoirs in the interior of the Columbia Basin (Grand Coulee, Dworshak, etc.) affect all juvenile Lower Columbia River coho salmon in the lower mainstem and estuary, and potentially in the plume—primarily by altering flow volume and timing. These alterations impair sediment routing, influence habitat-forming processes, reduce access to peripheral habitat, and change the dynamics of the Columbia River plume and the estuarine food web (see Section 6.4.2).[24] Moreover, the large reservoirs associated with mainstem dams contribute to elevated water temperatures downstream in late summer and fall. Although the management unit recovery plans identified temperature impacts of the

[22] Although the management unit plans identified temperature impacts in the estuary as a secondary limiting factor for juveniles in all populations, the timing of juvenile coho salmon migration raises questions about the significance of this limiting factor; see Section 6.4.3.

[23] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is unclear.

[24] It is likely that flow impacts of the hydropower system affect Lower Columbia River ESUs more through changes in habitat-forming processes (including impacts to the plume) and food web impacts than through changes in migratory travel time.

hydropower system as a secondary limiting factor for all juvenile coho salmon, migration of juvenile coho salmon peaks in mid-April through mid-July. Thus, it is unlikely that elevated mainstem temperatures are having a significant impact on this currently dominant coho salmon life history type. However, some coho salmon juveniles may be present year-round in the estuary (Dawley et al. 1986, McCabe et al. 1986, Roegner et al. 2004, Bottom et al. 2008, cited in Figure 2.2 of Carter et al. 2009). In addition, if recovery is successful in achieving more diverse life-history patterns for coho salmon, it is possible that temperature impacts of the hydropower system could become more significant in localized areas. For the Upper Gorge/Hood and Upper Gorge/White Salmon populations, which spawn above Bonneville Dam, passage issues at Bonneville and inundation of historical spawning habitat by Bonneville Reservoir are identified as secondary limiting factors.[25]

The effects of tributary dams vary by stratum. There are no tributary hydropower dams in the Coast stratum. In the Cascade stratum, tributary hydropower facilities are a primary limiting factor in the Cowlitz subbasin (for the Upper Cowlitz, Cispus, and Tilton populations, but not for the Lower Cowlitz population) and in the Lewis subbasin (for the North Fork Lewis population). Tributary hydropower facilities are a secondary limiting factor for the Clackamas population, impairing downstream passage of juveniles. Tributary hydropower was not identified as a limiting factor in the Sandy subbasin (the PGE Bull Run Hydroelectric Project, which consisted of Marmot Dam and the Little Sandy diversion dam, was removed in 2007-2008). There are no tributary hydropower facilities in the Coweeman, Toutle, Kalama, East Fork Lewis, Salmon Creek, or Washougal subbasins.[26]

In the Gorge stratum, the presence of Condit Dam was identified as a primary limiting factor for the Upper Gorge/White Salmon population. (The dam was breached in October 2011 and completely removed in September 2012, so this limiting factor has now been addressed.) Powerdale Dam on the Hood River was identified as a secondary limiting factor for adult and juvenile passage but was removed in 2010. Tributary hydropower is not a limiting factor for the Lower Gorge population.

6.4.4 Harvest Limiting Factors

Harvest-related mortality is identified as a primary limiting factor for all populations within the ESU and occurs as a result of direct and incidental mortality of natural-origin fish in ocean fisheries, Columbia River recreational fisheries, and commercial gillnet fisheries. The harvest targets hatchery-origin fish, which make up the vast majority of coho salmon returning to the Columbia River (Ford 2011). For the period from 1970 to 1993, harvest rates averaged 82 percent (NMFS 2008c). Since 2005, when NMFS listed Lower Columbia River coho salmon, harvest impacts have been reduced through measures such as mark-selective fisheries and time and area closures in both ocean and in-river fisheries, such that exploitation rates on natural-origin Lower Columbia River

---

[25] The exact extent to which Bonneville Reservoir inundated habitats for any species is unknown. Some biologists have hypothesized impacts to coho salmon as a result of inundation. Based on spawning habitat preferences, it is likely that the impacts of inundation were greatest on fall Chinook and chum salmon.
[26] However, the North Fork Toutle sediment retention structure currently blocks access to as many as 50 miles of habitat for anadromous fish.

coho salmon have averaged 16 percent.[27] However, some populations experience higher impacts. ODFW estimated that harvest impacts on natural- and hatchery-origin fish from the Youngs Bay and Big Creek populations are as high as 90 percent and 70 percent, respectively, because of terminal fisheries that target hatchery-origin returns to these off-mainstem areas. Some additional harvest affects the populations that pass Bonneville Dam as a result of tribal fisheries in Zone 6.[28] Although harvest has been reduced substantially in recent years, recovery efforts will continue to focus on refinements in harvest management.

6.4.5 Hatchery-Related Limiting Factors

From 2005 to 2009, an average of approximately 13 million hatchery coho salmon were released per year in the lower Columbia basin (Ford 2011). Additional hatchery coho salmon are released upstream in the Columbia Basin with potential effects on Lower Columbia River coho salmon through straying and competition and predation in the lower mainstem and estuary. Although this production is reduced from the peak in the late 1980s, legacy effects of hatchery fish and current hatchery production continue to pose a significant threat to Lower Columbia River coho salmon. It is likely that most coho salmon spawning naturally in the lower Columbia River are of hatchery origin. Population-level effects resulting from stray hatchery fish interbreeding with natural-origin fish are a primary limiting factor for the majority of the populations in the ESU and a secondary limiting factor for all other populations except the Scappoose and Sandy. Hatchery straying, combined with past stock transfers, has likely reduced genetic diversity within and among Lower Columbia River coho salmon populations. This, combined with the small number of populations with significant natural production, has resulted in reduced diversity within the ESU. Population productivity, abundance, and resilience has likewise declined as a result of the influence of hatchery-origin fish.

Some scientists suspect that closely spaced releases of hatchery fish from all Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the estuary. NMFS (2011a) and LCFRB (2010a) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon and steelhead in freshwater, estuarine, and nearshore ocean habitats.

6.4.6 Predation Limiting Factors

Direct mortality from predation is a secondary limiting factor for all coho salmon populations. Anthropogenic changes to habitat structure have led to increased predation by Caspian terns, double-crested cormorants, and various other seabird species in the

---

[27] Fishery impact rates for LCR coho are based on data for the Clackamas and Sandy populations, but because of differences in ocean distribution among populations, there is uncertainty about whether this impact rate applies to all populations.

[28] The mainstem Columbia River is divided into management areas (i.e., zones) in order to manage harvest under the *U.S. v. Oregon* agreement. Zone 6 extends from Bonneville Dam upstream to McNary Dam.

Columbia River estuary and plume. Coho salmon, particularly those spawning above Bonneville Dam, also are subject to predation by non-salmonid fish (primarily pikeminnows above and below the dam but also walleye and smallmouth bass in the reservoir).

6.5 Baseline Threat Impacts and Reduction Targets

Table 6-6 shows the estimated impact on each Lower Columbia River coho salmon population resulting from potentially manageable threats, organized into six categories: tributary habitat degradation, estuary habitat degradation, hydropower, harvest, hatcheries, and predation. Both baseline and target impacts are shown, with the targets representing levels that would be consistent with long-term recovery goals. Impact values indicate the percentage reduction in abundance and productivity that is attributable to human activities related to a particular threat category. The value associated with any particular threat category can be interpreted as the percent reduction in abundance and productivity from historical conditions if that threat category were the only one affecting the population. The table also shows the overall percentage improvement that is needed to achieve the target impacts and corresponding population status.[29] These cumulative values across all threat categories (both baseline and target) are multiplicative rather than additive. Both the Oregon and Washington management unit plans use cumulative survivals across threat categories to illustrate the overall level of improvement needed. Each plan assumes that there is a direct proportional relationship between the projected changes in cumulative survival and the required changes in natural-origin spawner abundance and productivity. For populations where the survival improvement needed is larger than 500 percent, Table 6-6 does not report the exact value, in part because the value is highly uncertain.[30]

As an example, the baseline status of the Grays/Chinook subbasin coho population, circa 1999, has been severely reduced by the combined effects of multiple threats. The cumulative reduction in status was estimated at 94.6 percent from the multiplicative impacts of multiple threats acting across the salmon life cycle. Thus, current status is just 5.4 percent of the historical potential with no human impact. Tributary habitat, harvest, and hatchery impacts each accounted for reductions in population productivity of 50 percent or more, with corresponding reductions in abundance, spatial structure, and diversity. The Washington management unit plan identifies a recovery strategy involving significant reductions in the impact of several threats. For instance, the plan targets tributary habitat impacts to be reduced from the estimated baseline level of 70 percent to 40 percent (i.e., an approximately 100 percent improvement relative to

[29] The percentage of survival improvement needed is the percentage change in net impacts, is derived from information in the Washington and Oregon management unit plans, and is calculated as follows: $[(1-\text{Cumulative}_{\text{Target}})-(1-\text{Cumulative}_{\text{Baseline}})]/[1-\text{Cumulative}_{\text{Baseline}}] \times 100$. These values generally correspond to population improvement targets identified for Washington populations in LCFRB (2010). Comparable numbers are not explicitly reported in ODFW (2010) but are implicit in the modeling approach that Oregon recovery planners used to derive target impacts.

[30] For some populations—many of them small—the survival improvement needed is very large and highly uncertain because various other factors also are uncertain (i.e., the population's baseline persistence probability, the exact degree of impact of human activities on tributary habitat, and whether the population's response to reductions in impacts will be linear). In addition, very small populations do not necessarily follow predictable patterns in their response to changing conditions.

baseline conditions). With the targeted reductions in individual impacts, the cumulative effect of all impacts would drop from 94.6 percent at baseline to 74.7 percent at the target status. This change would translate into a 370 percent improvement in survival relative to the baseline. Although the population would still be experiencing abundance and productivity that are 74.7 percent lower than historical conditions, the extinction risk at this mortality level would be estimated sufficient to meet the targets for this plan.

Oregon and Washington recovery planners used somewhat different definitions or methods to quantify the estimated impacts of anthropogenic threats. Baseline impacts for Washington populations reflect conditions prevalent at the time of ESA listing (circa 1999), while the baseline impacts for Oregon populations reflect conditions through 2004. Dam impacts for Washington populations reflect passage mortality, habitat loss caused by inundation, and loss of access to historical production areas; for Oregon populations, the estimates of impacts in the "Dams" column of Table 6-6 reflect direct upstream and downstream passage mortality only, with other dam impacts accounted for in the habitat and predation threat categories. Hatchery impacts for Washington populations were limited to not more than 50 percent per population, in accordance with Hatchery Scientific Review Group (HSRG) assessments of the potential for genetic effects (Hatchery Scientific Review Group 2009); Oregon recovery planners estimated that hatchery impacts were equivalent to the rates at which hatchery fish were found on natural spawning grounds, based on analyzed relationships and reflecting a concern for both genetic and ecological effects. Washington recovery planners derived estimates of impacts to tributary habitat using the Ecosystem Diagnosis and Treatment (EDT) model. Oregon recovery planners estimated the mortality associated with estuary habitat degradation, hydropower, harvest, hatcheries, and predation and assigned all remaining mortality (relative to the difference between the current modeled abundance and estimated historical abundance) to tributary habitat. In general, the tributary habitat values in Table 6-6 have the highest degree of uncertainty relative to the other threat categories and, for Oregon populations, may include causes of mortality associated with the other threat categories but not directly captured in those mortality estimates. (See Section 5.5 for more on the methodologies used to estimate baseline impacts.)

Estimates of threat impacts are useful in showing the relative magnitude of impacts on each population. Given the differences in methodologies, some values in Table 6-6 for Oregon and Washington populations are not necessarily directly comparable. Thus, values for Oregon populations are most directly comparable to those for other Oregon populations, and values for Washington populations are most directly comparable to those for other Washington populations. Regardless of differences in specific threat impact definitions and methods, the net effect of changes from all threats is useful in understanding the magnitude of population improvement needed to achieve the target population status.

The target impacts in Table 6-6 represent one of several possible combinations of threat reductions that could conceivably close the conservation gap and lead to a population achieving its target status. The particular threat reductions shown in Table 6-6 reflect policy decisions and the methodologies and assumptions used by the different recovery planning teams. (For a description of how target impacts were developed, see Section 5.6.) In estimating impacts, management unit recovery planners evaluated each threat category independently (i.e., values in the table reflect the mortality of coho exposed to that particular category of threats, whether or not they are exposed to threats in the other categories). The estimates of baseline threat impacts have high levels of uncertainty and in many cases should be considered working hypotheses that are testable as part of recovery plan implementation. Despite this uncertainty, it is the expert judgment of NMFS and management unit scientists that, based on the best available information at this time, the estimates of baseline threat impacts provide a reasonable estimate of the relative magnitude of different sources of anthropogenic mortality and serve as an adequate basis for designing initial recovery actions.[31] As more and better information is collected, it will be applied to recovery efforts in an adaptive management framework.

As shown in Table 6-6, loss and degradation of tributary habitat are the single largest threat to most coho salmon populations—and where the greatest gains in viability are expected to be achieved. Notable exceptions are the Clackamas, Upper Cowlitz, and Cispus populations. For the Clackamas population, protection of existing well-functioning habitat and reductions in hatchery impacts will play a key role in achieving the target status. The Upper Cowlitz and Cispus populations are projected to benefit greatly from hatchery reintroduction programs and dam passage improvements designed to restore their access to key historical spawning and rearing habitats. However, significant tributary habitat protection and restoration efforts also will be necessary for these populations. In most cases, population recovery objectives cannot be achieved without substantial improvements in habitat, even when the impacts of other non-habitat threats are practically eliminated.

Harvest and hatchery effects have been a significant threat to most Lower Columbia River coho salmon populations. Although recent actions have substantially reduced coho salmon harvest levels from baseline conditions, further refinements in harvest management are still needed. Hatchery impacts remain significant for many populations, including the Youngs Bay, Grays/Chinook, Big Creek, Elochoman, and Mill/Abernathy/Germany populations in the Coast stratum; the Upper Cowlitz, Cispus, Washougal, and, to a lesser degree, the Clackamas populations in the Cascade stratum; and all Gorge-stratum populations. Threat reductions associated with estuary habitat improvements and predation management are needed for recovery and will benefit every Lower Columbia River coho salmon population; however, net reductions targeted in these threat categories are smaller than those for tributary habitat, harvest, hatcheries, and, in some cases, hydropower because for most populations the impacts of estuarine and predation threats are less.

Several populations designated as primary are targeted for significant reductions in almost every threat category. These include the Grays/Chinook, Elochoman, Upper Cowlitz and Cispus, Lower Gorge, Upper Gorge/White Salmon, and Upper Gorge/Hood populations. However, Oregon notes in its management unit plan that the tributary habitat and hatchery-related threat reductions targeted for the Upper Gorge/Hood population probably are unattainable. (See Sections 6.3 and 6.7 for

[31] As implementation proceeds, research, monitoring, and evaluation and adaptive management will be key in helping to refine scientific understanding of the impact of threats on population persistence and of the extent to which management actions are reducing threats.

additional discussion of issues related to the feasibility of achieving abundance and productivity targets for the Upper Gorge/Hood population.)

More information on threat reduction scenarios, including descriptions of the methodologies used to determine baseline and target impacts, is available in the management unit plans (ODFW 2010, pp. 151-177 and LCFRB 2010a, pp. 4-30 through 4-33, and 6-49 through 6-52).

Table 6-6

Impacts of Potentially Manageable Threats and Impact Reduction Targets Consistent with Recovery of LCR Coho Salmon Populations

	Impacts at Baseline[32]							Impacts at Target							% Survival Improvement Needed[40]
Population	**T.Hab[33]**	**Est[34]**	**Dams[35]**	**Harv[36]**	**Hat[37]**	**Pred[38]**	**Cumul-ative[39]**	**T.Hab**	**Est**	**Dams**	**Harv**	**Hat**	**Pred**	**Cumul-ative**	
Coast															
Youngs Bay (OR)	0.98	0.10	0.00	0.90	0.86	0.06	0.9998	0.97	0.08	0.00	0.90	0.86	0.03	0.9996	60

32 Impact figures represent a percentage reduction in abundance and productivity that is attributable to human activities related to a particular threat category. Methods used to estimate impacts differ for Oregon and Washington populations. For example, baseline impacts reflect conditions circa 1999 for Washington populations and through 2004 for Oregon populations. Given the methodological differences, impact figures are not necessarily directly comparable. See Sections 5.5 and 5.6 for more on methodologies.

33 Reduction in tributary habitat production potential relative to historical conditions. Oregon and Washington used different methods to estimate historical abundance. Oregon's approach, which incorporates safety margins and includes causes of mortality that are not captured in the other five threat categories, tends to indicate a higher potential impact from tributary habitat loss and degradation than does Washington's.

34 Reduction in juvenile survival in the Columbia River estuary as a result of habitat changes (relative to historical conditions); excludes predation.

35 Reflects passage mortality, habitat loss caused by inundation, and loss of access to historical production areas for Washington populations; for Oregon populations, dam impacts reflect direct passage mortality only.

36 Includes direct and indirect mortality.

37 Reflects only the negative impacts of hatchery-origin fish, such as high pHOS and low PNI (proportion of natural influence), not the benefits of conservation hatchery programs.

38 Includes the aggregate predation rate in the mainstem and estuary by northern pikeminnow, marine mammals, Caspian terns, and cormorants.

39 Cumulative values (both baseline and target) are multiplicative rather than additive and are equal to $(1-[(1-M_{thab})(1-M_{est})(1-M_{dams})(1-M_{harv})(1-M_{hatch})(1-M_{pred})])$. Minor differences from numbers in ODFW (2010) are due to rounding.

40 Survival improvements indicate the percentage improvement (rounded to the nearest 10) in population survival needed to achieve target impacts and are derived from the cumulative values (baseline and target). For most populations this was calculated using the following equation: $[(1-Cumulative_{Target})-(1-Cumulative_{Baseline})]/[1-Cumulative_{Baseline}] \times 100$. For some Washington populations (Mill/Abernathy/Germany, Lower Cowlitz, Kalama, Upper Gorge), this equation yields a different result than that reported in LCFRB (2010a) because, for populations that have a very low probability of persistence and require very large improvements, the Washington management unit plan limited threat-specific reductions to 50 percent of the current impact as interim targets until the population response to improvements can be accurately gauged. For those populations, the numbers reported in this table are consistent with LCFRB (2010a) rather than with the aforementioned equation. In addition, these cumulative impact numbers are not explicitly reported in ODFW (2010) but are implicit in the modeling approach that Oregon recovery planners used to derive target impacts. For populations where the survival improvement needed is larger than 500 percent, this table does not report the exact value, for the reasons explained in Section 6.5. For Oregon populations designated as stabilizing (Youngs Bay and Big Creek), a survival improvement is shown because of improvements that are expected in tributary habitat, estuary conditions, and predation.

Table 6-6

Impacts of Potentially Manageable Threats and Impact Reduction Targets Consistent with Recovery of LCR Coho Salmon Populations

	Impacts at Baseline[32]							Impacts at Target							
Population	**T.Hab[33]**	**Est[34]**	**Dams[35]**	**Harv[36]**	**Hat[37]**	**Pred[38]**	**Cumul-ative[39]**	**T.Hab**	**Est**	**Dams**	**Harv**	**Hat**	**Pred**	**Cumul-ative**	**% Survival Improve-ment Needed[40]**
Grays/Chinook (WA)	0.70	0.16	0.00	0.50	0.50	0.14	0.9458	0.40	0.09	0.00	0.29	0.29	0.08	0.7468	370
Big Creek (OR)	0.98	0.10	0.00	0.70	0.86	0.06	0.9993	0.97	0.08	0.00	0.70	0.86	0.03	0.9989	60
Eloch/Skam (WA)	0.60	0.16	0.00	0.50	0.50	0.14	0.9278	0.42	0.11	0.00	0.35	0.35	0.10	0.8037	170
Clatskanie (OR)	0.83	0.10	0.00	0.35	0.13	0.06	0.9187	0.68	0.08	0.00	0.25	0.10	0.04	0.8092	140
Mill/Ab/Germ (WA)	0.50	0.16	0.00	0.50	0.50	0.15	0.9108	0.25	0.08	0.00	0.25	0.25	0.08	0.6429	>500
Scappoose (OR)	0.83	0.10	0.00	0.35	0.05	0.06	0.9112	0.77	0.08	0.00	0.25	0.05	0.04	0.8553	60
Cascade															
Lower Cowlitz (WA)	0.70	0.16	0.00	0.50	0.50	0.15	0.9465	0.58	0.13	0.00	0.42	0.45	0.13	0.8986	100
Upper Cowlitz (WA)	0.40	0.16	1.00	0.50	0.50	0.15	1.00	0.20	0.08	0.50	0.25	0.25	0.08	0.8096	>500
Cispus (WA)	0.50	0.16	1.00	0.50	0.50	0.15	1.00	0.25	0.08	0.50	0.25	0.25	0.08	0.82	>500
Tilton (WA)	0.95	0.16	1.00	0.50	0.50	0.15	1.00	0.95	0.16	1.00	0.50	0.50	0.15	1.00	0[41]
SF Toutle (WA)	0.90	0.16	0.00	0.50	0.50	0.15	0.9822	0.79	0.14	0.00	0.44	0.44	0.13	0.9507	180
NF Toutle (WA)	0.90	0.16	0.00	0.50	0.50	0.15	0.9822	0.79	0.14	0.00	0.44	0.44	0.13	0.9507	180
Coweeman (WA)	0.80	0.16	0.00	0.50	0.20	0.15	0.9429	0.62	0.12	0.00	0.39	0.15	0.12	0.8474	170
Kalama (WA)	0.70	0.16	0.00	0.50	0.50	0.15	0.9465	0.56	0.12	0.00	0.40	0.40	0.12	0.8773	>500
NF Lewis (WA)	0.40	0.15	0.85	0.50	0.24	0.16	0.9756	0.38	0.14	0.80	0.47	0.22	0.15	0.9625	50
EF Lewis (WA)	0.80	0.15	0.00	0.50	0.21	0.16	0.9436	0.40	0.08	0.00	0.25	0.11	0.08	0.6610	>500
Salmon Creek (WA)	0.90	0.15	0.00	0.50	0.50	0.16	0.9822	0.90	0.15	0.00	0.50	0.50	0.16	0.9822	0
Clackamas (OR)	0.62	0.10	0.08	0.35	0.35	0.06	0.8750	0.61	0.08	0.06	0.25	0.10	0.04	0.7814	70
Sandy (OR)	0.83	0.10	0.04	0.35	0.09	0.06	0.9183	0.52	0.08	0.00	0.25	0.09	0.04	0.6948	250

41 The Upper Cowltiz, Cispus, and Tilton populations require improvements in every threat category. However, given that hydropower impacts are 100 percent for these populations, they will not benefit from improvements in the other threat categories until some degree of passage is restored. Although passage improvements alone will not lead to recovery, how successful passage improvements are will greatly influence how much improvement is needed in the other threat categories. In addition, the formula for percent survival improvement for these populations was modified to account for the 100 percent hydropower impacts (i.e., to avoid having to divide by zero).

Table 6-6

Impacts of Potentially Manageable Threats and Impact Reduction Targets Consistent with Recovery of LCR Coho Salmon Populations

	Impacts at Baseline[32]							Impacts at Target							% Survival Improve-ment Needed[40]
Population	T.Hab[33]	Est[34]	Dams[35]	Harv[36]	Hat[37]	Pred[38]	Cumul-ative[39]	T.Hab	Est	Dams	Harv	Hat	Pred	Cumul-ative	
Washougal (WA)	0.80	0.15	0.00	0.50	0.50	0.16	0.9643	0.40	0.08	0.00	0.25	0.25	0.08	0.7143	>500
Gorge															
L Gorge — WA portion	0.50	0.15	0.00	0.50	0.50	0.16	0.9108	0.20	0.06	0.00	0.20	0.20	0.07	0.5524	400
L Gorge — OR portion	0.95	0.10	0.00	0.35	0.80	0.06	0.9945	0.63	0.08	0.00	0.25	0.10	0.04	0.8162	>500
U Gorge/White Salmon (WA)[42]	0.50	0.14	0.06	0.50	0.75	0.19	0.9591	0.31	0.09	0.04	0.31	0.46	0.12	0.7475	>400
U Gorge/Hood (OR)[43]	0.94	0.10	0.27	0.35	0.80	0.07	0.9952	0.08	0.08	0.23	0.05	0.00	0.05	0.4412	>500

[42] Baseline and target impacts for the Upper Gorge/White Salmon population are from LCFRB (2010a).

[43] Oregon's analysis indicates a low probability of meeting the delisting objective of high viability persistence probability for this population.

6.6 ESU Recovery Strategy for LCR Coho Salmon

This section describes the recovery strategy for Lower Columbia River coho salmon. A general summary of the ESU-level strategy is presented first. This is followed by subsections on each of the threat categories and critical uncertainties that pertain to the strategy. Where appropriate, stratum-specific strategies are described for each threat category.

6.6.1 Strategy Summary

The ESU recovery strategy for coho salmon involves improvements in all threat categories to increase abundance, productivity, diversity, and spatial structure to the point that the Coast, Cascade, and Gorge strata are restored to a high probability of persistence. The ESU recovery strategy has seven main elements:

1. Protect and improve populations that have a clear record of continuous natural spawning and are likely to retain local adaptation (the Clackamas and Sandy), along with populations where there is documented natural production (the Clatskanie, Scappoose, and Mill/Abernathy/Germany).

2. Fill information gaps regarding the extent of natural production in other populations, and focus additional recovery efforts on populations that have the greatest prospects for improvement.

3. Protect existing high-functioning habitat for all populations.

4. Restore tributary habitat (particularly overwintering habitat) to the point that each subbasin can support coho salmon at the target status for that population. In most subbasins this will mean having adequate habitat to support a viable population.

5. Reduce hatchery impacts on natural-origin fish so that impacts are consistent with the target status of each population. (The Grays/Chinook, Elochoman/Skamokawa, Mill/Abernathy/Germany, Clatskanie, Clackamas, Washougal, and Gorge-stratum populations are targeted for large reductions in hatchery impacts.)

6. Refine harvest management so that impacts are consistent with population and overall ESU recovery goals.

7. Reestablish naturally spawning populations above tributary dams on the Cowlitz and North Fork Lewis rivers by improving passage at dams and continuing to reintroduce coho salmon in these mid- to high-elevation habitats.

Very large improvements are needed in the persistence probability of most coho salmon populations if the ESU is to achieve recovery. (See Table 6-4 for the target status for each coho salmon population and Figure 6-3 for the gaps between baseline and target status.)

The recovery strategy for Lower Columbia River coho salmon is a long-term, "all-H" approach in which plan implementers begin work on all of the elements described above immediately and implement actions associated with each of the six threat categories simultaneously.[44] As part of a series of 3- to 5-year implementation schedules, management unit planners will work with NMFS staff to prioritize individual actions within each threat category, rather than across threat categories (see Chapter 11 for more on implementation). Recovery will require improvements in every threat category, even those improvements in Table 6-6 that are relatively small. Substantial actions are needed to improve tributary habitat and reduce the effects of hatcheries, harvest, and hydropower; without improvements in all of these threat categories, the benefits of actions in any individual sector are unlikely to be fully realized and the expected threat reductions will not be achieved.

Immediate implementation of certain actions is expected to reduce short-term population risk relatively quickly. Examples include reducing harvest impacts (this has already begun), providing access to blocked habitat, and carrying out site-specific habitat restoration to provide crucial overwintering habitat. Hatchery actions are needed immediately to begin reducing the influence of hatchery-origin fish on natural populations; over the long term, the type and extent of hatchery actions will be adjusted based on the results of new, more extensive population monitoring. The benefits of some actions, such as restoring riparian conditions to improve watershed function, will not be felt for years or decades after implementation. These actions also must be begun as soon as possible so that adequate habitat is in place to support increasing and eventually viable coho salmon populations. Recovery also will require contributions from estuary habitat and predation management actions; however, for stream-type fish such as coho salmon, these gains are expected to be less than those from coordinated efforts to address tributary habitat, hatchery, harvest, and hydropower impacts. In addition, substantial increases are needed in the monitoring of coho salmon spawner abundance, the proportion of hatchery-origin spawners, and fishery impacts in order to fill information gaps, especially in Washington.

The subsections below describe recovery strategies and near-term and long-term priorities for each threat category. For specific management actions in each threat category, linked to population and location, see the management unit plans (LCFRB 2010a, ODFW 2010, NMFS 2013).

6.6.2 Tributary Habitat Strategy

Coho salmon will benefit from the regional tributary habitat strategy described in Section 4.1.2. The regional strategy is directed toward protecting and restoring high-quality, well-functioning salmon and steelhead habitat through a combination of (1) site-specific projects that will protect habitat and provide benefits relatively quickly, (2) watershed-based actions that will repair habitat-forming processes and provide benefits over the long term, and (3) landscape-scale programmatic actions that affect a class of activities (such as stormwater management or forest practices) over multiple watersheds. Because the lack of complex overwintering habitat is a primary limiting factor for coho salmon, an immediate priority is to implement actions to increase off-channel, side-channel, and floodplain habitat in a network of high- and low-elevation tributary and Columbia River floodplain locations. Improving riparian cover and

[44] In fact, implementation of recovery actions to reduce threats in each category is already under way, although the scale of effort is less than that called for in this recovery plan.

recruitment of large wood to streams also will be a priority. The subsections below summarize additional, stratum-specific tributary habitat strategies for coho salmon.

6.6.2.1 Coast-Stratum Tributary Habitat Strategies

In implementing the Lower Columbia River coho salmon tributary habitat strategy in the Coast stratum, considerations include the following:

- Upland areas are predominantly state and private timber land; these lands must be managed to protect and restore watershed processes.
- Lowland areas are primarily in agricultural or rural residential use. These areas have been extensively modified by dikes, levees, bank stabilization, and tide gates; efforts to protect and restore habitat complexity will be priorities here.
- Sediment source analyses and implementation of actions to reduce sediment will be needed in most Coast stratum tributaries.

In addition to the actions described as part of the regional strategy for tributary habitat, the Washington management unit plan calls for restoring passage at culverts and other artificial barriers in the Elochoman subbasin; this would restore access to as many as 10 miles of habitat for coho salmon (LCFRB 2010a, Volume II). The Oregon management unit plan identifies a need to investigate whether headwater springs in the Clatskanie and Scappoose are drying up as a result of land management practices (ODFW 2010).

Assuming that the impacts of other threats are reduced to the levels shown in Table 6-6, the scale of tributary habitat improvements needed for Coast-stratum coho salmon ranges from minimal in the Youngs Bay and Big Creek subbasins to increases of 45 to 50 percent in the productive capacity of tributary habitat in the Grays/Chinook and Mill/Abernathy/Germany subbasins, respectively (LCFRB 2010a, ODFW 2010). For Oregon populations, estimates of the number of additional miles of high-quality coho salmon habitat that are needed range from minimal in Youngs Bay and Big Creek to 19 miles and 10 miles in the Clatskanie and Scappoose subbasins, respectively (ODFW 2010).

6.6.2.2 Cascade-Stratum Tributary Habitat Strategies

In implementing the Lower Columbia River coho salmon tributary habitat strategy in the Cascade stratum, considerations include the following:

- Upper portions of the Upper Cowlitz, Cispus, Tilton, East Fork Lewis, Washougal, Clackamas, and Sandy subbasins are primarily federal forest lands. Continued implementation of the Northwest Forest Plan will be crucial in protecting and restoring coho salmon habitats in these areas.
- State or private forest land predominates in the upper portions of the Coweeman, Toutle, Kalama, North Fork Lewis, and Salmon Creek subbasins. These lands must be managed to protect and restore watershed processes.

- In the lower reaches of most Cascade subbasins, including the Lower Cowlitz, Coweeman, North Fork Lewis, East Fork Lewis, Toutle, Salmon Creek, and Clackamas, floodplains have been drastically altered or disconnected as a result of channel modification to facilitate and protect urban and industrial development, agricultural land, and, in some cases, gravel mining. Restoration in these areas will need to be balanced with the need to protect existing infrastructure and control flood risk.

- This stratum includes the most heavily urbanized areas in the Columbia Basin. Managing the impacts of growth and development on watershed processes and habitat conditions will be key to the protection and improvement of habitat conditions for coho salmon in these areas.

In addition to the actions described as part of the regional strategy for tributary habitat, addressing passage barriers such as culverts will benefit coho salmon by restoring access to habitat in a number of locations, including the Tilton, Cispus, Lower Cowlitz, and Upper Cowlitz subbasins (in some cases, additional assessment is needed to inventory and prioritize these blockages). Addressing sedimentation issues associated with the sediment retention structure will be a priority for the North Fork Toutle subbasin. In the Sandy subbasin, implementation of the city of Portland's Bull Run water supply habitat conservation plan will contribute significantly to the habitat improvements needed to achieve the recovery target.

Assuming that the impacts of other threats are reduced to the levels shown in Table 6-6, the scale of habitat improvements needed for Cascade-stratum coho salmon populations ranges from minimal—for the Tilton and Salmon Creek populations (which, as stabilizing populations are expected to remain at their baseline status of very low probability of persistence)—to a 35 to 50 percent increase in the productive capacity of tributary habitat in the Sandy, Washougal, and East Fork Lewis subbasins. Oregon estimated that, for the Clackamas population, existing habitat is adequate to achieve a very high probability of persistence. For the Sandy population, 37 additional miles of high-quality habitat (or 74 miles of moderate-quality habitat) are needed.

6.6.2.3 Gorge-Stratum Tributary Habitat Strategies

In implementing the Lower Columbia River coho salmon tributary habitat strategy in the Gorge stratum, considerations include the following:

- Gorge populations occur in watersheds that are largely federal, state, and private forest land. These lands must be managed to protect and restore watershed processes.

- In the lower reaches of most Gorge tributary streams, floodplains have been drastically altered or disconnected as a result of channel modification to facilitate and protect development and transportation infrastructure. For the Lower Gorge population, site-specific actions will include addressing or mitigating the impacts of the highway and railroad transportation corridors that run parallel to the Columbia River shoreline, traversing all creek drainages in ways that restrict access and disconnect upland and lowland habitat processes.

In addition to the actions described as part of the regional strategy for tributary habitat, for the Upper Gorge/Hood coho salmon population, reduced instream flow from irrigation withdrawals is a primary threat, so actions to identify and implement flow improvements will be important. Improving fish passage at Laurance Lake Dam on the Clear Branch River and at other barriers in the Hood subbasin, such as irrigation diversions and road and railroad crossings, also will benefit the Upper Gorge/Hood population.

In the White Salmon subbasin, the breaching of Condit Dam in October 2011 (full removal was completed in September 2012) created near-term negative effects in the habitat below the dam and the habitat within the footprint of the former reservoir because of sediment release and scouring. Long-term effects are expected to be positive because of restored natural flow and sediment transport regimes. The White Salmon management unit plan outlines four broad tributary habitat strategies: (1) gain information to identify and prioritize habitat actions, (2) when the dam is removed, restore mainstem habitat, (3) protect and conserve natural ecological processes, and (4) improve habitat in upriver reaches (NMFS 2013). In the near-term, evaluating the effects of the dam breaching and removal on habitat and performing additional assessment of habitat limiting factors are high priorities.

Restoring floodplain connectivity and function is called for at locations below Bonneville Dam; however, there is little opportunity to implement floodplain measures above Bonneville Dam because most mainstem floodplain habitat was inundated by Bonneville Reservoir. For this reason, habitat efforts above the dam will rely on other strategies.

Assuming that the impacts of other threats are reduced to the levels shown in Table 6-6, the Washington management unit plan identifies a 60 percent reduction in baseline tributary habitat impacts to meet the recovery target for the Washington portion of the Lower Gorge population and a 38 percent reduction to meet the target for the Upper Gorge/White Salmon population. Oregon calculated a 35 percent reduction in impact (equivalent to an additional 10 miles of high-quality habitat) needed in the Oregon portion of the Lower Gorge population to achieve recovery targets. For the Upper Gorge/Hood population, achieving delisting targets would entail reducing habitat impacts by about 90 percent, or creating 53 additional miles of high-quality habitat. The Oregon planning team believed that 10 miles of additional high-quality habitat is a feasible goal. There is significant uncertainty surrounding the estimate of 53 additional miles of high-quality habitat because of questions about the historical size of the Upper Gorge/Hood population.

6.6.3 Estuary Habitat Strategy

Improving Columbia River estuary habitat as described in the regional estuary habitat strategy will benefit all Columbia Basin ESUs, including Lower Columbia River coho salmon. (For a summary of the regional estuarine habitat strategy, see Section 4.2.2.) The regional strategy reflects actions presented in the Oregon and Washington management unit plans to reduce estuarine habitat-related threats and is consistent with actions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a).

The *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) assumes that feasible estuarine habitat improvements and predation management measures could result in a maximum increase of 20 percent in the number of coho salmon outmigrating from the Columbia River estuary. Oregon and Washington recovery planners set targets of reducing anthropogenically enhanced mortality in the estuary for coho salmon populations based on the estuary module and their own approaches to threat reductions (ODFW 2010, pp. 160, 166-173, and Tables 6-5 through 6-12; LCFRB 2010a, p. 2-79, Table 2-16).

6.6.4 Hydropower Strategy

The hydropower recovery strategy for Lower Columbia River coho salmon is to address impacts of tributary hydropower dams through implementation of Federal Energy Regulatory Commission (FERC) relicensing agreements and thereby reestablish viable populations in the Upper Cowltiz, Cispus, North Fork Lewis, and White Salmon subbasins; achieve survival gains in the Hood and Clackamas subbasins; maintain the Tilton population at its baseline persistence probability of very low; and address downstream habitat impacts of the operation of some tributary hydropower dams.

The strategy also includes measures to improve passage survival at Bonneville Dam for the Upper Gorge/Hood and Upper Gorge/White Salmon populations and implementation of mainstem flow management operations designed to benefit spring migrants from the interior of the Columbia Basin; NMFS expects that these flow management operations will also improve survival in the estuary and, potentially, the plume for all Lower Columbia River salmon and steelhead populations. NMFS estimates that survival of Columbia River coho salmon passing Bonneville Dam was 95.1 percent for juveniles from 2002 to 2009 and 96.9 percent for adults from 2002 to 2007 (NMFS 2008a). NMFS expects that implementation of actions in the 2008 FCRPS Biological Opinion and its 2010 Supplement will improve juvenile coho salmon survival at Bonneville Dam by less than ½ percent, and that adult survival will be maintained at recent high levels (NMFS 2008a). Consequently, Oregon has not incorporated survival benefits from passage improvements at Bonneville into the hydropower threat reduction targets for Oregon populations above Bonneville.[45] The Washington management unit plan assumes that actions identified in the 2008 FCRPS Biological Opinion and its 2010 Supplement will aid adults and juveniles from all coho salmon populations originating above Bonneville Dam. For more on actions to improve mainstem dam passage, see the regional hydropower strategy in Section 4.3.2.

In its management unit plan, Oregon incorporated several actions addressing impacts of the Columbia River hydropower system that are not included in the FCRPS Biological Opinion and its 2010 Supplement but that Oregon maintains are needed to benefit Lower Columbia River salmon and steelhead populations that spawn above Bonneville Dam. The state of Oregon's position is that the FCRPS action agencies should conduct operations in addition to those incorporated in the FCRPS Biological Opinion to address the needs of ESA-listed salmon and steelhead. Oregon is a plaintiff in litigation against various federal agencies, including NMFS, challenging the adequacy of measures in the

[45] Hydropower-related threat reduction targets for Oregon populations above Bonneville Dam are associated with removal of Powerdale Dam on the Hood River.

FCRPS Biological Opinion and its 2010 Supplement. NMFS does not agree with Oregon regarding the need for or likely efficacy of the additional actions Oregon proposed in that litigation, including the actions in the Oregon management unit plan that are not part of the FCRPS Biological Opinion and its 2010 Supplement. For more detail on these actions and NMFS' view of them, see the regional hydropower strategy in Section 4.3.2.

The subsections below summarize stratum-level hydropower strategies for coho salmon.

6.6.4.1 Coast-Stratum Hydropower Strategy

There are no tributary dams in the Coast ecozone, so the hydropower strategy for Coast-stratum coho salmon is to implement the flow management operations designed to benefit spring migrants from the interior of the Columbia Basin; these flow management operations will also improve survival in the estuary and, potentially, the plume for all Lower Columbia River salmon and steelhead populations.

6.6.4.2 Cascade-Stratum Hydropower Strategy

The hydropower strategy for Cascade-stratum coho salmon is to create or improve passage at projects on the Cowlitz and Lewis rivers and to use hatchery reintroduction programs to reestablish viable populations in the Upper Cowlitz and Cispus subbasins and improve the persistence probability of the North Fork Lewis population (the Tilton population, in the Cowlitz system, is not expected to improve above its baseline persistence probability of very low). In addition, the efficiency of downstream passage facilities at hydropower dams in the Clackamas subbasin will be improved. These changes will be implemented under the terms of FERC relicensing agreements completed with (1) Tacoma Power for the Cowlitz River Project (settlement agreement completed in 2000), (2) PacifiCorp and the Cowlitz PUD for the Lewis River Hydroelectric Projects (settlement agreement in 2004), and (3) PGE for the Clackamas River Hydro Project in 2006. Habitat above the dams in these systems is relatively intact, with well-functioning watershed processes and a high percentage of federal land ownership (although the Tilton subbasin contains more development and a higher percentage of non-federal lands than do the Upper Cowlitz, Cispus, and Lewis subbasins). High-elevation habitat may also become increasingly important as lower elevation habitats are affected by changing climate (LCFRB 2010a).

In the Cowlitz subbasin, the hatchery Barrier Dam prevents all volitional passage of anadromous fish above RM 49.5. As of late 2011, coho salmon are collected at the dam, natural-origin fish are separated from hatchery broodstock, and hatchery- and natural-origin fish are transported upstream of Cowlitz Falls dam and released into the Upper Cowlitz and Cispus rivers.[46] Coho salmon smolts are collected at Cowlitz Falls Dam, briefly held in stress-relief ponds, and released into the lower Cowlitz (LCFRB 2010a). Passage at these dams is expected to be improved at some point as part of the 2000 FERC relicensing agreement. Tacoma Power will evaluate fish returns and survival through the reservoirs and assess passage options. Adult passage will be by trap and haul unless certain settlement agreement criteria (fish sorting, productivity, etc.) are met. If met, then passage at Mayfield Dam is likely to be provided through construction of a ladder,

[46] Hatchery coho salmon also are released into the Tilton subbasin to support a fishery.

whereas passage at the much larger Mossyrock Dam will likely be provided by either trap and haul or a tramway.

In the North Fork Lewis subbasin, three dams (Merwin, Yale, and Swift) block passage to the upper North Fork Lewis, beginning with Merwin Dam at RM 20. As part of the 2004 FERC relicensing agreement for these dams, reintroduction of coho salmon into habitat upstream of the three dams is being evaluated and is likely to occur beginning in 2012-2013. The keys to successful reintroduction will be adequate passage of juveniles and adults to and from the upper watershed, hatchery supplementation, and habitat improvements. In addition, hydroregulation on the Lewis River has altered the natural flow regime below Merwin Dam, and the flow regime will be need to be adjusted to provide adequate flows for habitat formation, fish migration, water quality, floodplain connectivity, habitat capacity, and sediment transport. However, floodplain and channel alterations in the lower river will limit the ability to restore the natural flow regime, and flow modifications will need to take place in concert with restoration of lower river floodplain function and with management considerations for Lewis River late-fall Chinook salmon.

In the Clackamas subbasin, there are both upstream and downstream passage facilities at the River Mill-Faraday-North Fork Dam complex operated by PGE. Early-run coho salmon, which are mostly of hatchery origin, also reproduce naturally in lower river tributaries and in the upper Clackamas above North Fork Dam. Clackamas late-run coho salmon are naturally produced fish and spawn mostly above North Fork Dam. As part of the 2006 FERC relicensing agreement, PGE agreed to improve downstream juvenile mortality through the dam complex to 3 percent or less and has already rebuilt the ladder and trap at North Fork Dam.

6.6.4.3 Gorge-Stratum Hydropower Strategy

Tributary hydropower impacts for the Upper Gorge/White Salmon and Upper Gorge/Hood populations largely have been addressed by the removal of Condit and Powerdale dams, respectively. Condit Dam, on the White Salmon River, was breached by PacifiCorp in October 2011 and, under the terms of a 1999 decommissioning agreement and a 2006 Biological Opinion, was completely removed in September 2012. Removal reopens access to 17.7 miles of historical coho salmon habitat and will allow reestablishment of natural spawning in an area where coho salmon have been extirpated. The strategy calls for 4 to 5 years of monitoring after dam removal to determine whether natural recolonization is occurring through natural straying and then use of a hatchery reintroduction program if needed.

Powerdale Dam, on the Hood River, was operated by PacifiCorp and removed in 2010 under the terms of a settlement agreement reached in 2003. The dam had passage systems in place, but removal is expected to improve access to historical coho salmon spawning and rearing habitat, further improve upstream and downstream survival, and reduce hydropower-related mortality for the Upper Gorge/Hood coho salmon population (ODFW 2010).

Actions in the 2008 FCRPS Biological Opinion and its 2010 Supplement will also provide slight improvements in juvenile survival at Bonneville Dam for the two Upper Gorge populations (see the regional hydropower strategy in Section 4.3.2).

6.6.5 Harvest Strategy

Managers have implemented substantial reductions in coho salmon harvest impacts, which averaged 82 percent for the period from 1970 to 1993 (NMF 2008c). Since NMFS listed Lower Columbia River coho salmon in 2005, harvest rates have averaged 16 percent. Consistent with the regional harvest strategy (see Section 4.5.2), the Oregon and Washington management unit plans both call for further refinements in harvest management practices so that they are consistent with population and overall ESU recovery goals while also maintaining harvest opportunities that target hatchery coho salmon.

Harvest rates on naturally produced coho salmon currently are established using an abundance-based harvest matrix that considers spawning escapement and marine survival. Annual coho salmon harvest rates are set through the Pacific Fishery Management Council's annual planning process in consultation with NMFS. The matrix is based on the status of the Clackamas and Sandy populations—the only populations within the ESU that were being monitored at the time the matrix was developed, and the two populations believed to be the ESU's strongest. Consequently, the matrix does not adequately consider the effects of harvest on the ESU's weaker populations. All coho salmon recreational fisheries have been mark-selective since 1998. Some commercial ocean fisheries have also been mark-selective in recent years, but mainstem gillnet fisheries currently are not.

The management unit plans envision refinements in coho salmon harvest through (1) replacement or refinement of the existing harvest matrix to ensure that it adequately accounts for weaker components of the ESU, (2) continued use of mark-selective recreational fisheries, and (3) management of mainstem commercial fisheries to minimize impacts to natural-origin coho salmon.[47] In refining the harvest matrix, the objective is to ensure that harvest management is consistent with maintaining trajectories in populations where natural production is beginning to be observed (e.g., the Clatskanie and Scappoose), with the assumption that additional refinements will be evaluated as natural production is documented in additional populations. Managing coho salmon harvest to minimize impacts to natural-origin fish is complicated by uncertainties regarding annual natural-origin spawner abundance and actual harvest impacts on natural-origin fish (in both ocean and mainstem Columbia fisheries). The management unit plans note these uncertainties and highlight the need for improved monitoring of harvest mortality and natural-origin spawner abundance.

In terms of recommended harvest rates, Oregon modeled a harvest rate of 25 percent as a long-term average under an abundance-based framework. The Washington management unit plan recommends a phased harvest strategy involving lower near-term rates to reduce population risks until habitat has improved. Modeling in the

[47] The Youngs Bay and Big Creek populations would continue to experience higher harvest rates to accommodate terminal fisheries targeting hatchery fish in those areas.

Washington management unit plan shows a scenario in which harvest rates would be managed for benchmarks of 8 to 25 percent throughout the first three of multiple 12-year evaluation periods (i.e., from 1999 through 2034). Then, the modeling shows that, assuming that benchmarks for habitat and other improvements have been met, harvest rates could rise (to 15 to 35 percent in the 2035 to 2046 period and to 20 to 50 percent thereafter) (LCFRB 2010a). These modeling results are planning targets and not predictions of future harvest rates; managers will establish future harvest rates based on observed indicators in Lower Columbia River coho salmon populations.

Near-term priorities for implementing this harvest strategy include:

- Obtaining better information on natural-origin and hatchery-origin spawner escapement and better estimates of natural population productivity
- Obtaining a better estimate of harvest impact rates for natural-origin Lower Columbia River coho salmon in ocean and Columbia River mainstem fisheries (and, in particular, addressing uncertainties related to harvest impacts in mainstem fisheries)
- Evaluating and refining harvest strategies for periods of poor ocean conditions and for years when returns are strong
- Incorporating into the matrix a method of managing for weaker stocks that would benefit from harvest reductions
- Developing mark-selective fishing methods that can be used in the commercial mainstem fisheries

6.6.5.1 Coast-Stratum Harvest Strategies

The ESU-level harvest strategies will reduce harvest impacts on most populations in the Coast stratum. Exceptions are the Youngs Bay and Big Creek populations, which are and will continue to be subject to higher harvest rates than most coho salmon populations because of Select Area fisheries. These fisheries, which are separate from the mainstem Columbia River fisheries, target hatchery coho salmon that return a few weeks earlier than the historical coho salmon run did (ODFW 2010). Under the harvest recovery strategy, the Select Area fisheries will continue, as will the corresponding high harvest impacts on the Youngs Bay and Big Creek populations (estimated at 90 and 70 percent, respectively). ODFW may adjust the end dates for the Youngs Bay and Big Creek fisheries to further reduce impacts to natural-origin coho salmon in those subbasins (ODFW 2010). WDFW also opens fisheries in the Grays to target coho salmon originating in the Deep River net pen program and straying to the Grays.

6.6.5.2 Cascade-Stratum Harvest Strategies

ESU-level harvest strategies will benefit populations in this stratum. In addition, if the hatchery coho salmon program in the Clackamas subbasin is maintained, ODFW may increase the within-basin harvest rate on those hatchery fish to help reduce pHOS.

6.6.5.3 Gorge-Stratum Harvest Strategies

ESU-level harvest strategies will benefit populations in this stratum.

6.6.6 Hatchery Strategy

The regional hatchery strategy described in Section 4.4.2 summarizes goals and approaches relevant to Lower Columbia River coho salmon. Details of how the hatchery strategy will be implemented in each coho stratum will be developed as part of the transition schedules, but the subsections below provide some information. In instances where the run timings in coho salmon hatchery programs do not correspond to historical run timings, NMFS expects to work with its fish resource co-managers to determine the appropriate implementation strategy relative to historical run timing.

6.6.6.1 Coast-Stratum Hatchery Strategies

The preliminary intent for hatcheries in the Coast stratum includes maintaining the Youngs Bay and Big Creek subbasins as areas of hatchery production to support Select Area fisheries. Some hatchery coho salmon production from the Clackamas, Sandy, and Lower Gorge populations will be shifted to Youngs Bay to reduce hatchery-origin spawners in those upriver populations. Existing weirs in both Youngs Bay and Big Creek will be used to exclude hatchery-origin fish and create natural-origin spawning areas.[48] The Clatskanie, Scappoose, Elochoman, and Mill/Abernathy/Germany subbasins will remain areas where no hatchery fish are released. If the level of hatchery fish straying from programs in other subbasins to spawn naturally in the Clatskanie and Scappoose systems is found to exceed 10 percent over a 9-year period, then ODFW will consider additional actions to reduce pHOS, including the installation of a weir and trap to sort hatchery fish. In the Grays subbasin, hatcheries will continue to be operated to support coho salmon harvest and potentially to enhance natural production through development of hatchery broodstocks similar to the late-returning historical populations (LCFRB 2010a).

6.6.6.2 Cascade-Stratum Hatchery Strategies

In the Cascade stratum, hatcheries will be used in the near term to reintroduce coho salmon in the Upper Cowlitz subbasin (Upper Cowlitz, Cispus, and Tilton populations) and North Fork Lewis subbasin (LCFRB 2010a). Hatchery-origin adult coho salmon already are being released upstream of dams to spawn naturally in the Upper Cowlitz, Cispus, and Tilton rivers, and in the North Fork Lewis, hatchery programs will be used to reintroduce coho salmon to the upper Lewis.

The preliminary intent is also that the Coweeman River in Washington will remain an area with no hatchery releases, along with the Clackamas River above North Fork Dam. For the Clackamas population, ODFW intends to meet a pHOS target of 10 percent or less by reducing coho salmon hatchery releases (from 500,000 to 350,000 beginning in

---

[48] Clackamas coho production was reduced from 500,000 to 350,000 beginning in 2009. Sandy coho production was reduced from 700,000 to 500,000 in 2010, with the difference shifted to Youngs Bay. Lower Gorge releases were reduced from 1.2 million to 725,000 in 2010, with the difference shifted to the lower Columbia.

2009), increasing harvest rates on hatchery coho salmon below North Fork Dam, and operating the trap at Eagle Creek hatchery for longer periods of time if needed. Coho salmon produced at the Eagle Creek hatchery are also used in reintroduction programs in the Yakima and Umatilla subbasins. When the Yakima and Umatilla programs are able to obtain broodstock from coho salmon returning to those subbasins, ODFW expects to work with the U.S. Fish and Wildlife Service (which manages the Eagle Creek hatchery) to explore options for eliminating the in-basin program altogether (ODFW 2010).

WDFW may consider short-term supplementation programs in some Cascade populations to bolster natural fish numbers above critical levels in selected areas until habitat is restored to levels where a population can be self-sustaining (LCFRB 2010a, Vol. II). Hatchery production for fishery enhancement will be the focus of hatchery programs in the Washougal, some programs in the Lower Cowlitz and North Fork Lewis, the North Fork Toutle, the Kalama, the Clackamas, and the Sandy (LCFRB 2010a, ODFW 2010). A weir will be installed in the lower Washougal River to separate hatchery- and natural-origin fish and to control the proportion of hatchery-origin fish on the spawning grounds. An existing weir in the lower Kalama River will be used for the same purpose.

6.6.6.3 Gorge-Stratum Hatchery Strategies

For the Lower Gorge population, Oregon proposes to reduce pHOS by reducing coho salmon releases from the Bonneville hatchery from 1.2 million to 725,000 (with the difference in production shifted to Youngs Bay) and, possibly, using a trap and weir to separate hatchery-origin adults. Additionally, Oregon proposes discussions with tribes regarding longer acclimation and rearing at tribal release sites; this would increase imprinting to reduce hatchery-origin fish straying into the lower Gorge tributaries (ODFW 2010). Washington may consider a supplementation program for its Lower Gorge tributaries at some point in the future (LCFRB 2010a, Vol. II)

For the Upper Gorge/Hood population, Oregon outlines a strategy to reduce hatchery strays and to evaluate whether a reintroduction program is needed. The primary source of stray hatchery-origin coho salmon in the Hood subbasin is from releases of hatchery coho salmon into the Klickitat and Umatilla subbasins as part of reintroduction programs. Releases into the Umatilla subbasin dropped from 1.5 million to 1 million in 2010. Additional reductions are expected for Klickitat River releases; however, reductions in these programs must be balanced with their intended purpose to support fisheries. Coho produced in tribal hatchery programs in the Klickitat River will also be marked. ODFW also will investigate opportunities to place weirs to trap and sort hatchery fish, but feasibility depends on finding a site where enough fish would be intercepted to achieve management objectives and that would allow for safe and reliable operation at an acceptable cost in a large system such as the Hood (ODFW 2010).

For the Upper Gorge/White Salmon population, coho salmon releases from the Little White Salmon National Fish Hatchery ended in 2004, under an agreement among the parties to U.S. v. Oregon. In the White Salmon subbasin, the White Salmon Working Group, made up of federal, state, and tribal fisheries managers and representatives of PacifiCorp, has recommended monitoring natural coho salmon escapement and production for 4 to 5 years after Condit Dam is removed.[49] Depending on the results, they will then recommend either proceeding with natural recolonization or with supplementation (perhaps with hatchery juveniles from the Washougal and/or Bonneville/Cascade hatchery or offspring of wild broodstock from the Klickitat or White Salmon rivers) (NMFS 2013).

6.6.7 Predation Strategy

The regional predation strategy (see Section 4.6.2) involves reducing predation by birds, fish, and marine mammals and will benefit all Lower Columbia ESUs, including coho salmon.

6.6.8 Critical Uncertainties

Each aspect of the coho salmon recovery strategy has a number of critical uncertainties; in addition, there are critical uncertainties related to the historical structure of coho salmon populations, primarily in the Gorge ecozone. For all ESUs, there are uncertainties regarding how habitat actions will translate into changes in productivity and capacity (Roni et al. 2011). Prioritizing and identifying next steps in resolving uncertainties is a near-term priority. Critical uncertainties specific to the Lower Columbia River coho salmon recovery strategy include the following:

- Historical role of the Gorge populations and appropriate target persistence probabilities and abundance and productivity targets for those populations

- Current natural-origin and hatchery-origin spawner escapement and productivity

- Relationship of current run timings (early/late) to historical run timings, harvest impacts on specific populations relative to their return timing, and the appropriate harvest strategy in light of this information (particularly the suitability of timing harvest to coincide with the return of the Cowlitz coho salmon population)

- Impact of climate change on freshwater and ocean habitats, including the impact of ocean acidification on the marine food webs on which salmon depend[50]

- Effectiveness of various approaches to developing integrated hatchery/natural populations

- Effectiveness of weirs in achieving pHOS targets

- Feasibility of achieving hatchery production and performance targets and maintaining harvest levels

---

[49] Condit Dam was breached in October 2011 and completely removed in September 2012.

[50] The impact of climate change is a critical uncertainty for all species addressed in this recovery plan but is particularly pertinent to coho because coho are sensitive to local ocean conditions. See Section 4.7 for additional discussion of the impacts of climate change on Lower Columbia River salmon and steelhead.

- Effective methods of providing adequate downstream passage efficiency for juveniles migrating past tributary dams
- Diversity of coho salmon life history strategies and how much coho salmon displaying less dominant life history strategies use the Columbia River estuary

These critical uncertainties represent preliminary priorities identified by Oregon and Washington recovery planners and NMFS Northwest Regional Office and Northwest Fisheries Science Center staff during a November 2010 workshop. They are preliminary priorities only (and are not in ranked order); as described in Chapter 10, additional discussion among local recovery planners and NMFS staff will be needed to finalize future research and monitoring priorities for Columbia River coho salmon.

The management unit plans identify more comprehensive critical uncertainties and research, monitoring, and evaluation needs that, along with the list above, will provide the basis for these future discussions. The White Salmon and Washington management unit plans have discrete sections on critical uncertainties for all of the ESUs in general (see Section 8.3 of NMFS 2013, pp. 8-4 through 8-6, and Section 9.6 of LCFRB 2010a, pp. 9-68 through 9-73), while the Oregon management unit plan embeds relevant critical uncertainties within subsections on monitoring and evaluation needs related to the four VSP parameters and five ESA listing factors (see Sections 8.4 and 8.5, respectively, of ODFW 2010). In addition, in June 2010, the Lower Columbia Fish Recovery Board completed the *Research, Monitoring, and Evaluation Program for Lower Columbia Salmon and Steelhead* as a companion to its recovery plan (LCFRB 2010b). This document also describes critical uncertainties. The list above also does not include critical uncertainties that apply to multiple ESUs; these will be discussed and considered as decisions are made in implementation. In addition, the critical uncertainties above are of a technical nature; there are also many critical uncertainties related to social, political, and economic issues.

Critical uncertainties are one element of research, monitoring, and evaluation (RME) and adaptive management, which will be key components of the coho salmon recovery strategy (see Chapter 10 for more discussion of RME and adaptive management for this recovery plan).

6.7 Delisting Criteria Conclusion for LCR Coho Salmon

The requirement for determining that a species no longer requires the protection of the ESA is that the species is no longer in danger of extinction or likely to become endangered within the foreseeable future, based on evaluation of the listing factors specified in ESA section 4(a)(1). To remove the Lower Columbia River coho salmon ESU from the Federal List of Endangered and Threatened Wildlife and Plants (that is, to delist the ESU), NMFS must determine that the ESU, as evaluated under the ESA listing factors, is no longer likely to become endangered.

The ESA requires that recovery plans, to the maximum extent practicable, incorporate objective, measurable criteria that, 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). The recovery criteria in this plan (both biological and threats criteria) meet this statutory requirement.

As described in Section 6.3, if the scenario in Table 6-4 were achieved, it would exceed the WLC TRT's viability criteria, particularly in the Cascade stratum (see Table 6-7).[51] Exceeding the criteria in the Cascade stratum was intentional on the part of local recovery planners to compensate for uncertainties about the feasibility of meeting the WLC TRT's criteria in the Gorge stratum, in particular the questions raised by Oregon about the feasibility of meeting the target status for the Upper Gorge/Hood population.

Table 6-7
Coho Salmon Recovery Scenario Scores Relative to WLC TRT's Viability Criteria

Species	Number of Primary Populations					Stratum Average Criteria			
Coho		Coast	Cascade	Gorge	Total		Coast	Cascade	Gorge
	n ≥ high	4	9	3	16	Avg. score	2.29	2.39	3
	TRT criterion (n ≥ 2) met?	Yes	Yes	Yes		TRT criterion (avg. ≥ 2.25) met?	Yes	Yes	Yes

Source: Based on LCFRB (2010a), Table 4-7.

Oregon recovery planners' uncertainty about the feasibility of meeting the recovery target of high persistence probability for the Upper Gorge/Hood population is based in part on questions about the feasibility of meeting the habitat and hatchery threat reduction targets for this population (ODFW 2010) and in part on questions raised by both Oregon and Washington management unit planners regarding Gorge strata and population delineations and the historical role of the Gorge populations (LCFRB 2010a, ODFW 2010). These questions include whether the Gorge populations were highly persistent historically, whether they functioned as independent populations within their stratum in the same way that the Coast and Cascade populations did, and whether the Gorge stratum itself should be considered a separate stratum from the Cascade stratum.

As discussed in Section 3.2, NMFS has considered the WLC TRT's viability criteria (from McElhany et al. 2003 and 2006 and summarized in Table 2-3), the additional recommendations in McElhany et al. (2007), the recovery scenarios and population-level goals in the management unit plans, and the questions management unit planners raised regarding the historical role of the Gorge strata.

NMFS has concluded that the WLC TRT's criteria adequately describe the characteristics of an ESU that meet or exceed the requirement for determining that a species no longer needs the protection of the ESA. These criteria provide a framework within which to evaluate specific recovery scenarios. NMFS has evaluated the recovery scenario

[51] For example, in the Cascade stratum, nine populations are targeted for high or very high persistence probability, and, using the WLC TRT's scoring system, the average viability score for all populations in the stratum would be 2.39. As discussed in Section 2.5.4, the TRT's criteria for high probability of stratum persistence require that two or more populations be viable and that the average score for all populations in the stratum be 2.25 or higher.

presented in the management unit plans for Lower Columbia River coho salmon (summarized in Table 3-1 of this recovery plan) and the associated population-level abundance and productivity goals (see Section 6.3) and has concluded that they also adequately describe the characteristics of an ESU that no longer needs the protections of the ESA. NMFS endorses the Lower Columbia River coho salmon recovery scenario and the associated population-level goals in the management unit plans (summarized in Table 3-1 and Section 6.3) as one of multiple possible scenarios consistent with delisting.

NMFS also agrees with the management unit planners that the historical role of the Gorge populations and stratum merits further examination. The extent to which compensation in the Cascade stratum is ultimately considered necessary to achieve an acceptably low risk at the ESU level will depend on how questions regarding the historical role of the Gorge populations are resolved.

NMFS therefore has developed the following delisting criteria for the Lower Columbia River coho salmon ESU. (NMFS has amended the WLC TRT's criteria to incorporate the concept that each stratum should have a probability of persistence consistent with its historical condition, thus allowing for resolution of questions regarding the Gorge stratum):

1. All strata that historically existed have a high probability of persistence or have a probability of persistence consistent with their historical condition. High probability of stratum persistence is defined as:

    a. At least two populations in the stratum have at least a 95 percent probability of persistence over a 100-year time frame (i.e., two populations with a score of 3.0 or higher based on the TRT's scoring system).

    b. Other populations in the stratum have persistence probabilities consistent with a high probability of stratum persistence (i.e., the average of all stratum population scores is 2.25 or higher, based on the TRT's scoring system). (See Section 2.6 for a brief discussion of the TRT's scoring system.)

    c. Populations targeted for a high probability of persistence are distributed in a way that minimizes risk from catastrophic events, maintains migratory connections among populations, and protects within-stratum diversity.

    A probability of persistence consistent with historical condition refers to the concept that strata that historically were small or had complex population structures may not have met Criteria A through C, above, but could still be considered sufficiently viable if they provide a contribution to overall ESU viability similar to their historical contribution.

2. The threats criteria described in Section 3.2.2 have been met.

7. Lower Columbia River Chinook Salmon

7.1 Chinook Salmon Biological Background

7.1.1 Life History and Habitat

Lower Columbia River Chinook salmon (*Oncorhynchus tshawytscha*) are classified as spring, fall, or late fall based on when adults return to fresh water. Other life history differences among run types include the timing of spawning, incubation, emergence in freshwater, migration to the ocean, maturation, and return to fresh water. This life history diversity allows different runs of Chinook salmon to use streams as small as 10 feet wide and rivers as large as the mainstem Columbia. Stream characteristics determine the distribution of run types among lower Columbia River streams. Depending on run type, Chinook rear for a few months to a year or more in freshwater streams, rivers, or the estuary before migrating to the ocean in spring, summer, or fall. All runs migrate far into the north Pacific on a multi-year journey along the continental shelf to Alaska before circling back to their river of origin. The spawning run typically includes three or more age classes. Adult Chinook salmon are the largest of the salmon species, and Lower Columbia River fish occasionally reach sizes up to 25 kilograms. Chinook salmon require clean gravels for spawning and pool and side-channel habitats for rearing (see Table 7-1 for freshwater habitat needs). All Chinook salmon die after spawning (LCFRB 2010a).

7.1.1.1 Spring Chinook Salmon Life History

Lower Columbia River spring Chinook salmon spawn primarily in upstream, higher elevation portions of large subbasins. Adults enter the lower Columbia River from March through June, well in advance of spawning in August and September (see Figure 7-1).

Spring Chinook salmon are “stream-type” salmon that generally rear in the river for a full year. This extended freshwater residency is characteristic of Chinook salmon that inhabit watersheds where temperature and flow conditions provide suitable habitat conditions throughout the year. Most stream-type juveniles emigrate from fresh water as yearlings, typically in the spring of their second year. However, some juveniles from Lower Columbia River spring Chinook salmon populations migrate downstream from their natal tributaries in the fall and early winter into larger rivers, including the mainstem Columbia River, where they are believed to over-winter before outmigrating the next spring as yearling smolts (LCFRB 2010a).

Once spring Chinook salmon leave freshwater, they usually move quickly through the estuary, into coastal waters, and ultimately to the open ocean. Once in the ocean, spring Chinook salmon migrate as far north as the Aleutian Islands and are widely distributed in the open ocean, far from coastal waters. Most remain at sea from 1 to 5 years (more commonly 2 to 4 years) and return to spawn at 3 to 6 years of age (LCFRB 2010a).

Table 7-1
Key Habitat for Fall and Spring Chinook Salmon, by Life Stage

Life Stage	Key Habitat Descriptions
Spawning	Riffles, tailouts, and the swifter areas in glides containing a mixture of gravel and cobble sizes with flow of sufficient depth for spawning activity
Incubation	As for spawning, but with sufficient flow for egg and alevin development
Fry Colonization	Shallow, slow-velocity areas within the stream channel, including backwater areas, often associated with stream margins and back eddies and usually in relatively low-gradient reaches.
Active Rearing	Relatively slow-water habitat types, often near velocity shears, often associated with relatively low-gradient stream channel reaches, including primary pools, backwaters, tailouts, glides, and beaver ponds.
Inactive Rearing	Non-turbulent habitat types, particularly deeper water types within the main channel, but also including slower portions of large cobble riffles.
Migrant	All habitat types having sufficient flow for free movement of juvenile migrants.
Pre-Spawning Migrant	All habitat types having sufficient flow for free movement of sexually mature adult migrants.
Pre-Spawning Holding	Relatively slow, deep-water habitat types typically associated with (or immediately adjacent to) the main channel.

Source: Adapted from Northwest Power and Conservation Council (2004b).

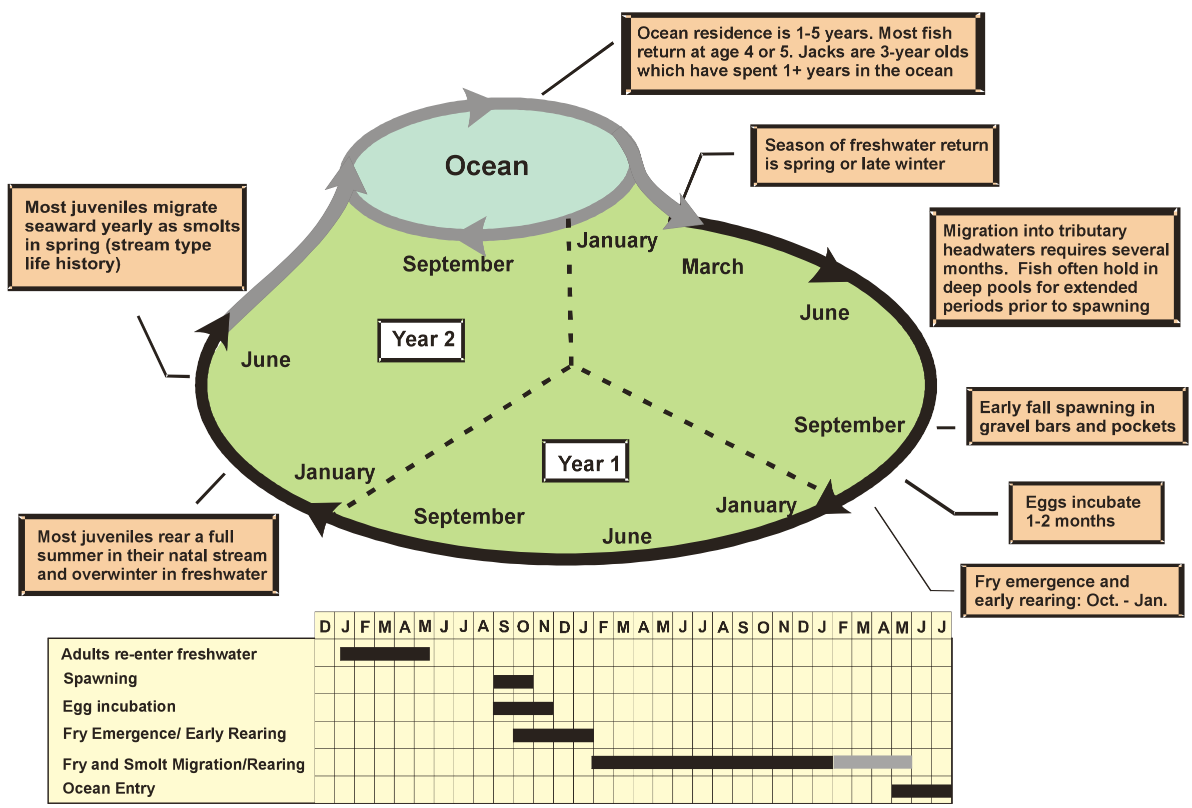

Figure 7-1. *Life Cycle of Lower Columbia River Spring Chinook Salmon*

(Source: LCFRB 2010a)

7.1.1.2 Fall Chinook ("Tule") Salmon Life History

Fall Chinook salmon spawn in moderate-sized streams and large river mainstems, including most tributaries of the lower Columbia River. Most Lower Columbia River fall Chinook salmon enter freshwater from August to September and spawn from late September to November, with peak spawning activity in mid-October (see Figure 7-2). These fish, referred to as "tule" stock, are distinguished by their dark skin coloration and advanced state of maturation at their return to fresh water. Tule fall Chinook salmon populations historically spawned in rivers and streams from the mouth of the Columbia River to the Klickitat River.

Lower Columbia River fall Chinook salmon display an "ocean-type" life history. Juveniles typically begin emigrating downstream as subyearlings at 1 to 4 months of age and enter salt water in late summer or autumn. Juvenile trapping indicates that individual populations display different combinations of two basic temporal patterns: an early fry outmigration downstream into intertidal areas in the early spring, followed by a component that rears for a longer period in natal tributary habitat and outmigrates in late spring/early summer (Cooney and Holzer 2011). Ocean-type juveniles make extensive use of the estuary. Rivers with well-developed estuaries, such as the Columbia, are able to sustain large populations of ocean-type salmon. Subyearling Chinook salmon can be found in the Columbia River estuary during every month of the year. After spending weeks or months rearing in the estuary, Lower Columbia River fall Chinook salmon migrate northward into ocean waters off of Washington, British Columbia, and Southeast Alaska. Most fall Chinook salmon remain at sea from 1 to 5 years (more commonly 3 to 5 years) and return to spawn at 2 to 6 years of age. They return to fresh water in late summer or fall and usually spawn within a few weeks (LCFRB 2010a).

7.1.1.3 Late-Fall ("Bright") Chinook Salmon Life History

Late-fall Chinook salmon, commonly referred to as "brights," generally return later than tule fall Chinook salmon, are less mature when they enter the Columbia, and spawn later in the year. Late-fall Chinook salmon enter the Columbia River from August to October and spawn from November to January, with peak spawning in mid-November. Late-fall Chinook salmon return to Washington's Lewis River and the Sandy River in Oregon.[1] Late-fall Chinook salmon exhibit a stream-type life history (LCFRB 2010a).

[1] In addition, bright fall Chinook salmon that originate from out-of-ESU hatchery fish spawn in the Columbia River mainstem immediately downstream of Bonneville Dam and in the Wind and White Salmon subbasins; these fish are not part of the Lower Columbia River ESU and are not addressed in this recovery plan. Natural-origin Lower Columbia River bright Chinook are referred to as the "lower river wild" stock in the US v. Oregon process.

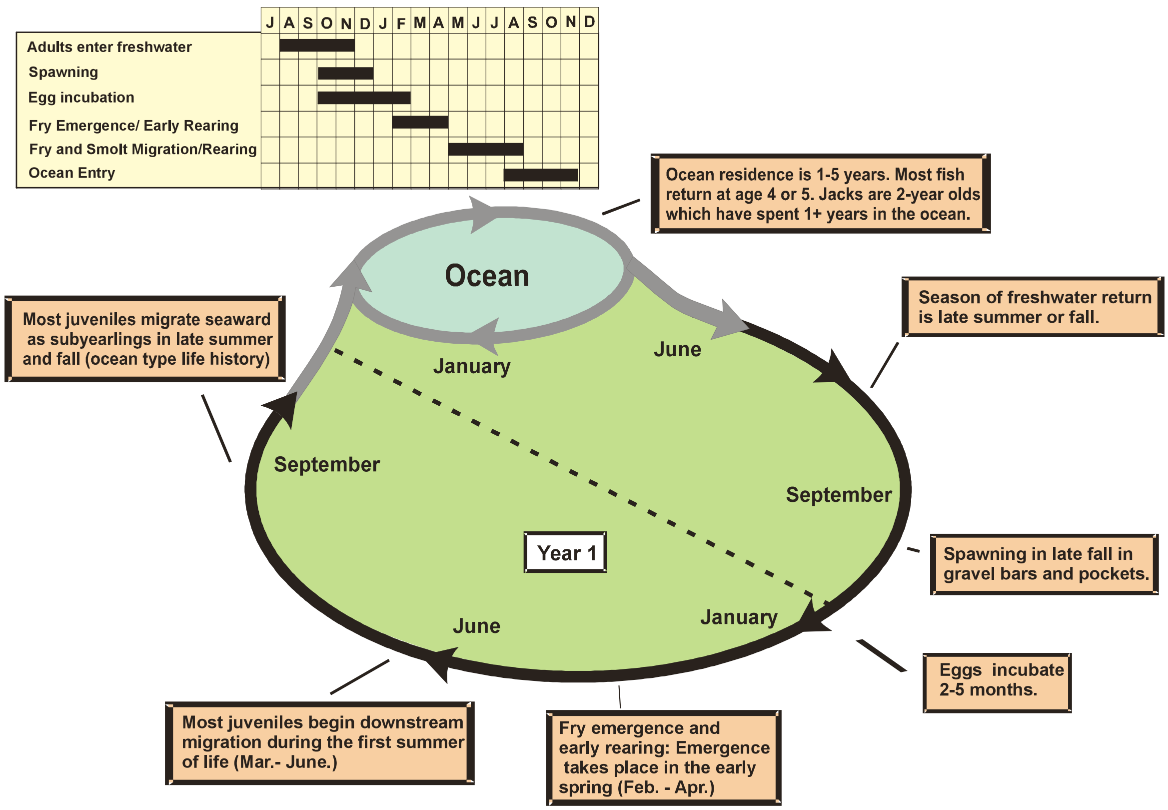

Figure 7-2. *Life Cycle of Lower Columbia River Fall Chinook Salmon*

(Source: LCFRB 2010a)

7.1.2 Historical Distribution and Population Structure of LCR Chinook Salmon

The WLC TRT identified a total of 32 historical independent populations in this ESU: 21 fall, two late-fall, and nine spring-run populations. Table 7-2 lists these populations and indicates core populations (which historically were highly productive) and genetic legacy populations (which represent important historical genetic diversity). Figures 7-3, 7-4, and 7-5 show the geographical distribution of Lower Columbia River Chinook salmon strata and populations.

Up through 2008, 17 artificial propagation programs produced Chinook salmon considered to be part of this ESU. In 2009, the Elochoman tule fall Chinook salmon program was discontinued, and in 2011, NMFS recommended removing this program from the ESU (76 *Federal Register* 50448). Four new fall Chinook salmon programs have been initiated: Deep River Net-Pen Fall Chinook, Klaskanine Hatchery Fall Chinook, Bonneville Hatchery Tule Fall Chinook, and Little White Salmon National Fish Hatchery Tule Fall Chinook. These programs are changes in release locations for fish produced at, and previously released from, existing hatchery programs that are part of the ESU. In 2011, NMFS recommended including these programs in the ESU (76 *Federal Register* 50448; Jones et al. 2011). Table 7-3 shows the 20 Chinook salmon hatchery programs that currently are included in the ESU. For a list of Chinook salmon hatchery programs not included in the ESU, see Jones (2011).

Table 7-2
Historical LCR Chinook Salmon Populations

Stratum	Historical Populations	Core or Genetic Legacy Populations
Cascade spring	Upper Cowlitz (WA)	Core, genetic legacy
	Cispus (WA)	Core
	Tilton (WA)	
	Toutle (WA)	
	Kalama (WA)	
	NF Lewis (WA)	Core
	Sandy (OR)	Core, genetic legacy
Gorge spring	White Salmon (WA)	Core
	Hood (OR)	
Coast fall	Youngs Bay (OR)	
	Grays/Chinook (WA)	
	Big Creek (OR)	Core
	Elochoman (WA)	Core
	Clatskanie (OR)	
	Mill (WA)	
	Scappoose (OR)	
Cascade fall	Lower Cowlitz (WA)	Core
	Upper Cowlitz (WA)	
	Toutle (WA)	Core
	Coweeman (WA)	Genetic legacy
	Kalama (WA)	
	Lewis (WA)	Genetic legacy
	Salmon Creek (WA)	
	Clackamas (OR)	Core
	Sandy River early (OR)	
	Washougal (WA)	
Gorge fall	Lower Gorge (WA & OR)	
	Upper Gorge (WA & OR)	Core
	White Salmon (WA)	Core
	Hood (OR)	
Cascade late fall	Lewis (WA)	Core, genetic legacy
	Sandy (OR)	Core, genetic legacy

Source: McElhany et al. (2003), Myers et al. (2006).

Table 7-3
Artificial Propagation Programs Included in the LCR Chinook Salmon ESU

Run Type	Washington Programs	Oregon Programs
Spring Chinook	Upper Cowlitz Cispus Friends of the Cowlitz Kalama Lewis River Fish First	Sandy River
Tule Fall Chinook*	Sea Resources Cowlitz (Deep River Net-Pen) North Fork Toutle Kalama Washougal Spring Creek (Little White Salmon and Bonneville)	Big Creek Astoria High School (STEP) Warrenton High School (STEP) Klaskanine

* The last returns from the Elochoman tule fall Chinook hatchery program are expected in 2013. This program has been part of the ESU in the past but was discontinued in 2009, so it is no longer included in the ESU.

Source: 70 *Federal Register* 37177, 76 *Federal Register* 50448, and Jones (2011).

7.2 Baseline Population Status for LCR Chinook Salmon

Populations of Lower Columbia River Chinook salmon have declined substantially from historical levels. Out of the 32 populations that make up this ESU, only the two late-fall runs—the North Fork Lewis and Sandy—are considered viable. Most populations (26 out of 32) have a very low probability of persistence over the next 100 years (and some are extirpated or nearly so (LCFRB 2010a, ODFW 2010, Ford 2011).[2] Five of the six strata fall significantly short of the WLC TRT criteria for viability; one stratum, Cascade late-fall, meets the WLC TRT criteria (see Figures 7-3, 7-4, and 7-5).

Low abundance, poor productivity, losses of spatial structure, and reduced diversity all contribute to the very low persistence probability for most Lower Columbia River

[2] As described in Sections 2.5 and 2.6, the WLC TRT recommended methods for evaluating the status of Lower Columbia River salmon and steelhead populations. The TRT's approach is based on evaluating the population parameters of abundance, productivity, spatial structure, and diversity and then integrating those assessments into an overall assessment of population persistence probability. As also described in Section 5.1, management unit recovery planners evaluated their respective populations' baseline status in a manner generally consistent with the WLC TRT's approach, with the baseline period being either circa 1999 (for Washington populations) or 2006-2008 (for Oregon populations). Unless otherwise noted, NMFS and the management unit planners believe that those assessments accurately reflect the status of the population at that time; the assessments are the basis for the summaries presented here and are consistent with the conclusions of the Northwest Fisheries Science Center in its *Status Review Update for Pacific Salmon and Steelhead Listed under the Endangered Species Act* (Ford 2011). New information on population status will continue to accumulate over time and will be taken into account as needed to reflect the best available science regarding a population's status.

Chinook salmon populations. Many of the ESU's populations are believed to have very low abundance of natural-origin spawners (100 fish or fewer), which increases genetic and demographic risks. Other populations have higher total abundance, but several of these also have high proportions of hatchery-origin spawners. Particularly for tule fall Chinook salmon populations, poor data quality prevents precise quantification of population abundance and productivity; data quality has been poor because of inadequate spawning surveys and the presence of unmarked hatchery-origin spawners (Ford 2011).[3] Spatial structure has been substantially reduced in several populations. Low abundance, past broodstock transfers and other legacy hatchery effects, and ongoing hatchery straying may have reduced genetic diversity within and among Lower Columbia River Chinook salmon populations. Hatchery-origin fish spawning naturally may also have reduced population productivity (LCFRB 2010a, ODFW 2010).

7.2.1 Baseline Status of LCR Spring Chinook Salmon

Six out of the nine spring Chinook salmon populations that are part of this ESU are estimated to have a very low probability of persistence (see Figure 7-3). Two—the White Salmon and Hood River populations—are considered extirpated, either because dams have blocked or impeded access to historical spawning habitat and/or because it is assumed that no remnants exist either in a hatchery or in the wild.[4] No spring Chinook salmon population is considered viable at baseline levels.

The very low persistence probabilities (and, in some cases, the likely extirpation) of most spring Chinook salmon populations are a function of losses in abundance, productivity, spatial structure, and diversity. The spatial structure of most spring Chinook salmon populations has been severely reduced by tributary dams that block access to core headwater spawning areas. In areas that remain accessible, distribution has been limited by habitat degradation. The genetic and life history diversity of spring Chinook salmon also has likely been greatly reduced, primarily as a result of population bottlenecks within the natural populations, habitat loss, and hatchery practices. Although hatchery programs are an important conservation tool for spring Chinook populations in some subbasins—primarily the Cowlitz and Lewis, where hatchery programs are serving as genetic reserves for use in reintroduction program—the long-term effects of the high fraction of hatchery-origin spawners in natural production areas is a concern (LCFRB 2010a, ODFW 2010).

---

[3] Both Oregon and Washington have recently begun efforts to identify and address data gaps, and all hatchery fall Chinook salmon are now marked.

[4] A reintroduction program for spring Chinook salmon in the Hood subbasin is under way using out-of-ESU broodstock. Some natural production is occurring there. At this time, the origin of that natural production is unknown. For additional discussion of this reintroduction program, see Section 7.4.3.6.

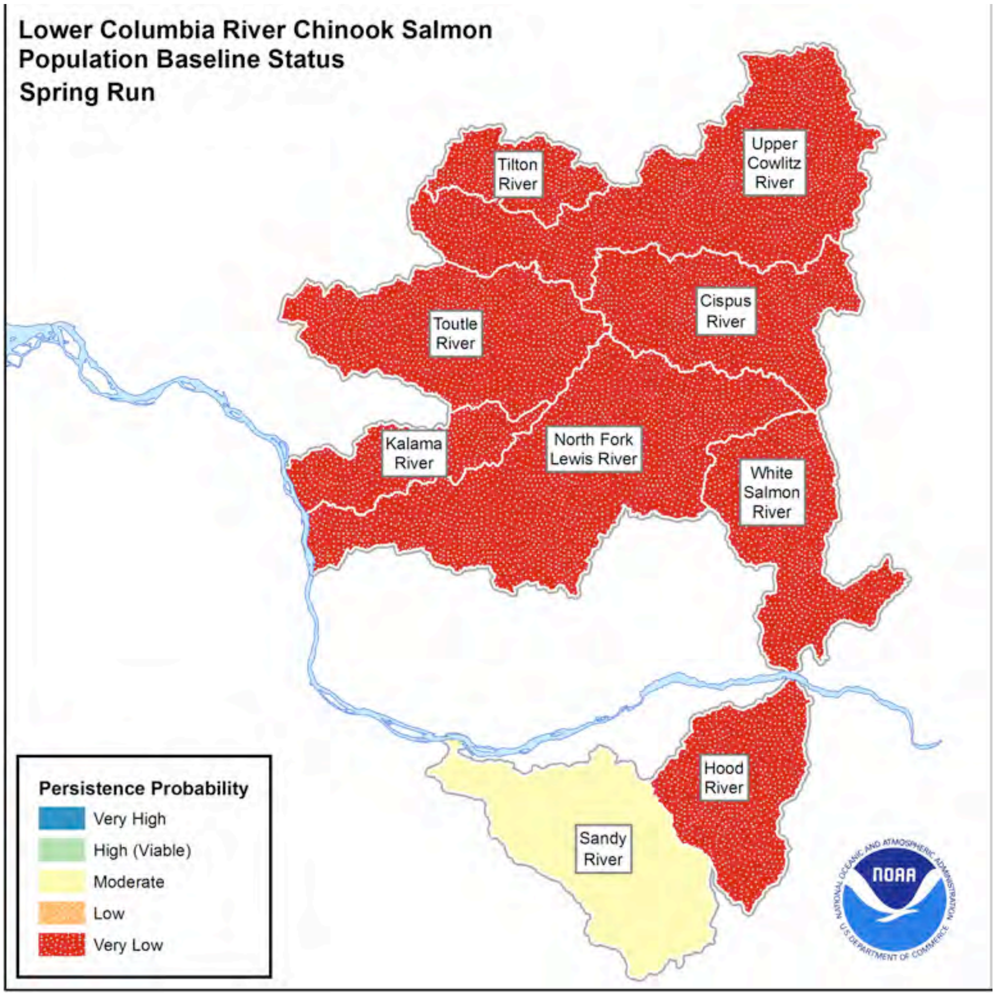

Figure 7-3. *Baseline Status of Lower Columbia River Spring Chinook Salmon Populations*

7.2.2 Baseline Status of LCR Tule Fall Chinook Salmon

Population status assessments conducted by Oregon and Washington management unit planners and based on the WLC TRT's recommended methods and criteria indicate that all 21 Lower Columbia River tule fall Chinook salmon populations have a baseline persistence probability of low or very low (see Figure 7-4) (LCFRB 2010a, ODFW 2010).

Spawner abundance and productivity estimates for these populations are generally based on expanded index-reach spawner counts and associated carcass sampling. In the past, data series used to estimate the hatchery proportion for most tule populations have been based on limited recoveries and, as a result, have had high uncertainty. Both the Oregon and Washington management unit plans identify obtaining improved estimates of annual abundance and wild/hatchery proportions of spawners as a short-term high-priority. In recent years, marking rates of tule Chinook salmon released from Lower Columbia River hatchery programs have significantly increased, facilitating estimates of hatchery-origin fish on natural spawning grounds. In addition, managers have reviewed carcass sampling efforts and expanded them in selected areas. Expansion methodologies used to estimate total spawner abundance based on sub-area counts are also being reviewed and evaluated against mark-recapture methods. The Oregon and Washington management unit plans will incorporate improved estimates of spawner abundance and productivity into periodic updates of population persistence probability.

Declines in persistence probability among tule fall Chinook salmon are related primarily to losses in abundance, productivity, and diversity. With the exception of the Upper Cowlitz population, whose access to historical habitat is blocked by tributary dams,[5] Lower Columbia River tule fall Chinook salmon populations generally can access most areas of historical spawning habitat. However, the abundance of most natural populations is very low. Abundance and genetic and life history diversity likely have been reduced through habitat degradation, historically high harvest rates, historical stock transfers, pervasive hatchery effects, and small population bottlenecks in the natural populations. In addition, hatchery-origin fish spawning naturally may have decreased population productivity. Hatchery-origin fish make up a large fraction of the spawners in most natural production areas. Exceptions are the Coweeman and East Fork Lewis subbasins, where hatchery influence has been relatively low. These two populations are considered genetic legacy populations (LCFRB 2010a, ODFW 2010). Coast stratum populations in particular have been subject to high levels of non-local hatchery broodstock, which raises questions about the extent to which tule Chinook salmon currently spawning there represent the genetic diversity and adaptation that was originally present. The probable lack of locally adapted populations may be a contributing factor to the apparent low productivity of these populations; however, we have no direct information on the level of local adaptation in these populations, and we do not know the geographic scale at which local adaptation occurred historically (an uncertainty that is not limited to this stratum or ESU).

To be consistent with the management unit plans and the methodologies recommended by the WLC TRT, this recovery plan uses status information from the Oregon and Washington management unit plans (ODFW 2010 and LCFRB 2010a) in describing baseline status for Lower Columbia River fall Chinook salmon populations. However, two additional analyses have been conducted in recent years to inform Biological Opinions related to harvest. Ford et al. (2007) describes the results of two quantitative population viability models used to evaluate the probability of persistence for three tule populations—the Coweeman, Grays/Chinook, and Lewis—under alternative assumptions about future harvest rates. NMFS' Northwest Fisheries Science Center (NWFSC 2010) used a life-cycle modeling approach to analyze the impact of various harvest rates on population risk, taking into consideration the effects of hatcheries, habitat conditions, and a subset of recovery actions; this assessment evaluated eight of the tule populations targeted for high persistence probability.

The various assessments show considerable agreement about the status of Lower Columbia tule populations; for example, all of the assessments suggest that the Coast stratum tule Chinook salmon populations have low or very low probabilities of persistence, and most of the assessments suggest that the Coweeman and Lewis tule populations have slightly higher persistence probabilities than other tule populations.

---

[5] Until recently, Condit Dam blocked the White Salmon population's access to historical habitat. Condit Dam was breached in October 2011 and completely removed in September 2012.

However, the assessments sometimes differ in their estimates of the status of individual populations, with Ford et al. (2007) and the Northwest Fisheries Science Center (2010) suggesting higher persistence probabilities for some populations than the management unit plans. It is likely that these differences are due in part to the different purposes, assumptions, baseline dates, data sets, and applications of data sets among the assessments.

The Northwest Fisheries Science Center (2010) modeling suggests that there may be important distinctions in viability within the populations categorized by ODFW (2010) and LCFRB (2010a) as having a low or very low probability of persistence—especially in the populations' ability to sustain harvest. Populations modeled by the NWFSC generally fell into three categories: (1) relatively large populations with relatively low projected quasi-extinction risks under current habitat conditions, reduced harvest rate scenarios, and a range of hatchery impact assumptions, (2) those with very high current or past hatchery and habitat impacts that modeling suggests could not be naturally self-sustaining without substantial improvements, even with no harvest, and (3) populations that are intermediate between these two and could possibly sustain themselves without hatchery input at low harvest rates under current conditions and under some modeled assumptions but not others.

In the Northwest Fisheries Science Center (2010) modeling, the Coweeman, Lewis, and Washougal populations fall into the first category, while the Elochoman/Skamokawa, Clatskanie, and Scappoose populations fall into the second category; however, LCFRB's (2010a) population viability analysis suggests that the Lewis and Elochoman/Skamokawa fit more appropriately in the intermediate category, and that the Lower Cowlitz and Grays/Chinook populations fall into the first and second categories, respectively.

These differences in results point to the need for better understanding of the factors driving the very low productivity of some populations, including the influence of hatchery-origin spawners on natural tule populations, the impact of harvest on different populations, and the ability of current and projected habitat conditions to support self-sustaining populations.

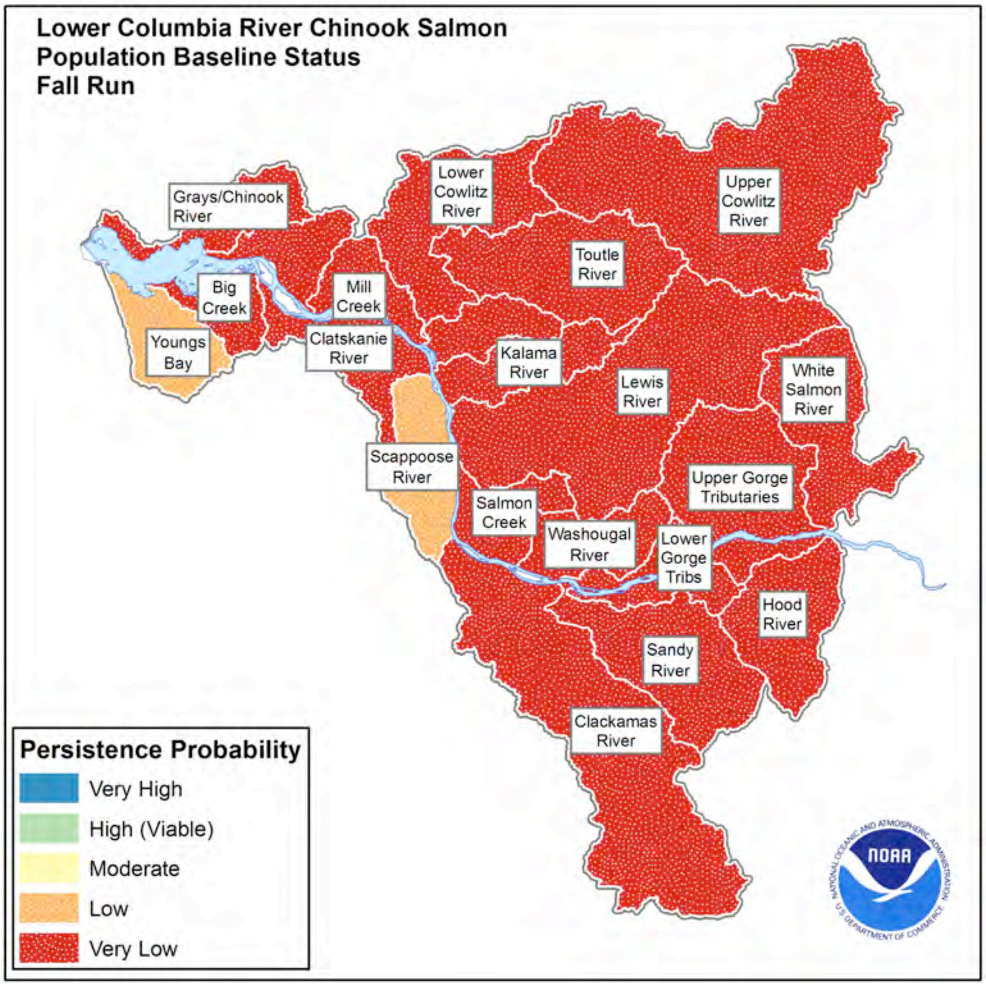

Figure 7-4. *Baseline Status of Lower Columbia River Fall (Tule) Chinook Salmon Populations, per Management Unit Plans*

7.2.3 Baseline Status of LCR Late-Fall (Bright) Chinook Salmon

The two late-fall Chinook salmon populations—North Fork Lewis and Sandy—are the only populations in this ESU whose baseline probability of persistence is estimated to be high (LCFRB 2010a, ODFW 2010). Both populations have remained largely uninfluenced by hatchery production and have not experienced the population bottlenecks seen in most tule fall Chinook salmon populations.

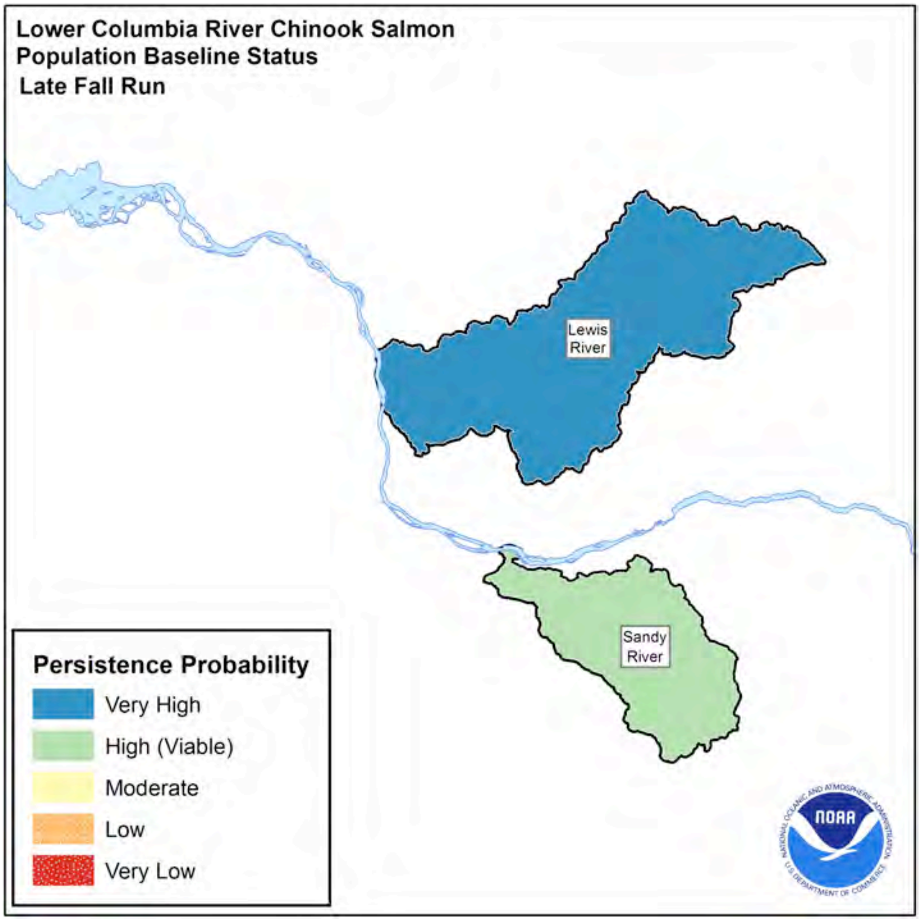

Figure 7-5. *Baseline Status of Columbia River Late-Fall Chinook Salmon Populations*

For additional discussion of Lower Columbia River Chinook salmon population status, see the management unit plans (LCFRB 2010a, pp. 6-7 through 6-13; ODFW 2010, pp. 54-55; and NMFS 2013, p. 4-1), Ford (2011), and, for Lower Columbia River tule fall Chinook salmon, Ford et al. (2007) and Northwest Fisheries Science Center (2010).

7.3 Target Status and Conservation Gaps for LCR Chinook Salmon Populations

Table 7-4 shows the baseline and target status for each Lower Columbia River Chinook salmon population, along with historical and target abundance. Local recovery planners coordinated with NMFS in making decisions about the target status for each population, taking into consideration opportunities for improvement in view of historical production, current habitat conditions and potential, and the desire to accommodate objectives such as maintaining harvest opportunities. (Note: the target statuses in Table 7-4 are the same as the persistence probabilities in the recovery scenario presented in Table 3-1.) As described in Chapter 5, although Oregon and Washington recovery planners used somewhat different methodologies to estimate baseline status and target abundance and productivity, the management unit planners agree that the methodologies led to similar conclusions regarding the generally low baseline status for most Lower Columbia River Chinook salmon populations.

Very large improvements are needed in the persistence probability of most spring and tule fall Chinook salmon populations if the ESU is to achieve recovery. For example, among the nine historical spring Chinook salmon populations, five are targeted for high or better persistence probability; four of these have baseline persistence probabilities of low or very low, or are extirpated or nearly so. Nine out of 21 tule fall Chinook salmon populations are targeted for high or better probability of persistence; all of these have a baseline persistence probability of very low or low. Some level of effort will be needed for every population to arrest or reverse long-term declining trends; this is true for stabilizing populations, which are expected to remain at their baseline persistence probability of low or very low, as well as for the two late-fall Chinook salmon populations, which need minimal improvement only. For most populations, meeting recovery objectives will require improvements in all VSP parameters: abundance, productivity, diversity, and spatial structure.

To achieve the recovery scenario for Cascade spring Chinook salmon, populations with high or better persistence probabilities must be reestablished in historical habitat blocked by tributary hydropower dams in the Upper Cowlitz, Cispus, and North Fork Lewis subbasins (all three of these populations were historically among the most productive, and the Upper Cowlitz is also a genetic legacy population), and in the Sandy subbasin (a core and genetic legacy population). In this stratum, only the Tilton population is expected to remain at its baseline persistence probability of very low, in part because of lower quality habitat. The Toutle spring Chinook salmon population is targeted to move from very low to medium persistence probability; this target status reflects uncertainties about how much spring Chinook salmon production the Toutle subbasin supported historically and concerns about the extent to which legacy effects of the Mount St. Helens eruption limit habitat productivity. The Kalama population is targeted to achieve low persistence probability, because habitat there was probably not as productive historically for spring Chinook salmon and because of the intent to maintain a fishery enhancement hatchery program there.

Achieving target status in the Gorge spring Chinook stratum will depend on reestablishing populations in the White Salmon and Hood River systems, where the historical populations are considered extirpated. Removal of Condit Dam in the White Salmon subbasin enhances prospects for recovery there, although questions remain about historical production and the potential to reestablish a population. (The dam was breached in October 2011 and completely removed in September 2012.) These questions led to a target of low-plus persistence probability for White Salmon spring Chinook salmon. The Oregon management unit plan is more optimistic that a viable spring Chinook salmon population can be reestablished in the Hood subbasin.[6]

Among the seven fall Chinook salmon populations in the Coast stratum, four are targeted for high persistence probability, including the Elochoman/Skamokawa, which is one of two core populations in the stratum. Big Creek, which is the other core

[6] Current reintroduction efforts in the Hood subbasin are using an out-of-ESU hatchery stock. See additional discussion of this issue below, in Section 7.4.3.6.

population, and the Youngs Bay population are targeted for low probability of persistence (up from very low for Youngs Bay). This decision reflects a strategic choice to provide harvest opportunity through terminal fisheries targeting hatchery fish in the Youngs Bay and Big Creek areas; consequently, the proportion of hatchery-origin spawners (pHOS) in these populations is expected to remain high. The Grays/Chinook population is targeted to move from very low to medium-plus persistence probability; this target status reflects concerns about potential habitat productivity and the ability to control stray hatchery fish, particularly from the Youngs Bay terminal fishery program.

In the Cascade fall Chinook stratum, four of ten populations are targeted for high-plus persistence probability, including the Toutle and Clackamas, which historically were among the most productive, and the Coweeman and Lewis, which are genetic legacy populations. Two populations are expected to remain at their very low baseline persistence probability: Salmon Creek, which is in a highly urbanized subbasin with limited habitat recovery potential, and the Upper Cowlitz, where reintroduction of spring Chinook salmon is the focus of recovery efforts (although fall Chinook are being passed into the Upper Cowlitz subbasin, as of 2010, in an effort to enhance that population).

In the Gorge fall Chinook stratum, only one of four populations—the Hood—is targeted for high persistence probability, with the other three populations targeted for medium persistence probability. In addition, the Oregon management unit plan notes that the feasibility of achieving the target status for the Hood population is low. Constraints to recovery for fall Chinook salmon in the Gorge include the small amount of historical and current habitat (and thus the limited options for restoration); anthropogenic impacts that are unlikely to change in the near future (e.g., inundation by Bonneville Reservoir and roads that restrict access to habitat); high uncertainty in the data and analyses for small populations[7]; and potentially inaccurate designation of population structure for this stratum. The Oregon management unit plan states that most of these issues are related to the population designation and suggests reevaluating the Gorge stratum population structure for all species (ODFW 2010).

The two populations of late-fall Chinook salmon are viable at their baseline levels, but the recovery scenario calls for the persistence probability of the Sandy population to be raised from high to very high.

If the scenario in Table 7-4 were achieved, it would exceed the WLC TRT's stratum-level viability criteria in the Coast and Cascade fall strata, the Cascade spring stratum, and the Cascade late-fall stratum (see Table 7-11).[8] However, the scenario for Gorge spring and Gorge fall Chinook salmon does not meet WLC TRT criteria because, within each

[7] In the method used by the WLC TRT and management unit planners to establish abundance goals, target abundance is based to some extent on the gap between current and historical abundance. If the historical abundance of Gorge stratum Chinook salmon populations has been significantly overestimated, then the abundance needed to achieve target status may also be overestimated (ODFW 2010).

[8] For example, in the Cascade fall stratum, four populations are targeted for high or very high persistence probability, and, using the WLC TRT's scoring system, the average viability score for all populations in the stratum would be 2.35. As discussed in Section 2.5.4, the TRT's criteria for high probability of stratum persistence require that two or more populations be viable and that the average score for all populations in the stratum be 2.25 or higher.

stratum, the scenario targets only one population (the Hood) for high persistence probability. Exceeding the WLC TRT criteria, particularly in the Cascade fall and Cascade spring Chinook strata, was intentional on the part of local recovery planners to compensate for uncertainties about meeting the WLC TRT's criteria in the Gorge fall and spring strata. In addition, multiple spring Chinook salmon populations are prioritized for aggressive recovery efforts to balance risks associated with the uncertainty of success in reintroducing spring Chinook salmon populations above tributary dams in the Cowlitz and Lewis systems. (Delisting criteria for the Lower Columbia River Chinook salmon ESU are described in Section 3.2 and below in Section 7.7.)

Figures 7-6 and 7-7 display the population-level conservation gaps for tule fall Chinook, late-fall Chinook, and spring Chinook graphically. The conservation gap reflects the magnitude of improvement needed to move a population from its baseline status to the target status. For additional discussion of target status and conservation gaps for Lower Columbia River Chinook salmon populations, see the management unit plans (LCFRB 2010a, pp. 6-13 to 6-15 and ODFW 2010, pp. 148-150).

Given the structure of the Lower Columbia River Chinook salmon ESU, with its three major adult run components and both ocean- and stream-type juvenile life histories represented, the remainder of the Chinook salmon recovery analysis is broken down by run component: spring, fall, and late-fall. Limiting factor summaries, threat impacts, and recovery strategies at the run component level are nested appropriately within these three larger sections.

Table 7-4

Baseline and Target Persistence Probability and Abundance of LCR Chinook Salmon Populations

			Baseline Persistence Probability[9]					Abundance		
Stratum	Population	Contribution	A&P	S	D	Net	Target Persistence Probability	Historical	Baseline[10]	Target
Cascade spring	Upper Cowlitz (WA)[C, G]	Primary	VL	L	M	VL	H+	22,000	300	1,800
	Cispus (WA)[C]	Primary	VL	L	M	VL	H+	7,800	150	1,800
	Tilton (WA)	Stabilizing	VL	VL	VL	VL	VL	5,400	100	100
	Toutle (WA)	Contributing	VL	H	L	VL	M	3,100	100	1,100
	Kalama (WA)	Contributing	VL	H	L	VL	L	4,900	100	300
	NF Lewis (WA)[C]	Primary	VL	L	M	VL	H	15,700	300	1,500
	Sandy (OR)[C, G]	Primary	M	M	M	M	H	26,899	714	1,230
Gorge spring	White Salmon (WA)[C]	Contributing	VL	VL	VL	VL	L+	--[11]	< 50	500
	Hood (OR)	Primary	VL	VH	VL	VL	VH	15,041	327	1,493
Coast fall	Youngs Bay (OR)	Stabilizing	L	VH	L	L	L	15,115	379	505
	Grays/Chinook (WA)	Contributing	VL	H	VL	VL	M+	800	< 50	1,000
	Big Creek (OR)[C]	Contributing	VL	H	L	VL	L	8,785	216	577
	Elochoman/Skamokawa (WA)[C]	Primary	VL	H	L	VL	H	3,000	< 50	1,500
	Clatskanie (OR)	Primary	VL	VH	L	VL	H	14,354	6	1,277
	Mill/Abernathy/Germany (WA)	Primary	VL	H	L	VL	H	2,500	50	900
	Scappoose (OR)	Primary	L	H	L	L	H	12,515	356	1,222
Cascade fall	Lower Cowlitz (WA)[C]	Contributing	VL	H	M	VL	M+	24,000	500	3,000
	Upper Cowlitz (WA)	Stabilizing	VL	VL	M	VL	VL	28,000	0	--

[9] A&P = Abundance and productivity, S = spatial structure, and D = genetic and life history diversity. Net = overall persistence probability of the population. VL = very low, L = low, M = moderate, H = high, VH = very high.

[10] Baseline abundance was estimated as described in Section 5.1 and does not equal observed natural-origin spawner counts. The baseline is a modeled abundance that represents 100-year forward projections under conditions representative of a recent baseline period using a population viability analysis that is functionally equivalent to the risk analyses in McElhany et al. (2007). Projections generally assume conditions similar to those from 1974 to 2004. Oregon numbers reflect fishery reductions between the 1990s and about 2004, while Washington numbers reflect fishery impacts prevalent in the period immediately prior to listing in 1999.

[11] "—" indicates that no data are available from which to make a quantitative assessment.

Table 7-4

Baseline and Target Persistence Probability and Abundance of LCR Chinook Salmon Populations

			Baseline Persistence Probability[9]					Abundance		
Stratum	Population	Contribution	A&P	S	D	Net	Target Persistence Probability	Historical	Baseline[10]	Target
	Toutle (WA)[C]	Primary	VL	H	M	VL	H+	11,000	< 50	4,000
	Coweeman (WA)[G]	Primary	L	H	H	L	H+	3,500	100	900
	Kalama (WA)	Contributing	VL	H	M	VL	M	2,700	< 50	500
	Lewis (WA)[G]	Primary	VL	H	H	VL	H+	2,600	< 50	1,500
	Salmon Creek (WA)	Stabilizing	VL	H	M	VL	VL	--	< 50	--
	Clackamas (OR)[C]	Contributing	VL	VH	L	VL	M	22,554	558	1,551
	Sandy (OR)	Contributing	VL	M	L	VL	M	6,237	144	1,031
	Washougal (WA)	Primary	VL	H	M	VL	H+	2,600	< 50	1,200
Gorge	Lower Gorge (WA & OR)	Contributing	VL	M	L	VL	M	--	< 50	1,200
fall	Upper Gorge (WA & OR)[C]	Contributing	VL	M	L	VL	M	--	< 50	1,200
	White Salmon (WA)[C]	Contributing	VL	L	L	VL	M	--	< 50	500
	Hood (OR)	Primary	VL	VH	L	VL	H*	1,391	33	1,245
Cascade	NF Lewis (WA)[C, G]	Primary	VH	H	H	VH	VH	23,000	7,300	7,300
late fall	Sandy (OR)[C, G]	Primary	VH	M	M	H	VH	10,000	1,794	3,561

C = Core populations, meaning those that historically were the most productive.

G = Genetic legacy populations, which best represent historical genetic diversity.

*Oregon's analysis indicates a low probability of meeting the delisting objective of high persistence probability for this population.

Source: LCFRB (2010a) and ODFW (2010).

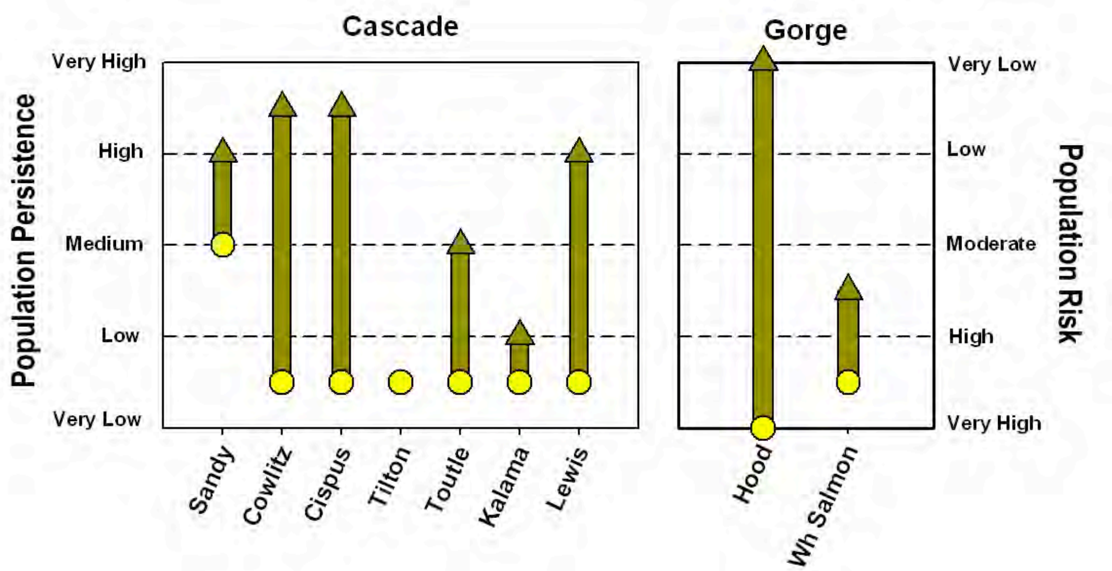

Figure 7-6. *Conservation Gaps for LCR Spring Chinook Salmon Populations: Difference between Baseline and Target Status*

Source: LCFRB 2010a.

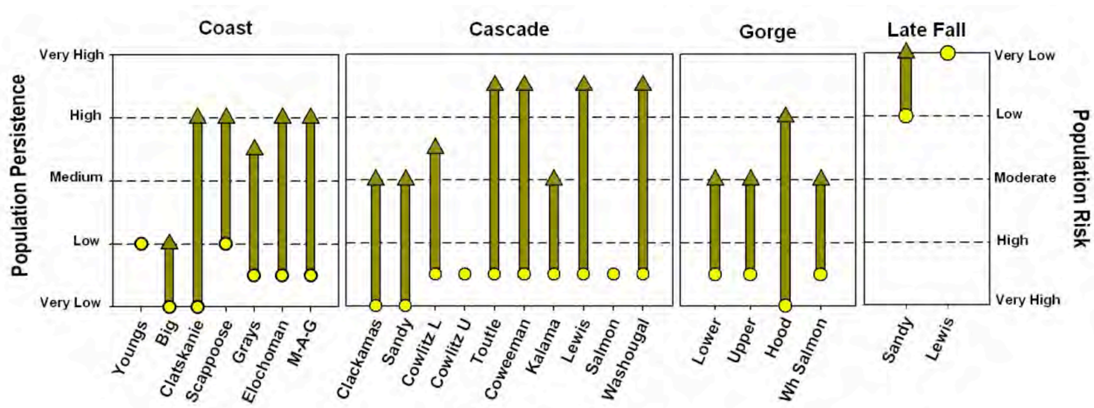

Figure 7-7. *Conservation Gaps for LCR Fall and Late-Fall Chinook Salmon Populations: Difference between Baseline and Target Status*

Source: LCFRB 2010a.

7.4 Spring Chinook Salmon Analysis: Limiting Factors, Threat Reductions, and Recovery Strategies

7.4.1 Spring Chinook Salmon Limiting Factors

Lower Columbia River spring Chinook salmon have been—and continue to be—affected by a legacy of habitat degradation, hydropower impacts, harvest, and hatchery production that, together, have reduced the persistence probability of all Lower Columbia River spring Chinook salmon populations. One of the largest factors limiting this component of the Lower Columbia River Chinook salmon ESU has been the existence of tributary dams that block access to core headwater spawning areas in upper subbasins.[12] Spatial structure, productive potential, and survival are further constrained by widespread degradation of tributary habitat in downstream areas. In addition, the high historical harvest rates and the effects of hatchery fish on natural populations have undermined the genetic and life history diversity of spring Chinook salmon populations and contributed to significant losses in production and abundance.

Table 7-5 and the text that follows summarize baseline limiting factors and threats for Lower Columbia River spring Chinook salmon strata based on population-specific limiting factors and threats identified in the management unit plans. In cases where conditions have changed significantly since the management unit plans' analyses of limiting factors and threats (e.g., if harvest rates have dropped or a dam is no longer present), this is noted in the text. Unless otherwise noted, NMFS agrees that the management unit plans' identification of limiting factors provide a credible hypothesis for understanding population performance and identifying management actions.

Because the individual management unit plans used somewhat different terms in identifying limiting factors, NMFS has translated those terms into standardized and more general terminology taken from a NMFS "data dictionary" of possible ecological concerns that could affect salmon and steelhead species (Hamm 2012; see Section 5.4). In addition, in Table 7-5, NMFS has rolled up the population-specific limiting factors (see Appendix H) to the stratum level—a process that has resulted in some loss of specificity.

In addition, each management unit plan used a different approach for identifying limiting factors and threats (see Section 5.3).One difference relevant to the crosswalk is that although the Oregon management unit plan identified primary and secondary limiting factors for each population in each threat category,[13] the Washington management unit plan categorized limiting factors in this way only for habitat-related

[12] Steel and Sheer (2003) analyzed the number of stream kilometers of potential habitat historically and currently available to salmon populations in the lower Columbia River. For several spring Chinook salmon populations, historical habitat is almost completely blocked (100 percent in the Cispus and Tilton subbasins, 99 percent in the Upper Cowlitz, 76 percent in the Lewis, and—at the time of the analysis—100 percent in the White Salmon subbasin. Condit Dam, on the White Salmon River, was breached in October 2011 and completely removed in September 2012, thus eliminating the major blockage in that subbasin.). In the Toutle and Kalama subbasins much lower but still significant proportions of habitat are blocked (31 percent blocked in the Toutle and 23 percent in the Sandy). In the Kalama subbasin only 6 percent is blocked, and in the Hood, 1 percent.

[13] In the Oregon management unit plan, primary limiting factors are those that have the greatest impact and secondary limiting factors have a lesser but still significant impact.

limiting factors, and the White Salmon plan and the estuary module did not use the primary and secondary terminology. For the crosswalk and this table, NMFS assigned primary and secondary status to non-habitat limiting factors for Washington populations (based on the Washington management unit plan's quantification of threat impacts and the professional judgment of Lower Columbia Fish Recovery Board's staff and consultants). For populations that historically spawned in the White Salmon subbasin, NMFS staff inferred primary and secondary designations based on discussion in the Washington and White Salmon management unit plans (LCFRB 2010a, NMFS 2013). It is likely that some apparent distinctions in results between Washington and Oregon populations are artifacts of differences in limiting factor assessment methodologies and not an actual difference in conditions or their effects on salmon and steelhead populations. In addition, there is not necessarily a bright line between primary and secondary limiting factor designations. Nevertheless, NMFS believes that the designations are useful, particularly for looking across ESUs and populations and identifying patterns (see Chapter 4).

The management unit plans provide more detail on limiting factors and threats affecting Lower Columbia River spring Chinook salmon, including magnitude, spatial scale, and relative impact (see LCFRB 2010a, Chapter 3 and various sections of Volume II; ODFW 2010, pp. 116-128; and NMFS 2013, Chapter 5). For a regional perspective on limiting factors and threats that affect multiple salmon and steelhead ESUs, see Chapter 4 of this recovery plan. For a description of the data dictionary, the approach NMFS used to correlate management unit terms for limiting factors with the standardized NMFS terminology at the population scale, and the approach for rolling up from the population to the stratum scale, see Section 5.4 and Appendix H.

Management unit recovery planners in Oregon and Washington recognized that six major categories of manageable threats—tributary habitat, estuary habitat, hydropower, harvest, hatcheries, and predation—were useful as an organizing construct for grouping limiting factors, quantifying impacts on population productivity, and determining how much different categories of threats would need to be reduced to close the gap between baseline and target population status. Planners in both Washington and Oregon quantified the impacts of each of these major threat categories on population status, along with a reduction in each impact that would be consistent with achieving population target status. The results of that analysis are presented in Sections 7.4.2, 7.5., and 7.6.2 and provide a related but slightly different perspective on limiting factors. The threat reduction targets also allow actions to be scaled to achieve a specific impact reduction, and to be linked to monitoring and performance benchmarks.

Table 7-5

Baseline Limiting Factors and Threats Affecting LCR Spring Chinook Salmon: Stratum-Level Summary

Ecological Concern	Threat(s)	VSP Parameters Affected	Cascade Spring	Gorge Spring
Tributary Habitat Limiting Factors				
Riparian Condition	Past and/or current land use practices	All	Primary for juveniles in all populations	Secondary for juveniles in all populations

Table 7-5

Baseline Limiting Factors and Threats Affecting LCR Spring Chinook Salmon: Stratum-Level Summary

Ecological Concern	Threat(s)	VSP Parameters Affected	Cascade Spring	Gorge Spring
Channel Structure and Form	Past and/or current land use practices/ transportation corridor	All	Primary for juveniles in all populations	Secondary for juveniles in all populations
Peripheral and Transitional Habitats: Side Channel and Wetland Conditions	Past and/or current land use practices/ transportation corridor	All	Primary for juveniles in all populations	Secondary for juveniles in all populations
Peripheral and Transitional Habitats: Floodplain Conditions	Past and/or current land use practices/ transportation corridor	All	Primary for juveniles in all populations	Secondary for juveniles in all populations
Sediment Conditions	Past and/or current land use practices/ transportation corridor	All	Secondary for Sandy juveniles, primary for juveniles in all other populations	Secondary for juveniles in all populations
Water Quality (Temperature)	Land uses that impair riparian function/decrease streamflow, dams	A,P,D	Primary for Tilton and Toutle juveniles, secondary for Kalama and North Fork Lewis juveniles	
Water Quantity (Flow)	Dams, land use, irrigation, municipal, and hatchery withdrawals	All	Secondary for juveniles in all populations	
Estuary Habitat Limiting Factors[14]				
Toxic Contaminants	Agricultural chemicals, urban and industrial practices	A,P,D	Secondary for juveniles in all populations	
Food[15] (Shift from macrodetrital- to microdetrital-based food web)	Dam reservoirs	All	Secondary for juveniles in all populations	

[14] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the ESU, the estuarine limiting factors in this table and Section 7.4.1.2 reflect the determinations in the Oregon management unit plan, applied to all Lower Columbia River spring Chinook salmon populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

[15] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is unclear.

Table 7-5

Baseline Limiting Factors and Threats Affecting LCR Spring Chinook Salmon: Stratum-Level Summary

Ecological Concern	Threat(s)	VSP Parameters Affected	Cascade Spring	Gorge Spring
Peripheral and Transitional Habitats: Estuary Condition	Past and/or current land use practices/transportation corridor, mainstem dams	All	Secondary for juveniles in all populations	
Channel Structure and Form	Past and/or current land use practices/ transportation corridor	All	Primary for juveniles in all populations	
Sediment Conditions	Past and/or current land use practices/transportation corridor, dams	All	Primary for juveniles in all populations	
Water Quality (Temperature)	Land uses that impair riparian function/decrease streamflow, dam reservoirs	A,P,D	Secondary for juveniles in all populations	
Water Quantity (Flow)	Columbia River mainstem dams	All	Primary for juveniles in all populations	
Hydropower Limiting Factors				
Habitat Quantity (Access)	Bonneville Dam	All		Secondary for White Salmon and Hood
Habitat Quantity (Inundation)	Bonneville Dam	All		Secondary for Hood juveniles[16]
Habitat Quantity (Access)	Tributary dams	All	Primary for Upper Cowlitz, Cispus, Tilton, and North Fork Lewis adults and juveniles, secondary for Sandy adults and juveniles	Primary for White Salmon adults and juveniles, secondary for Hood adults and juveniles
Harvest Limiting Factors				
Direct Mortality	Fisheries	A,D	Primary for Upper Cowlitz, Cispus, Tilton, Toutle, Kalama, and North Fork Lewis adults, secondary for Sandy adults	Primary for Hood adults, secondary for White Salmon adults

[16] The exact extent to which Bonneville Reservoir inundated habitats for any species is unknown. Some biologists have hypothesized impacts to spring Chinook salmon as a result of inundation. Based on spawning habitat preferences, it is likely that impacts of inundation were greatest on fall Chinook and chum salmon.

Table 7-5
Baseline Limiting Factors and Threats Affecting LCR Spring Chinook Salmon: Stratum-Level Summary

Ecological Concern	Threat(s)	VSP Parameters Affected	Cascade Spring	Gorge Spring
Hatchery Limiting Factors				
Food[17]	Smolts from all Columbia Basin hatcheries competing for food and space in the estuary	All	Secondary for all populations	
Population Diversity	Stray hatchery fish interbreeding with wild fish	A,P,D	Primary for adults in all populations	Primary for adults in all populations
Predation Limiting Factors				
Direct Mortality	Land use	A,P,D	Secondary for juveniles in all populations	
Direct Mortality	Dams	A,P,D		Secondary for adults (marine mammals) and juveniles (non-salmonid fish) in all populations

7.4.1.1 Tributary Habitat Limiting Factors

Because spring Chinook salmon are stream-type salmon that typically rear in tributary reaches for a full year, they depend heavily on tributary habitat conditions for their survival (LCFRB 2010a). Loss and degradation of tributary habitat is one of the main limiting factors for Lower Columbia River spring Chinook salmon, along with blocked access to historical spawning habitat as a result of tributary hydropower dams (see Table 7-5).

Impaired side channel and wetland conditions and degraded floodplain habitat have significant negative impacts on juvenile spring Chinook salmon throughout the ESU and are identified as primary limiting factors for all Cascade spring populations and secondary factors for all Gorge spring populations. Extensive channelization, diking, wetland conversion, stream clearing, and, in some subbasins, gravel extraction have barred spring Chinook salmon from historically productive habitats and simplified much of the remaining tributary habitats, weakening watershed processes that are essential to the maintenance of healthy ecosystems. Degraded riparian conditions and channel structure and form issues also are primary limiting factors for all Cascade spring populations and secondary factors for all Gorge spring populations within the

[17] Some scientists suspect that closely spaced releases of hatchery fish from all Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the estuary. NMFS 2011a and LCFRB (2010) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon in freshwater, estuarine, and nearshore ocean habitats.

ESU. Lack of large woody debris and appropriately sized gravel in the remaining accessible tributary habitat has significantly reduced the amount of suitable spawning and rearing habitat for spring Chinook salmon.

Sediment conditions are identified as a primary limiting factor for all Washington populations with the exception of the White Salmon, but are considered to be secondary for the Oregon portion of the ESU.[18] The high density of forest and rural roads in the Lower Columbia subdomain, combined with past, and in some cases current, logging and other forest management practices and other land use patterns on unstable slopes adjacent to riparian habitat, contributes to an abundance of fine sediment in tributary streams.[19] The resulting excess fine sediment covers spawning gravel, limiting egg development and incubation, and increases turbidity. In addition, water quality—specifically elevated water temperature brought about through land use, lack of functioning riparian habitat, and reservoir operations—is a primary limiting factor for the Tilton and Toutle populations and a secondary limiting factor for the Kalama and North Fork Lewis populations. The influence of water storage and release operations, land use, and water withdrawals for irrigation, municipal use, and hatchery operations has led to altered hydrology and flow timing being identified as secondary factors for all spring Chinook salmon populations.

In the Cascade stratum, tributary habitat limiting factors are largely the same as those described above for all spring Chinook salmon populations. Land uses that have led to the conditions limiting habitat productivity in this stratum include forest management and timber harvest, agriculture, rural residential and urban development, and gravel extraction. A mix of private, state, and federal forest land predominates in the upper mainstem and headwater tributaries of the Cascade subbasins, while the lower mainstem and tributary reaches of most subbasins are characterized by agricultural and rural residential land use, with some urban development.

A unique issue in the Cascade stratum is legacy effects in the Toutle subbasin of the 1980 Mount St. Helen's eruption. The North Fork Toutle in particular was heavily affected by sedimentation from the eruption. A sediment retention structure (SRS) was constructed on the North Fork Toutle in an attempt to prevent continued severe sedimentation of stream channels and associated flood conveyance, transportation, and habitat degradation problems. The SRS currently blocks access to as many as 50 miles of habitat for anadromous fish. Although fish are transported around the structure via a trap and haul system, the SRS remains a source of chronic fine sediment to the lower river; this reduces habitat quality and has interfered with fish collection at the base of the SRS.

In addition, spawning of Sandy spring Chinook salmon is negatively affected by impaired gravel recruitment related to the City of Portland's Bull Run water system dams.

In the Gorge spring Chinook stratum, habitat limiting factors are generally the same as those described for all spring Chinook salmon populations, although tributary habitat

---

[18] This distinction is likely an artifact of differences in limiting factor assessment processes between the two states and not an actual physical difference in sediment conditions in tributary streams or their effects on Chinook populations.

[19] By itself, road density is not necessarily a good measure of delivery of fine sediment to streams.

limiting factors are identified as secondary. Riparian, side-channel, wetland, and floodplain habitat conditions have been compromised by land uses and inundation by the reservoirs behind Bonneville and Condit dams.[20] Land uses that have contributed to habitat limiting factors include forest management and timber harvest in the upper mainstem and headwater reaches of the Hood and White Salmon, and transportation and rural residential land uses, with some urban development, in lower mainstem and tributary reaches. Water quantity issues related to altered hydrology and flow timing—specifically caused by irrigation withdrawals or diversions or low-head hydro diversions—have been identified as secondary limiting factors.

Habitat within the White Salmon subbasin was altered by the breaching of Condit Dam (in October 2011, with full removal in September 2012). Alterations include near-term negative effects from sediment release and scouring. Scientists and managers expect long-term positive effects as the result of restoration of natural flow regimes and sediment transport, but monitoring is needed to evaluate habitat and fish response to dam removal, and additional assessment of habitat limiting factors will be needed to refine understanding of limiting factors.

7.4.1.2 Estuary Habitat Limiting Factors[21]

As stream-type fish, spring Chinook salmon spend less time in the Columbia River estuary and plume than do ocean-type salmon such as fall Chinook, yet estuary habitat conditions nevertheless play an important role in the survival of spring Chinook salmon juveniles, particularly those displaying less dominant life history strategies. Water quantity issues related to altered hydrology and flow timing are identified as a primary limiting factor for all populations, as is impaired sediment and sand routing; these limiting factors are associated with hydroregulation at large storage reservoirs in the interior of the Columbia Basin, and, in the case of sediment issues, land uses both past and present. Much of the land surrounding the Columbia River estuary is in agricultural or rural residential use and has been extensively modified via dikes, levees, bank stabilization, and tide gates. Altered hydrology and sediment routing influence habitat-forming processes, the quantity and accessibility of habitats such as side channels and wetlands, the dynamics of the Columbia River plume, and the estuarine food web. Channel structure issues, in the form of reduced habitat complexity and diversity, also are a primary limiting factor for juveniles from all populations. Again, simplification of

---

[20] Condit Dam, in the White Salmon subbasin, was breached in October 2011 and completely removed in September 2012.

[21] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the ESU, the estuarine limiting factors in this section and in Table 7-5 reflect the determinations in the Oregon management unit plan, applied to all Lower Columbia River spring Chinook salmon populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

channel structure is related to conversion of land to other uses—agricultural, rural residential, and as a transportation corridor.

Lack of access to peripheral and transitional habitats, such as side channels and wetlands, is a secondary limiting factor for juveniles from all populations, with access being impaired by land uses—including the transportation corridor—and by flow alterations caused by mainstem dams. Other secondary limiting factors in the estuary that affect all spring Chinook populations are exposure to toxic contaminants (from urban, industrial, and agricultural sources) and elevated late summer and fall water temperatures, which are related to (1) land use practices that impair riparian function or decrease streamflow, and (2) large hydropower reservoirs.[22] Altered food web dynamics involving a transition from a macrodetrital-based food web to a microdetrital-based food web also are considered a secondary limiting factor for all populations. [23] These changes in the estuarine food web are caused primarily by increased microdetrital inputs from hydropower reservoirs and the loss of wetland habitats through diking and filling.

7.4.1.3 Hydropower Limiting Factors

Tributary hydropower development is one of the main limiting factors for Lower Columbia River spring Chinook salmon (see Table 7-5). In addition, flow management operations at large storage reservoirs in the interior of the Columbia Basin (Grand Coulee, Dworshak, etc.) affect all juvenile Lower Columbia River spring Chinook salmon in the lower mainstem and estuary, and potentially in the plume—primarily by altering flow volume and timing. These alterations impair sediment routing, influence habitat-forming processes, reduce access to peripheral habitat, and change the dynamics of the Columbia River plume and the estuarine food web (see Section 7.4.1.2).[24] Moreover, the large reservoirs associated with mainstem dams contribute to elevated water temperatures downstream in late summer and fall. Although the management unit plans identified temperature impacts of the hydropower system as a secondary limiting factor for all juvenile spring Chinook salmon, migration of juvenile spring Chinook salmon occurs from March through July and peaks in May (Dawley et al. 1986, McCabe et al. 1986, Roegner et al. 2004, Bottom et al. 2008, cited in Figure 2.2 of Carter et al. 2009). Thus, it is unlikely that elevated mainstem temperatures are having a significant impact on juvenile spring Chinook salmon. For the Hood and White Salmon populations, which spawn above Bonneville Dam, passage issues at Bonneville and

[22] Although the management plans identified temperature impacts as a secondary limiting factor for juveniles of all populations, the timing of juvenile spring Chinook salmon migration raises questions about the significance of this limiting factor; see Section 7.4.1.3.
[23] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is unclear.
[24] It is likely that flow impacts of the hydropower system affect Lower Columbia River ESUs more through changes in habitat-forming processes (including impacts to the plume) and food web impacts than through changes in migratory travel time.

inundation of historical spawning habitat by the Bonneville Reservoir are identified as secondary limiting factors.[25]

In the Cascade stratum, tributary hydropower is a primary limiting factor for the Upper Cowlitz, Cispus, Tilton, and North Fork Lewis populations, which historically were among the most productive populations but which have been extirpated or nearly so as a result of blocked passage. In addition, tributary dams have had adverse impacts on downstream habitat through reduced gravel recruitment and other effects. Tributary hydropower issues related to downstream passage of juveniles were identified as a secondary limiting factor for Sandy spring Chinook salmon, but the PGE Bull Run Hydroelectric Project (which consisted of Marmot and Little Sandy dams) was removed in 2007-2008, so this is no longer a factor. There are no tributary hydropower facilities in the Toutle or Kalama subbasins.[26]

In the Gorge stratum, the presence of Condit Dam was identified as a primary limiting factor for the White Salmon population because, until recently, the dam blocked upstream passage to virtually all historical spring Chinook salmon spawning habitat. (Condit Dam was breached in October 2011 and completely removed in September 2012, so this limiting factor has been addressed.) Passage issues related to adult passage at Powerdale Dam in the Hood subbasin were identified as a secondary limiting factor, but the dam was removed in 2010. In addition, passage issues at Bonneville Dam have impacts on the Hood and White Salmon populations.

7.4.1.4 Harvest Limiting Factors

Harvest-related mortality is identified as a primary limiting factor for all spring Chinook salmon populations within the ESU except the Sandy, for which harvest is identified as a secondary limiting factor (because ODFW considered it more resilient to the impacts of harvest [ODFW 2010]). About three-quarters of the harvest that affects spring Chinook salmon takes place in ocean fisheries from Oregon to Alaska. Some harvest also occurs in commercial and recreational fisheries in the mainstem Columbia River below Bonneville Dam, in tributary fisheries targeting hatchery fish, and in Zone 6 tribal fisheries for Lower Columbia River spring Chinook salmon spawning above Bonneville Dam (a tribal fishery also targets the Hood population in the tributary). From 1980 to 1993, harvest rates on spring Chinook salmon harvest averaged 51 percent, but during the period since listing (i.e., 1999 to 2006) they dropped to approximately 20 percent (ODFW 2010).

Although both the Washington and Oregon recovery plans discuss harvest as a limiting factor for Lower Columbia River spring Chinook salmon, they do not consider baseline harvest rates as significant a limiting factor as dam passage constraints, tributary habitat degradation, and hatchery effects.

---

[25] The exact extent to which Bonneville Reservoir inundated habitats for any species is unknown. Some biologists have hypothesized impacts to spring Chinook salmon as a result of inundation. Based on spawning habitat preferences, it is likely that impacts of inundation were greatest on fall Chinook and chum salmon.

[26] However, the North Toutle sediment retention structure currently blocks access to as many as 50 miles of habitat for anadromous fish.

7.4.1.5 Hatchery-Related Limiting Factors

It is estimated that hatchery fish make up anywhere from 34 to 90 percent of spring Chinook salmon spawners, depending on the population in question (ODFW 2010, Table 4-8 and LCFRB 2010a, Table 3-8). Population-level effects resulting from stray hatchery fish interbreeding with natural-origin fish are identified as a primary limiting factor for all populations except the White Salmon. Hatchery straying, combined with past stock transfers, has likely altered the genetics of spring Chinook salmon populations and may have reduced diversity within the ESU. Productivity also has likely declined as a result of the influence of hatchery-origin fish. Notably, however, high proportions of hatchery-origin spawners are sometimes intentional because hatchery fish are being used to reintroduce spring Chinook salmon where they have been extirpated or nearly so (e.g., in the Hood, Cowlitz, and Lewis subbasins). In identifying hatchery-related limiting factors, the management unit plans evaluated only negative impacts of hatchery fish on productivity of natural fish and not the positive demographic benefits that such reintroduction programs can provide in the short term.

Some scientists suspect that closely spaced releases of hatchery fish from all Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the estuary. NMFS (2011a) and LCFRB (2010a) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon in freshwater, estuarine, and nearshore ocean habitats.

7.4.1.6 Predation

Direct mortality from predation is a secondary limiting factor for all spring Chinook salmon populations. Anthropogenic changes to the structure of habitat have increased predator abundance and effectiveness and led to increased predation by Caspian terns, double-crested cormorants and various other species of seabirds in the Columbia River estuary and plume. Gorge spring Chinook salmon also face secondary predation threats from non-salmonid fish (primarily pikeminnows above and below the dam but also walleye and smallmouth bass in the reservoir) and from marine mammals (primarily sea lions) at Bonneville Dam.

7.4.2 Spring Chinook Salmon Baseline Threat Impacts and Threat Reduction Targets

Table 7-6 shows the estimated impact on each Lower Columbia River spring Chinook salmon population resulting from potentially manageable threats, organized into six threat categories: tributary habitat degradation, estuary habitat degradation, hydropower, harvest, hatcheries, and predation. Both baseline and target impacts are shown, with the targets representing levels that would be consistent with long-term recovery goals. Impact values indicate the percentage reduction in abundance and productivity that is attributable to human activities related to a particular threat category. The value associated with any particular threat category can be interpreted as the percent reduction in abundance and productivity from historical conditions if that threat category were the only one affecting the population. The table also shows the overall percentage improvement that is needed to achieve the target impacts and corresponding population status.[27] These cumulative values across all threat categories (both baseline and target) are multiplicative rather than additive. Both the Oregon and Washington management unit plans use cumulative survivals across threat categories to illustrate the overall level of improvement needed. Each plan assumes that there is a direct proportional relationship between the projected changes in cumulative survival and the required changes in natural-origin spawner abundance and productivity. For populations where the survival improvement needed is larger than 500 percent, Table 7-6 does not report the exact value, in part because the value is highly uncertain.[28]

As an example, the baseline status of the Upper Cowlitz spring Chinook salmon population, circa 1999, has been severely reduced by the combined effects of multiple threats. The cumulative reduction in status was estimated at 99.8 percent from the multiplicative impacts of multiple threats acting across the salmon life cycle. Thus, current status is just 0.2 percent of the historical potential with no human impact. Tributary habitat, hydropower, harvest, and hatchery impacts each accounted for reductions in population productivity of 50 percent or more, with corresponding reductions in abundance, spatial structure, and diversity. The Washington management unit plan identifies a recovery strategy involving significant reductions in the impact of several threats. For instance, the plan targets tributary habitat impacts to be reduced from the estimated baseline level of 90 percent to 45 percent (i.e., an approximately 100 percent improvement relative to baseline conditions). With the targeted reductions in individual impacts, the cumulative effect of all impacts would drop from 99.8 percent at baseline to 86.1 percent at the target status. This change would translate into a more than 500 percent improvement in survival relative to the baseline. Although the population would still be experiencing abundance and productivity that are 74.7 percent lower than historical conditions, the extinction risk at this mortality level would be estimated sufficient to meet the targets for this plan.

Oregon and Washington recovery planners used somewhat different definitions or methods to quantify the estimated impacts of anthropogenic threats. Baseline impacts for Washington populations reflect conditions prevalent at the time of ESA listing (circa 1999), while the baseline impacts for Oregon populations reflect conditions through 2004. Dam impacts for Washington populations reflect passage mortality, habitat loss caused by inundation, and loss of access to historical production areas; for Oregon

---

[27] The percentage of survival improvement needed is the percentage change in net impacts, is derived from information in the Washington and Oregon management unit plans, and is calculated as follows: [(1-$\text{Cumulative}_{\text{Target}}$)-(1-$\text{Cumulative}_{\text{Baseline}}$)]/[1-$\text{Cumulative}_{\text{Baseline}}$] x 100. These values generally correspond to population improvement targets identified for Washington populations in LCFRB (2010). Comparable numbers are not explicitly reported in ODFW (2010) but are implicit in the modeling approach that Oregon recovery planners used to derive target impacts.

[28] For some populations—many of them small—the survival improvement needed is very large and highly uncertain because various other factors also are uncertain (i.e., the population's baseline persistence probability, the exact degree of impact of human activities on tributary habitat, and whether the population's response to reductions in impacts will be linear). In addition, very small populations do not necessarily follow predictable patterns in their response to changing conditions.

populations, the estimates of impacts in the "Dams" column of Table 7-6 reflect direct upstream and downstream passage mortality only, with other dam impacts accounted for in the habitat and predation threat categories. Hatchery impacts for Washington populations were limited to not more than 50 percent per population, in accordance with Hatchery Scientific Review Group (HSRG) assessments of the potential for genetic effects (Hatchery Scientific Review Group 2009); for Oregon populations, recovery planners used hatchery impact rates equivalent to one-half the rates at which hatchery fish were found on natural spawning grounds, based on analyzed relationships and reflecting concern about genetic and ecological effects. Washington recovery planners derived estimates of impacts to tributary habitat using the Ecosystem Diagnosis and Treatment (EDT) model. Oregon recovery planners estimated the mortality associated with estuary habitat degradation, hydropower, harvest, hatcheries, and predation and assigned all remaining mortality (relative to the difference between the current modeled abundance and estimated historical abundance) to tributary habitat. In general, the tributary habitat values in Table 7-6 have the highest degree of uncertainty relative to the other threat categories and, for Oregon populations, may include causes of mortality associated with the other threat categories but not directly captured in those mortality estimates. (See Section 5.5 for more on the methodologies used to estimate baseline impacts.)

Estimates of threat impacts are useful in showing the relative magnitude of impacts on each population. Given the differences in methodologies, some values in Table 7-6 for Oregon and Washington populations are not necessarily directly comparable. Thus, values for Oregon populations are most directly comparable to those for other Oregon populations, and values for Washington populations are most directly comparable to those for other Washington populations. Regardless of differences in specific threat impact definitions and methods, the net effect of changes from all threats is useful in understanding the magnitude of population improvement needed to achieve the target population status.

The target impacts in Table 7-6 represent one of several possible combinations of threat reductions that could conceivably close the conservation gap and lead to a population achieving its target status. The particular threat reductions shown in Table 7-6 reflect policy decisions and the methodologies and assumptions used by the different recovery planning teams. (For a description of how target impacts were developed, see Section 5.6.) In estimating impacts, management unit recovery planners evaluated each threat category independently (i.e., values in the table reflect the mortality of spring Chinook exposed to that particular category of threats, whether or not they are exposed to threats in the other categories). The estimates of baseline threat impacts have high levels of uncertainty and in many cases should be considered working hypotheses that are testable as part of recovery plan implementation. Despite this uncertainty, it is the expert judgment of NMFS and management unit scientists that, based on the best available information at this time, the estimates of baseline threat impacts provide a reasonable estimate of the relative magnitude of different sources of anthropogenic mortality and serve as an adequate basis for designing initial recovery actions.[29] As more and better

[29] As implementation proceeds, research, monitoring, and evaluation and adaptive management will be key in helping to refine scientific understanding of the impact of threats on population persistence and of the extent to which management actions are reducing threats.

information is collected, it will be applied to recovery efforts in an adaptive management framework.

As shown in Table 7-6, almost every spring Chinook salmon population is greatly affected by the loss and degradation of tributary habitat, and five populations—the Upper Cowlitz, Cispus, Tilton, North Fork Lewis, and White Salmon—have experienced impacts from tributary dams that are comparable to or even greater than those associated with other factors that affect tributary habitat. Accordingly, for most populations, the greatest gains in viability are expected from tributary habitat and dam passage improvements (combined with hatchery reintroduction programs). Exceptions are the Tilton—a stabilizing population that is expected to remain at its baseline status—and the Sandy and Hood populations, for which reductions in hatchery impacts are targeted to provide the greatest benefit.

Baseline hatchery and harvest impacts also are significant for most spring Chinook salmon populations. Although recent actions have substantially reduced harvest of spring Chinook salmon from baseline conditions, ancillary and precautionary actions are needed to ensure that harvest does not adversely affect conservation and recovery in the future. For all but the Tilton population, hatchery-related impacts are targeted to be reduced by half or more, with the largest reductions targeted in the Sandy and Hood populations.[30] Achieving recovery goals also will require improvements in predation management and estuary habitat impacts; however, net reductions in these threat categories are smaller than those for tributary habitat, hydropower, hatcheries, and harvest because the impacts of estuarine and predation threats are less.

Four of the nine spring Chinook salmon populations are targeted for significant reductions in every threat category, including hydropower (in the form of tributary dam removal or upstream and downstream passage improvements). These populations are the Upper Cowlitz, Cispus, North Fork Lewis, and White Salmon. Of these, only the White Salmon is not designated as primary.

More information on threat reduction scenarios, including methodologies used to determine baseline and target impacts, is available in the management unit plans (ODFW 2010, pp. 151-177 and LCFRB 2010a, pp. 4-30 through 4-33, and 6-49 through 6-52).

[30] See the discussion below, in Section 7.4.3.6, regarding use of out-of-ESU stock for reintroducing spring Chinook salmon in the Hood River.

Table 7-6

Impacts of Potentially Manageable Threats and Impact Reduction Targets Consistent with Recovery of LCR Spring Chinook Salmon Populations

	Impacts at Baseline[31]							Impacts at Target							% Survival Improve-ment Needed[39]
Population	T. Hab[32]	Est[33]	Dams[34]	Harv[35]	Hat[36]	Pred[37]	Cumul-ative[38]	T. Hab	Est	Dams	Harv	Hat	Pred	Cumul-ative	
Cascade Spring															
Upper Cowlitz (WA)	0.90	0.15	0.90	0.50	0.50	0.22	0.9983	0.45	0.08	0.45	0.25	0.25	0.11	0.8607	>500
Cispus (WA)	0.90	0.15	1.00	0.50	0.50	0.22	1.0000	0.45	0.08	0.50	0.25	0.25	0.11	0.8733	>500[40]

---

31 Impact figures represent a percentage reduction in abundance and productivity that is attributable to human activities related to a particular threat category. Methods used to estimate impacts differ for Oregon and Washington populations. For example, baseline impacts reflect conditions circa 1999 for Washington populations and through 2004 for Oregon populations. Given the methodological differences, impact figures are not necessarily directly comparable. See Sections 5.5 and 5.6 for more on methodologies.

32 Reduction in tributary habitat production potential relative to historical conditions. Oregon and Washington used different methods to estimate historical abundance. Oregon's approach, which incorporates safety margins and includes causes of mortality that are not captured in the other five threat categories, tends to indicate a higher potential impact from tributary habitat loss and degradation than does Washington's.

33 Reduction in juvenile survival in the Columbia River estuary as a result of habitat changes (relative to historical conditions); excludes predation.

34 Reflects passage mortality, habitat loss caused by inundation, and loss of access to historical production areas for Washington populations; for Oregon populations, dam impacts reflect direct passage mortality only.

35 Includes direct and indirect mortality.

36 Reflects only the negative impacts of hatchery-origin fish, such as high pHOS and low PNI (proportion of natural influence), not the benefits of conservation hatchery programs.

37 Includes the aggregate predation rate in the Columbia River mainstem and estuary by northern pikeminnow, marine mammals, Caspian terns, and cormorants.

38 Cumulative values (both baseline and target) are multiplicative rather than additive and are equal to $(1-[(1-M_{thab})(1-M_{est})(1-M_{dams})(1-M_{harv})(1-M_{hatch})(1-M_{pred})])$. Minor differences from numbers in ODFW 2010 are due to rounding.

39 Survival improvements indicate the percentage improvement (rounded to the nearest 10) in population survival needed to achieve target impacts and are derived from the cumulative values (baseline and target). For most populations this was calculated using the following equation: $[(1-Cumulative_{Target})-(1-Cumulative_{Baseline})]/[1-Cumulative_{Baseline}] \times 100$. These cumulative impact numbers are not explicitly reported in ODFW (2010) but are implicit in the modeling approach that Oregon recovery planners used to derive target impacts. For populations where the survival improvement needed is larger than 500 percent, this table does not report the exact value, for the reasons explained in Section 7.4.2

40 The Cispus population requires improvements in every threat category. However, given that hydropower impacts are 100 percent for this population, it will not benefit from improvements in other threat categories until some degree of passage is restored. Although passage improvements alone will not lead to recovery, how successful passage improvements are will greatly influence how much improvement is needed in the other threat categories. The Tilton population also has hydropower impacts of 100 percent but is a stabilizing population not targeted for improvements in any threat category. Because hydropower impacts are 100 percent for both these populations, the formula for percent survival improvement for these populations was modified to account for the 100 percent hydropower impacts (i.e., to avoid having to divide by zero).

Table 7-6

Impacts of Potentially Manageable Threats and Impact Reduction Targets Consistent with Recovery of LCR Spring Chinook Salmon Populations

	Impacts at Baseline[31]							Impacts at Target							% Survival Improve-ment Needed[39]
Population	**T. Hab[32]**	**Est[33]**	**Dams[34]**	**Harv[35]**	**Hat[36]**	**Pred[37]**	**Cumul-ative[38]**	**T. Hab**	**Est**	**Dams**	**Harv**	**Hat**	**Pred**	**Cumul-ative**	
Tilton (WA)	0.80	0.15	1.00	0.50	0.50	0.22	1.0000	0.80	0.15	1.00	0.50	0.50	0.22	1.0000	0
Toutle (WA)	0.90	0.15	0.00	0.50	0.50	0.22	0.9834	0.45	0.08	0.00	0.25	0.25	0.11	0.7467	>500
Kalama (WA)	0.90	0.15	0.00	0.50	0.50	0.22	0.9834	0.45	0.08	0.00	0.25	0.25	0.11	0.7467	>500
NF Lewis (WA)	0.40	0.15	0.95	0.50	0.50	0.22	0.9950	0.20	0.08	0.48	0.25	0.25	0.11	0.8084	>500
Sandy (OR)	0.94	0.10	0.08	0.25	0.27	0.12	0.9761	0.92	0.08	0.00	0.25	0.05	0.07	0.9512	100
Gorge Spring															
White Salmon (WA)[41]	0.70	0.14	0.96	0.50	0.50	0.27	0.9981	0.35	0.07	0.48	0.25	0.25	0.13	0.8462	>500
Hood (OR)	0.89	0.10	0.35	0.25	0.45	0.16	0.9777	0.82	0.08	0.12	0.25	0.05	0.07	0.9034	330

41 Baseline and target impacts for the Upper Gorge/White Salmon population are from LCFRB (2010a).

7.4.3 Spring Chinook Salmon Recovery Strategy

7.4.3.1 Strategy Summary

The recovery strategy for spring Chinook salmon is aimed at restoring the Cascade spring stratum to a high probability of persistence and improving the persistence probability of the two Gorge spring populations. Although the strategy involves threat reductions in all categories, the most crucial elements are as follows:

1. Protect and improve the Sandy spring Chinook salmon population, which is the best-performing population and the only Lower Columbia River spring Chinook salmon population with appreciable natural production. This will be accomplished by protecting high-quality, well-functioning spawning and rearing habitat, reducing the proportion of hatchery-origin spawners (pHOS), managing predation, and restoring tributary and estuarine habitat.[42]

2. Reestablish naturally spawning populations above dams on the Cowlitz and North Fork Lewis rivers, in areas that historically were highly productive, by improving adult and juvenile dam passage and developing hatchery reintroduction programs using broodstock from within-subbasin hatchery programs. Reestablishing populations in mid- to upper-elevation habitats is key to recovering the spring component of the Lower Columbia River Chinook salmon ESU.

3. Protect favorable tributary habitat and restore degraded but potentially productive habitat, particularly in the upper subbasins where spring Chinook salmon hold, spawn, and rear. Tributary habitat improvements are crucial for all populations.

4. Reestablish spring Chinook salmon in the White Salmon and Hood subbasins.

Very large improvements will be needed in the persistence probability of most spring Chinook salmon populations if the Lower Columbia River Chinook salmon ESU is to recover. (See Table 7-4 for the target persistence probability for each spring Chinook salmon population and Figure 7-6 for the gaps between baseline and target status.) Improving the status of the two Gorge populations will be difficult because of the challenges of reestablishing an extirpated population in the White Salmon subbasin after the removal of Condit Dam and of developing a locally adapted population in the Hood subbasin based on hatchery reintroduction. To compensate for limited prospects in the Gorge stratum, a goal of high persistence probability has been established for more than the minimum number of populations in the Cascade spring Chinook stratum.

The recovery strategy for spring Chinook salmon is a long-term, "all-H" approach in which plan implementers begin work on all of the elements described above immediately and implement actions associated with each of the six threat categories

[42] Some reduction in impacts on the Sandy population already have been achieved through removal of Marmot Dam and the Little Sandy River diversion in 2008 and protection of associated instream water rights for fish.

simultaneously.[43] As part of a series of 3- to 5-year implementation schedules, management unit planners will work with NMFS staff to prioritize individual actions within each threat category, rather than across threat categories (see Chapter 11 for more on implementation). Recovery will require improvements in every threat category, even those improvements in Table 7-6 that are relatively small. Although restoring effective passage into historical natural production areas in the upper Cowlitz and Lewis systems will be key in meeting recovery objectives for spring Chinook salmon, the full potential of dam passage improvements will be limited without significant habitat restoration and protection. Site-specific restoration is needed in upper subbasins immediately, along with implementation of tributary habitat protection and watershed-based restoration actions; these measures will ensure adequate habitat quantity and function for viable populations over the long term. Harvest rates will be maintained at their current relatively low level until actions in other threat categories have taken effect; once populations have been reestablished above tributary dams and natural production has increased, harvest rates can be reevaluated.

Key critical uncertainties that need to be addressed to support implementation of near-term actions relate to passage efficiencies past tributary dams, juvenile production in upper subbasins, the pace at which reintroduced populations become functional and self-sustaining, and the amount of pinniped predation on spring Chinook salmon in the Columbia River estuary (see Section 7.4.3.8).

The subsections below describe recovery strategies and near-term and long-term priorities for each threat category. For specific management actions in each threat category, linked to population and location, see the management unit plans (LCFRB 2010a, ODFW 2010, NMFS 2013).

7.4.3.2 Tributary Habitat Strategy

Spring Chinook salmon will benefit from the regional tributary habitat strategy described in Section 4.1.2. The regional strategy is directed toward protecting and restoring high-quality, well-functioning spring Chinook salmon and steelhead habitat through a combination of (1) site-specific management actions that will protect habitat and provide benefits relatively quickly, (2) watershed-based actions that will repair habitat-forming processes and provide benefits over the long term, and (3) landscape-scale programmatic actions that affect a class of activities (such as stormwater management or forest practices) over multiple watersheds. Actions of particular benefit to spring Chinook salmon focus on protecting and restoring floodplain connectivity and function, access to side channels and off-channel habitats, and habitat complexity and diversity, especially in mid- to high-elevation habitat. Improving riparian cover and recruitment of large wood to streams also will be a priority. Headwater areas are targeted for protection and restoration to maintain sources of cool, clean water and normative hydrologic conditions; this includes protecting intact forests, managing forest lands to protect watershed processes and habitat conditions (LCFRB 2010a), and restoring upland processes that will reduce inputs of fine sediment to the spawning

[43] Implementation of recovery actions to reduce threats in each category is already under way, although the scale of effort is less than that called for in this recovery plan.

gravel of spring Chinook salmon. The subsections below summarize additional, stratum-specific tributary habitat strategies for spring Chinook salmon.

Cascade Spring Chinook Salmon Tributary Habitat Strategies

In implementing the Lower Columbia River spring Chinook salmon tributary habitat strategy in the Cascade stratum, considerations include the following:

- Generally, habitat conditions are favorable in the upper portions of the Cowlitz, Cispus, and North Fork Lewis subbasins, where populations are targeted for high or high-plus persistence probability but where access has been blocked by dams. In these areas, protecting high-quality habitat and restoring upslope processes, valley floodplain function, and stream habitat diversity will be priorities. Large portions of these areas are in federal forest land, which highlights the importance of Northwest Forest Plan implementation to protect habitats in those areas.

- Particularly for the Washington populations, substantial restoration also will be needed in currently accessible areas. Because spring Chinook salmon use mid- to high-elevation valley habitats for spawning and rearing, restoration efforts will focus on such areas, both in historically highly productive watersheds as well as some where production potential is more limited. Actions will include those described above for spring Chinook salmon generally.

- Habitat conditions are generally favorable in the Sandy subbasin (this population is targeted for high persistence probability). Again, large portions of this subbasin are in federal forest land. Implementation of the City of Portland's Bull Run water supply habitat conservation plan will also play a key role in habitat restoration and protection in the Sandy subbasin. Under this plan, the city will implement habitat actions throughout the subbasin as mitigation for its water supply project on the Bull Run River.

- State or private forest land predominates in the upper portions of the Toutle, Kalama, and North Fork Lewis subbasins. These lands must be managed to protect and restore watershed processes.

Addressing passage barriers such as culverts will benefit Cascade spring Chinook salmon populations by restoring access to habitat in a number of locations, including the North Fork Lewis, Tilton, Cispus, and Upper Cowlitz subbasins. (In some cases, additional assessment is needed to inventory and prioritize these blockages.) For the Toutle population, addressing sedimentation and passage issues at the North Fork Toutle sediment retention structure will be key.

Assuming that the impacts of other threats are reduced to the levels shown in Table 7-6, the scale of habitat improvements needed for Cascade spring Chinook stratum populations is minimal in the case of the Sandy population and the Tilton population, which, as a stabilizing population, is expected to remain at its baseline status.[44] For the Upper Cowlitz, Cispus, Toutle, Kalama, and North Fork Lewis populations, baseline impacts to tributary habitat productivity are targeted to be reduced by 50 percent to meet recovery targets.

Gorge Spring Chinook Salmon Tributary Habitat Strategies

In implementing the Lower Columbia River spring Chinook salmon tributary habitat strategy in the Gorge stratum, considerations include the following:

- Gorge populations occur in watersheds that are largely federal, state, and private forest land. These lands must be managed to protect and restore watershed processes.

The Oregon management unit plan identifies an approximately 8 percent reduction in tributary habitat impacts needed to achieve the target status for the Hood spring Chinook salmon population. Site-specific actions will focus on restoring or creating off-channel and side-channel habitat (alcoves, wetlands, floodplains, etc.), providing access to off-channel and side-channel habitat, and restoring riparian areas and instream habitat complexity, including recruitment of large wood to streams. Because water quantity issues associated with irrigation withdrawals are identified as a limiting factor for the Hood spring Chinook salmon population, the Oregon management unit plan identifies a number of actions to address flow issues (e.g., ensure that low-head hydropower projects do not adversely impact winter streamflows and work the Oregon Water Resources Department and others to keep water saved through publicly funded water conservation efforts instream for fish).

In the White Salmon subbasin, all historical spring Chinook salmon habitat is assumed to be located above Condit Dam. The breaching of Condit Dam in October 2011 (with full removal in September 2012) created near-term negative effects in the habitat below the dam and the habitat within the footprint of the former reservoir because of sediment release and scouring. Long-term effects are expected to be positive because of restored natural flow and sediment transport regimes. The White Salmon plan outlines four broad tributary habitat strategies: (1) gain information to identify and prioritize habitat actions, (2) when the dam is removed, restore mainstem habitat, (3) protect and conserve natural ecological processes, and (4) improve habitat in upriver reaches (NMFS 2013). In the near term, evaluating the effects on of the dam breaching and removal on habitat and performing additional assessment of habitat limiting factors are high priorities.

7.4.3.3 Estuary Habitat Strategy

Improving Columbia River estuary habitat as described in the regional estuary habitat strategy will benefit all Columbia Basin ESUs, including Lower Columbia River spring Chinook salmon. (For a summary of the regional estuarine habitat strategy, see Section 4.2.2). The regional strategy reflects actions presented in the Oregon and Washington management unit plans to reduce estuarine habitat-related threats and is consistent with

---

[44] Because of dam passage issues and relatively low habitat quality, the Tilton population is expected to remain at its baseline probability persistence of very low.

actions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a).

The *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) assumes that feasible estuarine habitat improvements and predation management measures could result in a maximum increase of 20 percent in the number of spring Chinook salmon leaving the Columbia River estuary. Oregon and Washington management recovery planners set targets of reducing anthropogenically enhanced mortality in the estuary for spring Chinook salmon populations based on the estuary module and their own approaches to threat reductions (ODFW 2010, Tables 6-24 and 6-25; LCFRB 2010a, Table 6-2).

7.4.3.4 Hydropower Strategy

The hydropower recovery strategy for Lower Columbia River spring Chinook salmon is to address the impacts of tributary hydropower dams through implementation of FERC relicensing agreements and thereby reestablish viable spring Chinook salmon populations in the Upper Cowlitz, Cispus, and North Fork Lewis subbasins; achieve survival gains in the Sandy, White Salmon, and Hood populations; and maintain the Tilton population at its baseline persistence probability of very low. Accomplishing these objectives will involve the removal of FERC-licensed dams (completed in the Sandy, Hood, and White Salmon) and development of adult and juvenile passage systems and hatchery reintroduction programs in the Cowlitz (Upper Cowlitz, Cispus populations) and Lewis subbasins.[45]

The strategy also includes measures to improve passage survival at Bonneville Dam for the Hood and White Salmon populations and implementation of mainstem flow management operations designed to benefit spring migrants from the interior of the Columbia Basin; NMFS expects that these flow management operations will also improve survival in the estuary and, potentially, the plume for all Lower Columbia River salmon and steelhead populations. NMFS estimates that survival of spring Chinook salmon passing Bonneville Dam was 95.1 percent for juveniles from 2002 to 2009 and 98.6 percent for adults from 2002 to 2007 (NMFS 2008a). NMFS expected that implementation of actions in the 2008 FCRPS Biological Opinion and its 2010 Supplement would improve juvenile spring Chinook salmon survival at Bonneville Dam by less than ½ percent, and that adult survival would be maintained at recent high levels (NMFS 2008a). Consequently, Oregon did not incorporate survival benefits from passage improvements at Bonneville into the hydropower threat reduction targets for Oregon populations above Bonneville.[46] The Washington management unit plan assumed that actions identified in the 2008 FCRPS Biological Opinion and its 2010 Supplement would aid adults and juveniles from all Lower Columbia River spring Chinook salmon populations originating above Bonneville Dam. However, preliminary information indicates that survival gains for yearling Chinook at Bonneville Dam are higher than expected and are above 96 percent (U.S. Army Corps of Engineers 2011b).

---

[45] Spring Chinook salmon will likely also be reintroduced into the Tilton subbasin eventually, but those efforts will be delayed to facilitate reintroduction into the Upper Cowlitz and Cispus subbasins.
[46] Hydropower-related threat reduction targets for Oregon populations above Bonneville Dam are associated with removal of Powerdale Dam on the Hood River.

For more on actions to improve mainstem dam passage, see the regional hydropower strategy in Section 4.3.2.

In its management unit plan, Oregon incorporated several actions addressing impacts of the Columbia River hydropower system that are not included in the FCRPS Biological Opinion and its 2010 Supplement but that Oregon maintains are needed to benefit Lower Columbia River salmon and steelhead populations that spawn above Bonneville Dam. The state of Oregon's position is that the FCRPS action agencies should conduct operations in addition to those incorporated in the FCRPS Biological Opinion to address the needs of ESA-listed salmon and steelhead. Oregon is a plaintiff in litigation against various federal agencies, including NMFS, challenging the adequacy of measures in the FCRPS Biological Opinion and its 2010 Supplement. NMFS does not agree with Oregon regarding the need for or likely efficacy of the additional actions Oregon proposed in that litigation, including the actions in the Oregon management unit plan that are not part of the FCRPS Biological Opinion and its 2010 Supplement. For more detail on these actions and NMFS' view of them, see the regional hydropower strategy in Section 4.3.2.

The subsections below summarize stratum-level hydropower strategies for spring Chinook salmon.

Cascade Spring Chinook Salmon Hydropower Strategy

The Cascade-stratum hydropower strategy is crucial to successful recovery of the spring life history component of the Lower Columbia River Chinook salmon ESU. The strategy involves creating or improving passage at projects on the Cowlitz and Lewis rivers and using hatchery reintroduction programs to reestablish viable populations in the Upper Cowlitz, Cispus, and North Fork Lewis subbasins (the Tilton population, in the Cowlitz system, is not expected to improve above its baseline persistence probability of very low). These changes are being implemented under the terms of FERC relicensing agreements completed with Tacoma Power for the Cowlitz River Project (Settlement Agreement completed in 2000) and with PacifiCorp and the Cowlitz PUD for the Lewis River Hydroelectric Projects (Settlement Agreement in 2004). Although there are many challenges to reestablishing natural spawning above the dams, the upper portions of the Cowlitz, Cispus, and North Fork Lewis subbasins still have relatively intact and well-functioning habitat that support spring Chinook salmon spawning and rearing.

In the Cowlitz subbasin, the hatchery Barrier Dam prevents all volitional passage of anadromous fish above RM 49.5. Currently, spring Chinook salmon are collected, natural-origin fish are separated from hatchery broodstock, and natural-origin fish are transported upstream of Barrier, Mayfield, Mossyrock, and Cowlitz Falls dams and released into the Upper Cowlitz and Cispus rivers.[47] Spring Chinook salmon smolts are collected at Cowlitz Falls Dam, briefly held in stress-relief ponds, and released into the lower Cowlitz (LCFRB 2010a). Survival of juveniles through reservoirs and past dams is especially problematic in this system (LCFRB 2010a). Both upstream passage and downstream passage at these dams are expected to be improved as part of the 2002 FERC relicensing order. High collection rates of downstream migrants will be key to

[47] Spring Chinook salmon will likely also be reintroduced into the Tilton subbasin eventually, but those efforts will be delayed to facilitate reintroduction into the Upper Cowlitz and Cispus subbasins.

recovery of the populations above Cowlitz Falls. Tacoma Power will evaluate fish returns and survival through the reservoirs and assess passage options. Adult passage at Mayfield Dam will be by trap and haul unless certain settlement agreement criteria (fish sorting, productivity, etc.) are met. If met, then passage at Mayfield Dam is likely to be provided through construction of a ladder, whereas passage at the much larger Mossyrock Dam would likely be provided by either trap and haul or a tramway.

In the North Fork Lewis subbasin, three dams—Merwin, Yale, and Swift—block passage to the upper North Fork Lewis, starting with Merwin Dam at RM 20. As part of the 2004 FERC relicensing agreement with PacifiCorp and the Cowlitz Public Utility District, spring Chinook salmon will be reintroduced into habitat upstream of the three dams. Almost all remaining historical spring Chinook salmon spawning habitat for the North Fork Lewis population is located in the upper North Fork Lewis watershed, above Swift Reservoir (LCFRB 2010a). The keys to successful reintroduction will be adequate passage of adults to and juveniles from the upper watershed, hatchery supplementation, and habitat improvements. In addition, because hydroregulation on the Lewis River has altered the natural flow regime below Merwin Dam, further adjustments in flow regime may be needed to provide adequate flows for habitat formation, fish migration, water quality, floodplain connectivity, habitat capacity, and sediment transport.[48] However, floodplain and channel alterations in the lower river will limit the ability of changes in flow regime to restore lower floodplain function, so flow modifications will need to take place in concert with restoration of lower river floodplain function.

Downstream passage of juveniles through tributary hydropower projects was identified as a secondary limiting factor for the Sandy spring Chinook salmon population, but the PGE Bull Run Hydroelectric Project (consisting of Marmot and Little Sandy dams) was removed in 2007-2008, so this is no longer a limiting factor.

Gorge Spring Chinook Salmon Hydropower Strategy

Tributary hydropower impacts for the White Salmon and Hood populations largely have been addressed by the removal of Condit and Powerdale dams, respectively. Condit Dam, operated on the White Salmon River by PacifiCorp, was breached in October 2011 and, under the terms of a 1999 decommissioning agreement and a 2006 Biological Opinion, was completely removed in September 2012. Removal reopens access to 12.8 miles of historical spring Chinook salmon habitat (NMFS 2013). This represents virtually all the historical habitat for the White Salmon spring Chinook salmon population. Now that dam removal has been completed, natural escapement and production will be monitored for 4 to 5 years; if recolonization has not occurred adequately by that time, appropriate hatchery adults and/or juveniles may be released into the White Salmon River.

Powerdale Dam, on the Hood River, and also operated by PacifiCorp, was removed in 2010 under the terms of a settlement agreement reached in 2003. The dam acted as a partial barrier that delayed upstream migration of returning adults.[49] Removal of

---

[48] Changes in flow regime will need to consider the needs of all listed species in the Lewis Basin.

[49] Downstream migrants were not entrained or delayed at Powerdale Dam once hydropower operations were suspended in late 2006.

Powerdale will eliminate this hydropower-related mortality for the Hood spring Chinook salmon population.

Actions in the 2008 FCRPS Biological Opinion and its 2010 Supplement will also provide slight improvements in juvenile survival for the two Gorge spring Chinook salmon populations (see the regional hydropower strategy in Section 4.3.2).

7.4.3.5 Harvest Strategy

Harvest impacts on natural-origin spring Chinook salmon averaged about 51 percent per year around the time of listing and currently are around 20 percent (about half of which occurs in mixed-stock ocean fisheries). The Oregon management unit plan considers a baseline harvest rate of 25 percent to be consistent with recovery of natural-origin spring Chinook salmon and does not include reductions in harvest in its population threat reduction scenarios for spring Chinook salmon (ODFW 2010); however, the Oregon management unit plan does include ancillary and precautionary actions to ensure that harvest does not adversely affect conservation and recovery in the future.

The Washington management unit plan also estimated that fishery impacts of 25 percent were consistent with long-term objectives. For harvest in general, the Washington management unit plan recommends a phased harvest strategy involving lower near-term rates to reduce population risks until habitat has improved. Modeling in the plan shows a scenario in which spring Chinook salmon harvest rates would be managed for benchmarks of 15 to 25 percent for three consecutive 12-year evaluation periods (i.e., from 1999-2010, 2011-2022, and 2023-2034). The 15 to 25 percent benchmark reflects the possible need for (1) rates lower than 25 percent in some years to reduce the risk of critically low escapements in years of low ocean survival, and (2) fishery restrictions within selected subbasins to protect local populations (LCFRB 2010a). Then, the modeling shows that, assuming that habitat improvements have been achieved and hatchery reintroductions have been successful in establishing natural production, harvest impacts on natural-origin fish could then be higher, in the range of 20 to 30 percent (LCFRB 2010a). These modeling results are planning targets and not predictions of future harvest rates; managers will establish future harvest rates based on observed indicators in Lower Columbia River spring Chinook salmon populations.

Although near-term harvest impact reduction benchmarks have been met (in the case of the Washington management unit plan) or are not needed (in the case of the Oregon management unit plan), the plans do contain some actions related to spring Chinook salmon that are consistent with the regional harvest strategy (see Section 4.5.2). Most of these actions have either already been implemented or involve the continuation of ongoing efforts, including the following:

- Supporting mark-selective ocean fisheries when the Pacific Salmon Treaty is renegotiated in 2018 (ODFW 2010).

- Employing time and area restrictions to address specific annual or population concerns (LCFRB 2010a, ODFW 2010).

Over the long term, as reintroduction and passage improvement efforts begin to yield more natural production, it will be necessary to reevaluate harvest impacts and determine an appropriate harvest strategy.

Cascade Spring Chinook Salmon Harvest Strategy

The Lower Columbia River spring Chinook salmon harvest strategy described in Section 7.4.3.5 will benefit populations in this stratum.

Gorge Spring Chinook Salmon Harvest Strategy

The ESU-level harvest strategies described in Section 7.4.3.5 will benefit populations in this stratum. In addition, because Lower Columbia River spring Chinook salmon spawning above Bonneville Dam (i.e., the Hood population at present, but once they are reestablished, the White Salmon population as well) are intercepted in Zone 6 tribal fisheries, the Oregon management unit plan includes an action to discuss with tribes potential actions to reduce those impacts. (Potential actions include extending sanctuaries from the mouths of tributaries and/or modifying season length or timing.)

7.4.3.6 Hatchery Strategy

The regional hatchery described in Section 4.4.2 summarizes goals and approaches relevant to Lower Columbia River spring Chinook salmon. Goals for spring Chinook salmon include using hatchery broodstocks to reestablish populations that have been extirpated (the Hood) or whose access to spawning and rearing habitat has been blocked by hydropower dams (the upper Cowlitz, North Fork Lewis, and Cispus populations and, potentially, the White Salmon). In general, reducing hatchery impacts on natural-origin spring Chinook salmon will be accomplished by (1) changing hatchery practices related to broodstock selection and management, numbers of releases, and locations and timing of acclimation and releases, and (2) physically excluding hatchery-origin fish from natural spawning areas by using weirs, traps, or other measures. For the Sandy and Hood populations, lessening the effects of hatchery-origin fish on naturally produced fish is expected to provide greater benefit than any other general category of action.

Details of how the hatchery strategy will be implemented in each spring Chinook salmon stratum will be developed as part of the transition schedules, but the subsections below provide some information.

Cascade Spring Chinook Salmon Hatchery Strategy

The hatchery strategy for the Cascade spring Chinook stratum centers on using hatchery spring Chinook salmon to reestablish the Upper Cowlitz and Cispus populations in historically accessible habitats in the Cowlitz subbasin and to reestablish the North Fork Lewis population in historically accessible habitats in the Lewis subbasin. (The Tilton population is targeted to be maintained at very low persistence probability, in part because of relatively poor habitat quality.) For the Kalama and Sandy populations, hatchery strategies will be targeted at reducing impacts on naturally spawning fish while continuing to produce spring Chinook salmon that provide fish for harvest. No hatchery spring Chinook salmon are released into the Toutle subbasin.

In the Cowlitz and Lewis systems, outplanting of hatchery-origin juveniles and adults is considered the initial stage of reintroduction. In this stage, broodstock choices are limited to existing hatchery stocks. In the Cowlitz, the Cowlitz hatchery broodstock has had negligible out-of-basin influence and is considered consistent with the original Cowlitz naturally spawning stock (LCFRB 2010a). Hatchery fish will be used to (1) reintroduce natural production in appropriate areas of the basin and adjacent tributary streams, (2) develop a local broodstock to reestablish historical diversity and life history characteristics, and (3) provide fishery mitigation in a manner that does not post significant risks to natural populations as they rebuild (LCFRB 2010a). The reintroduction program will include development of a biologically appropriate relationship and management strategy for hatchery and wild broodstock over time (LCFRB 2010a). Other considerations will include the timing of juvenile releases to minimize impacts to natural-origin fish (LCFRB 2010a).

In the North Fork Lewis subbasin, the Lewis River spring Chinook salmon program will be used to reintroduce spring Chinook salmon upstream of the hydrosystem. The Lewis hatchery spring Chinook salmon broodstock was developed from outside stocks, principally Cowlitz spring Chinook salmon, but currently is sustained without transfer from other hatcheries. As part of the reintroduction programs, facilities and operational strategies for these hatchery programs will address space, broodstock development, rearing methods, transfer of fish, marking strategies, and monitoring and evaluation (LCFRB 2010a).

In the near term, managing fisheries to meet hatchery escapement goals in the Cowlitz and Lewis systems is critical because recovery of spring Chinook salmon in those systems depends on the success of hatchery reintroduction programs, including the ability to collect enough fish at the hatcheries to meet the needs of the reintroduction program. Managing fisheries to meet hatchery escapement goals is therefore a key near-term strategy that integrates both harvest and hatchery objectives. As the reintroduction proceeds and natural production is established above the dams, the hatchery programs may shift to integrated supplementation to reduce risks to reestablished natural populations (as a first priority) and to improve the fitness of the hatchery stock (as a secondary priority). A matrix will be developed to manage naturally spawning fish in the broodstock, adult escapement to natural production areas and to the hatcheries, and hatchery fish on the spawning grounds (LCFRB 2010a).

To minimize potential predation on subyearling fall Chinook and chum salmon, the Washington management unit plan also calls for hatchery spring Chinook salmon release strategies that encourage rapid migration through the lower Cowlitz and Lewis; these strategies include volitional release, optimum release size, and release downstream of principal chum rearing areas (LCFRB 2010a).

In the Kalama and Sandy subbasins, hatchery programs will continue to produce fish for harvest concurrent with efforts to reduce impacts of hatchery fish on the natural populations. The spring Chinook salmon hatchery program in the Kalama is operated for fishery enhancement but with a dual supplementation objective: spring Chinook salmon that exceed broodstock needs are released above lower Kalama Falls to spawn naturally. Here, hatchery strategies will focus on (1) developing protocols regarding how many fish to pass upstream and (2) integrating hatchery and wild broodstock in the future after wild production is established. In the Sandy subbasin, ODFW will implement actions designed to meet the pHOS target of 10 percent or less established by ODFW for populations in Oregon targeted for high persistence probability. These actions will include acclimation practices to reduce straying, use of flows to attract more fish to the hatchery, and, potentially, the use of a trap to sort hatchery-origin fish within Cedar Creek and/or at the acclimation facilities. The Sandy spring Chinook salmon program formerly was an integrated hatchery program and now is being operated as a segregated program. ODFW intends to develop a matrix to govern take of natural-origin adults for inclusion in hatchery broodstock once the population has recovered to levels that can support an integrated hatchery program. Achieving the pHOS target for the Sandy spring Chinook salmon population is a high priority because the Sandy is one of the healthiest spring Chinook populations in the ESU. If the target has not been achieved by the year 2022, NMFS will urge other means of reducing pHOS, such as reducing hatchery smolt releases or moving production to another subbasin.

Gorge Spring Chinook Salmon Hatchery Strategy

The hatchery strategy for the Gorge spring Chinook stratum involves the continuation of hatchery reintroduction efforts in the Hood subbasin, and a potential hatchery reintroduction program in the White Salmon subbasin now that Condit Dam has been removed. (The dam was breached in October 2011 and completely removed in September 2012.)

The historical spring Chinook salmon population in the Hood subbasin is considered extirpated, and Deschutes river stock (an out-of-ESU stock) is being used for a hatchery reintroduction program.[50] The recovery strategy calls for the program to continue and eventually be developed into an integrated hatchery/natural program. Specific strategies include moving toward in-basin rearing of hatchery spring Chinook salmon for better local adaptation of the Deschutes stock, working with the Confederated Tribes of Warm Springs to evaluate reintroduction and explore alternatives if the existing program is not successful, working with the Confederated Tribes of Warm Springs to develop a sliding scale for take of wild spring Chinook salmon broodstock for the integrated hatchery program, and installing an adult fish ladder and fish trap at Moving Falls to remove stray hatchery spring Chinook salmon from natural spawning areas.[51] The recovery strategy also includes reevaluation of the program at some point and exploration of alternatives (including alternative broodstock) if the current program is not successful.

The historical spring Chinook salmon population also is extirpated in the White Salmon subbasin because until recently Condit Dam, which is operated by PacifiCorp, has blocked access to virtually all historical spawning habitat. Under the terms of a 1999 FERC decommissioning agreement and a 2006 Biological Opinion, PacifiCorp breached Condit Dam in October 2011 and removed the dam in 2012. The White Salmon Working Group, which is composed of federal, state, and tribal fisheries managers as well as

---

[50] Some natural production is occurring in the Hood subbasin. At this time, the origin of that natural production is unknown.
[51] Note that ODFW 2010, p. 270, action ID 300 - HD, describes plans for a floating weir; subsequently, managers determined that a fish ladder and trap were more appropriate in this location.

representatives of PacifiCorp, recommended that, once the dam has been removed, natural escapement and production be monitored over a 4- to 5-year period, at which point the need and suitability for hatchery supplementation would be evaluated. If hatchery supplementation is needed, the working group has recommended that an integrated Klickitat hatchery spring Chinook salmon stock be developed and used as the brood source for juvenile release into the White Salmon subbasin.

The working group has noted that the 4- to 5-year monitoring period also will allow time to explore production capacity at the Klickitat Hatchery and develop the integrated spring Chinook salmon broodstock. The working group determined that the Klickitat Hatchery spring Chinook salmon program would be the best source of broodstock for reintroduction to the White Salmon, even though it is not part of the Lower Columbia River Chinook salmon ESU. Two other potential broodstock sources are the Lewis River hatchery spring Chinook salmon program in Washington and the Sandy River spring Chinook salmon program in Oregon. The Lewis River program was excluded from consideration for use in the White Salmon because it is needed for reintroduction efforts in the Lewis subbasin, and production in the Sandy River is constrained by broodstock collection and funding shortfalls (NMFS 2013).

In both the Hood and White Salmon subbasins, managers are either using (in the Hood) or considering using (in the White Salmon) out-of-ESU broodstock for reintroduction efforts. In general, these subbasins are in a transition area between the Lower Columbia and Mid-Columbia ESUs. The Deschutes population appears more aligned with the Mid-Columbia ESU and the Hood population with the Lower Columbia ESU, although geographically these subbasins are clearly part of a transitional area. There has been discussion among NMFS scientists about whether to recommend assigning populations in the Klickitat and White Salmon subbasin to the Lower Columbia or Mid-Columbia ESU. In its most recent 5-year review, NMFS noted the transitional nature of this area and that it would be reasonable to assign the Klickitat spring Chinook population to either ESU but recommended maintaining the existing ESU boundaries (75 *Federal Register* 50448). In addition, options for broodstock in the White Salmon and Hood subbasins are limited by extirpations and other factors.

In the case of the Hood population, NMFS is supportive of efforts to reestablish natural production in the Hood subbasin. As noted above, the current hatchery program in the subbasin uses broodstock from the adjacent Deschutes River hatchery program, a Mid-Columbia ESU stock. The natural stock restoration strategy for the Hood River should include periodic genetic assessments to determine whether there are indications of local adaptation and/or contributions representative of the Lower Columbia fall Chinook lineage. NMFS will work with co-managers throughout the implementation and adaptive management process to consider options for incorporating fish from the Lower Columbia Chinook salmon ESU into the Hood River population and to evaluate the most appropriate ESU membership of this population.

NMFS also supports efforts to reestablish natural production in the White Salmon subbasin, either through recolonization or through hatchery reintroduction, as appropriate, now that Condit Dam has been removed. (The dam was breached in October 2011 and completely removed in September 2012.) Because NMFS noted in its most recent 5-year review (76 *Federal Register* 50448) that it would be reasonable to reassign the Klickitat population to either the Middle Columbia or the Lower Columbia River Chinook salmon ESU, the use of Klickitat stock for reintroduction in the White Salmon subbasin provides a more fluid situation in terms of ultimate ESU membership than does the use of Deschutes stock in the Hood subbasin. As in the Hood, NMFS expects that future 5-year reviews will reevaluate the most appropriate ESU membership for Klickitat and White Salmon populations.[52]

7.4.3.7 Predation Strategy

The regional predation strategy (see Section 4.6.2) involves reducing predation by birds, fish, and marine mammals and will benefit all Lower Columbia ESUs, including spring Chinook salmon.

7.4.3.8 Critical Uncertainties

Each aspect of the spring Chinook salmon recovery strategy has a number of critical uncertainties. For all ESUs, there are uncertainties regarding how habitat actions will translate into changes in productivity and capacity (Roni et al. 2011). Prioritizing and identifying next steps in resolving uncertainties is a near-term priority. Critical uncertainties specific to the Lower Columbia River spring Chinook salmon recovery strategy include the following:

- Effective methods of providing adequate downstream passage efficiency for juveniles migrating past tributary dams
- Effectiveness of natural recolonization (White Salmon) and hatchery reintroduction programs (Cowlitz, North Fork Lewis, Hood) and the pace at which these populations become functioning and self-sustaining; appropriate stock to use where reintroduction is necessary
- Productivity of reintroduced stocks in upper portions of subbasins
- Effectiveness of efforts to reduce straying in the Sandy and Hood subbasins now that Marmot and Powerdale dams have been removed
- Short-term and long-term survival benefits and risks at the population scale as a result of changes in hatchery production, changes in hatchery operation, and under various harvest rates
- How to reduce the risks of harvest of very small populations while still maintaining harvest opportunities on hatchery-origin fish

[52] The NMFS Recovery Implementation Science Team is currently developing a two-part report on the subject of reintroductions in the Columbia River Basin. The first part will address general principles for planning and implementing a reintroduction effort for anadromous salmonids. The second part will evaluate the biological benefit of a reintroduction in Columbia Basin regions from which anadromous salmonids have been extirpated. The final report is expected in 2012.

- Adequacy of actions to protect and restore watershed processes in maintaining habitat quality in upper basins (where spring Chinook salmon spawn) in the face of climate change
- Degree of pinniped predation on spring Chinook salmon in the Columbia River estuary
- The historical role of the Gorge populations and the appropriate persistence probabilities for these populations
- Most appropriate boundary between the Mid-Columbia and Lower Columbia river Chinook salmon ESUs[53]

These critical uncertainties represent preliminary priorities identified by Oregon and Washington recovery planners and NMFS Northwest Regional Office and Northwest Fisheries Science Center staff during a November 2010 workshop. They are preliminary priorities only (and are not in ranked order); as described in Chapter 10 additional discussion among local recovery planners and NMFS staff will be needed to finalize future research priorities for Lower Columbia River steelhead.

The management unit plans identify more comprehensive critical uncertainties and research, monitoring, and evaluation needs that, along with the list above, will provide the basis for these future discussions. The White Salmon and Washington management unit plans have discrete sections on critical uncertainties for all of the ESUs in general (see Section 8.3 of NMFS 2013, pp. 8-4 through 8-6, and Section 9.6 of LCFRB 2010a, pp. 9-68 through 9-73), while the Oregon management unit plan embeds relevant critical uncertainties within subsections on monitoring and evaluation needs related to the four VSP parameters and five ESA listing factors (see Sections 8.4 and 8.5, respectively, of ODFW 2010). In addition, in June 2010, the *Lower Columbia Fish Recovery Board completed the Research, Monitoring, and Evaluation Program for Lower Columbia Salmon and Steelhead* as a companion to its recovery plan (LCFRB 2010b). This document also describes critical uncertainties. The list above also does not include critical uncertainties that apply to multiple ESUs; these will be discussed and considered as decisions are made in implementation. In addition, the critical uncertainties above are of a technical nature; there are also many critical uncertainties related to social, political, and economic issues.

Critical uncertainties are one element of research, monitoring, and evaluation (RME) and adaptive management, which will be key components of the spring Chinook salmon recovery strategy (see Chapter 10 for more discussion of RME and adaptive management for this recovery plan).

[53] In its 2011 5-year review (NMFS 2011b), NMFS discussed uncertainties regarding the most appropriate boundary between the Mid-Columbia and Lower Columbia River ESUs. NMFS stated that, given the transitional nature of the Klickitat River Chinook salmon population, it might be reasonable either to reassign that population from the Middle Columbia to the Lower Columbia River Chinook salmon ESU or to maintain the existing ESU boundary. NMFS recommended maintaining the existing boundary but will reexamine the issue in future 5-year reviews as new information becomes available.

7.5 Fall Chinook Salmon Analysis: Limiting Factors, Threat Reductions, and Recovery Strategies

7.5.1 Fall Chinook Salmon Limiting Factors

The tule fall Chinook salmon component of the Lower Columbia River Chinook salmon ESU is limited by a combination of factors: widespread habitat degradation in both tributaries and the Columbia River estuary; a history of high harvest rates and large-scale hatchery production, with associated population depletions, reductions in productivity, and loss of genetic diversity; the effects of tributary and mainstem dams on critical downstream habitat; and predation by native fish, birds, and marine mammals. In addition, the productivity and diversity of fall Chinook salmon continue to be affected by ongoing straying of hatchery fish, and harvest impacts continue to be significant. For some populations, spatial structure is constrained by dams; for many more populations, spatial structure is constrained by urban, agricultural, and transportation development in lowland areas; development also contributes to losses in abundance as habitat quality is reduced.

Table 7-7 and the text that follows summarize baseline limiting factors and threats for Lower Columbia River fall Chinook salmon strata based on population-specific limiting factors and threats identified in the management unit plans. In cases where conditions have changed significantly since the management unit plans' analyses of limiting factors and threats (e.g., if harvest rates have dropped or a dam is no longer present), this is noted in the text. Unless otherwise noted, NMFS agrees that the management unit plans' identification of limiting factors provide a credible hypothesis for understanding population performance and identifying management actions.

Because the individual management unit plans used somewhat different terms in identifying limiting factors, NMFS has translated those terms into standardized and more general terminology taken from a NMFS "data dictionary" of possible ecological concerns that could affect salmon and steelhead (Hamm 2012; see Section 5.4). In addition, in Table 7-7, NMFS has rolled up the population-specific limiting factors (see Appendix H) to the stratum level—a process that has resulted in some loss of specificity.

In addition, each management unit plan used a different approach for identifying limiting factors and threats (see Section 5.3). One difference relevant to the crosswalk is that while the Oregon management unit plan identified primary and secondary limiting factors for each population in each threat category,[54] the Washington management unit plan categorized limiting factors in this way only for habitat-related limiting factors, and the White Salmon plan and the estuary module did not use the primary and secondary terminology. For the crosswalk and this table, NMFS assigned primary and secondary status to non-habitat limiting factors for Washington populations (based on the Washington management unit plan's quantification of threat impacts, and the professional judgment of Lower Columbia Fish Recovery Board's staff and consultants). For populations that historically spawned in the White Salmon subbasin, NMFS staff inferred primary and secondary designations based on discussion in the Washington

[54] In the Oregon management unit plan, primary limiting factors are those that have the greatest impact and secondary limiting factors have a lesser but still significant impact.

and White Salmon management unit plans (LCFRB 2010a, NMFS 2013). It is likely that some apparent distinctions in results between Washington and Oregon populations are artifacts of differences in limiting factor assessment methodologies and not an actual difference in conditions or their effects on salmon and steelhead populations. In addition, there is not necessarily a bright line between primary and secondary limiting factor designations. Nevertheless, NMFS believes that the designations are useful, particularly for looking across ESUs and populations and identifying patterns (see Chapter 4).

The management unit plans provide more detail on limiting factors and threats affecting Lower Columbia River fall Chinook salmon, including magnitude, spatial scale, and relative impact, see the management unit plans (LCFRB 2010a, Chapter 3 and various sections of Volume II; ODFW 2010, pp. 116 to 128; and NMFS 2013, Chapter 5).[55] For a regional perspective on limiting factors and threats that affect multiple salmon and steelhead ESUs, see Chapter 4 of this recovery plan. For a description of the data dictionary and the "crosswalk" tables that NMFS used to correlate management unit terms for limiting factors with the standardized NMFS terminology at the population scale, and the approach for rolling up from the population to the stratum scale, see Section 5.4 and Appendix H.

Management unit recovery planners in Oregon and Washington recognized that six major categories of manageable threats—tributary habitat, estuary habitat, hydropower, harvest, hatcheries, and predation—were useful as an organizing construct for grouping limiting factors, quantifying impacts on population productivity, and determining how much different categories of threats would need to be reduced to close the gap between baseline and target population status. Planners in both Washington and Oregon quantified the impacts of each of these major threat categories on population status, along with a reduction in each impact that would be consistent with achieving population target status. The results of that analysis are presented in Section 7.5.2 and provide a related but slightly different perspective on limiting factors. The threat reduction targets also allow actions to be scaled to achieve a specific impact reduction, and to be linked to monitoring and performance benchmarks.

---

[55] Limiting factors shown in the table for the White Salmon population reflect information from both the Washington (LCFRB 2010a) and White Salmon (NMFS 2013) management unit plans.

Table 7-7

Baseline Limiting Factors and Threats Affecting LCR Fall Chinook Salmon: Stratum-Level Summary

Ecological Concern	Threat(s)	VSP Parameters Affected	Coast Fall	Cascade Fall	Gorge Fall
Tributary Habitat Limiting Factors					
Riparian Condition	Past and/or current land use practices	All	Secondary for Elochoman juveniles, primary for juveniles in all other populations	Secondary for Washougal juveniles, primary for juveniles in all other populations	Secondary for White Salmon juveniles, primary for juveniles in all other populations
Channel Structure and Form	Past and/or current land use practices/ transportation corridor	All	Secondary for Elochoman juveniles, primary for juveniles in all other populations	Secondary for Washougal juveniles, primary for juveniles in all other populations	Secondary for White Salmon juveniles, primary for juveniles in all other populations
Peripheral and Transitional Habitats: Side Channel and Wetland Conditions	Past and/or current land use practices/ transportation corridor	All	Secondary for Elochoman juveniles, primary for juveniles in all other populations	Secondary for Washougal juveniles, primary for juveniles in all other populations	Primary for Upper and Lower Gorge and Hood juveniles
Peripheral and Transitional Habitats: Floodplain Conditions	Past and/or current land use practices/ transportation corridor	All	Secondary for Elochoman juveniles, primary for juveniles in all other populations	Secondary for Washougal juveniles, primary for juveniles in all other populations	Primary for Upper and Lower Gorge and Hood juveniles
Sediment Conditions	Past and/or current land use practices/ transportation corridor	All	Primary for WA juveniles, secondary for juveniles in OR populations[56]	Secondary for OR and Washougal juveniles, primary for juveniles in all other WA populations	Primary for White Salmon juveniles,[57] secondary for Hood juveniles
Water Quality (Temperature)	Land uses that impair riparian function/decrease streamflow, dams	A,P,D	Primary for juveniles in WA populations	Primary for Toutle, Coweeman, Kalama, and Lewis juveniles, secondary for Clackamas (land use and dams), Sandy, Salmon Creek, and Washougal juveniles.	

[56] This distinction is likely an artifact of differences in limiting factor assessment methodologies between the two states and not an actual difference in sediment conditions in tributary streams or their effects on fall Chinook populations.
[57] The designation of sediment conditions as a primary limiting factor for White Salmon fall Chinook juveniles is based on presumed high fine sediment loads delivered from the former lakebed to the lower river, now that Condit Dam has been removed. The White Salmon management unit plan notes that the net effect of the removal of Condit Dam on habitat will need to be assessed (see Table 5-2 of NMFS 2013)..

Table 7-7

Baseline Limiting Factors and Threats Affecting LCR Fall Chinook Salmon: Stratum-Level Summary

Ecological Concern	Threat(s)	VSP Parameters Affected	Coast Fall	Cascade Fall	Gorge Fall
Water Quantity (Flow)	Dams, land use, and water withdrawals for irrigation, municipal uses, and hatchery operations	All	Primary for Youngs Bay and Big Creek, and Scappoose juveniles, secondary for Grays/Chinook adults, secondary for juveniles in all other populations	Secondary for juveniles in all populations	Secondary for Upper and Lower Gorge and Hood juveniles (land use and dams); primary for Hood juveniles (irrigation withdrawals)
Estuary Habitat Limiting Factors[58]					
Toxic Contaminants	Agricultural chemicals, urban and industrial practices	A,P,D	Secondary for juveniles in all populations		
Food[59] (Shift from macrodetrital- to microdetrital-based food web)	Dam reservoirs	All	Secondary for juveniles in all populations		
Peripheral and Transitional Habitats: Estuary Condition	Past and/or current land use practices, transportation corridor, mainstem dams	All	Primary for juveniles in all populations		
Channel Structure and Form	Past and/or current land use practices/ transportation corridor	All	Primary for juveniles in all populations		
Sediment Conditions	Past and/or current land use practices/transportation corridor, dams	All	Primary for juveniles in all populations		

[58] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the ESU, the estuarine limiting factors in this table and Section 7.4.1.2 reflect the determinations in the Oregon management unit plan, applied to all Lower Columbia River fall Chinook salmon populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

[59] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is unclear.

Table 7-7

Baseline Limiting Factors and Threats Affecting LCR Fall Chinook Salmon: Stratum-Level Summary

Ecological Concern	Threat(s)	VSP Parameters Affected	Coast Fall	Cascade Fall	Gorge Fall
Water Quality (Temperature)	Land uses that impair riparian function/decrease streamflow, dam reservoirs	A,P,D	Secondary for juveniles in all populations		
Water Quantity (Flow)	Columbia River mainstem dams	All	Primary for juveniles in all populations		
Hydropower Limiting Factors					
Habitat Quantity (Access)	Bonneville Dam	All			Secondary for adults and juveniles in all populations
Habitat Quantity (Inundation)	Bonneville Dam	All			Primary for Upper Gorge adults and juveniles, secondary for Hood juveniles and White Salmon adults
Habitat Quantity (Access)	Tributary Dams	All		Primary for Upper Cowlitz adults and juveniles, secondary for Sandy juveniles	Primary for White Salmon adults and juveniles, secondary for Hood adults and juveniles
Harvest Limiting Factors					
Direct Mortality	Fisheries	A,D	Primary for adults in all populations	Primary for adults in all populations	Primary for adults in all populations
Hatchery Limiting Factors					
Food[60]	Smolts from all Columbia Basin hatcheries competing for food and space in the estuary	All	Secondary for juveniles in all populations		
Population Diversity	Stray hatchery fish interbreeding with wild fish	A,P,D	Primary for adults in all populations	Secondary for Coweeman adults, primary for adults in all other populations	Secondary for White Salmon adults, primary for adults in all other populations
Predation Limiting Factors					
Direct Mortality	Land use	A,P,D	Secondary for juveniles in all populations		

[60] Some scientists suspect that closely spaced releases of hatchery fish from all Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the estuary. NMFS 2011a and LCFRB (2010) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon in freshwater, estuarine, and nearshore ocean habitats.

Table 7-7
Baseline Limiting Factors and Threats Affecting LCR Fall Chinook Salmon: Stratum-Level Summary

Ecological Concern	Threat(s)	VSP Parameters Affected	Coast Fall	Cascade Fall	Gorge Fall
Direct Mortality	Dams	A,P,D			Secondary for Upper Gorge and Hood juveniles (non-salmonid fish)

7.5.1.1 Tributary Habitat Limiting Factors

Impaired side channel and wetland conditions, along with degraded floodplain habitat, have significant negative impacts on juvenile tule fall Chinook salmon throughout the ESU and are identified as primary limiting factors for all populations except the Elochoman/Skamokawa, Washougal, and White Salmon, where they are identified as secondary factors. Extensive channelization, diking, wetland conversion, stream clearing, and, in some subbasins, gravel extraction have barred tule Chinook salmon from historically productive habitats and simplified much of the remaining tributary habitats, weakening watershed processes that are essential to the maintenance of healthy ecosystems. Degraded riparian conditions and channel structure and form issues are also a primary limiting factor for all populations except the Elochoman/Skamokawa, Washougal, and White Salmon, where they are identified as secondary factors. The lack of large woody debris and appropriately sized gravel in the remaining accessible tributary habitat has significantly reduced the amount of suitable spawning and rearing habitat for tule fall Chinook salmon.

Sediment conditions are identified as a primary limiting factor for all Washington populations except the Washougal (for which they are considered a secondary limiting factor) and are identified as a secondary limiting factor for the Oregon portion of the ESU.[61] The high density of forest and rural roads throughout the area, as well as timber harvest practices and other land use patterns on unstable slopes adjacent to riparian habitat, contributes to an abundance of fine sediment in tributary streams.[62] The resulting excess fine sediment covers spawning gravel, limiting egg development and incubation, and increases turbidity. In addition, water quality, specifically elevated water temperature brought about through land use, lack of functioning riparian habitat, and dam reservoirs, is a primary limiting factor for most Washington populations, along with the Clackamas and Sandy populations.

In the Coast fall Chinook stratum, tributary habitat limiting factors are largely the same as those described above for fall Chinook salmon as a whole. However, for the Youngs Bay, Big Creek, and Scappoose tule fall Chinook salmon populations, water quantity issues related to altered hydrology and flow timing also have been identified as a

[61] This distinction most likely is an artifact of differences in the limiting factor assessment methodologies used by Oregon and Washington and not an actual physical difference in sediment conditions in tributary streams or their effects on Chinook populations.
[62] By itself, road density is not necessarily a good measure of delivery of fine sediment to streams.

primary limiting factor. These water quantity issues are caused by land use practices on upland slopes that have reduced soil stability and vegetative cover, increased impermeable surfaces, and altered drainage systems, resulting in altered water storage and delivery to streams. Many stream systems have higher peak flows and lower base flows than they did historically (ODFW 2010). Past and current land uses in Coast ecozone watersheds have led to these conditions. Private and state forest land predominates in the upper reaches of these watersheds. Lower reaches are mostly in agricultural and rural residential use and have been extensively modified by bank stabilization, levees, and tide gates.

For the Cascade fall Chinook stratum, tributary habitat limiting factors are largely the same as those described above for fall Chinook salmon as a whole, except that spawning by the Clackamas, Sandy,[63] and Cowlitz fall Chinook salmon populations is also negatively by impaired gravel recruitment related to tributary dams. Land uses that have led to the conditions limiting habitat productivity in this stratum include forest management and timber harvest, agriculture, rural residential and urban development, and gravel extraction. A mix of private, state, and federal forest land predominates in the upper mainstem and headwater tributaries of the Cascade subbasins, while the lower mainstem and tributary reaches of most subbasins are characterized by agricultural and rural residential land use, with some urban development, especially in the Salmon Creek and lower Clackamas subbasins. The Oregon management unit plan notes that in the Clackamas subbasin, high water temperatures are attributed in part to hydropower reservoirs.

A unique issue in the Cascade fall Chinook stratum is legacy effects in the Toutle subbasin of the 1980 Mount St. Helen's eruption. The North Fork Toutle in particular was heavily affected by sedimentation from the eruption. A sediment retention structure was constructed on the North Fork Toutle in an attempt to prevent continued severe sedimentation of stream channels and associated flood conveyance, transportation, and habitat degradation problems. The structure currently blocks access to as many as 50 miles of habitat for anadromous fish. Although fish are transported around the structure via a trap and haul system, the structure remains a source of chronic fine sediment to the lower river; this reduces habitat quality and has interfered with fish collection at the base of the structure.

In the Gorge fall Chinook stratum, tributary habitat limiting factors are largely the same as those described above for fall Chinook salmon as a whole, save for some unique water quantity and habitat issues. Water quantity problems caused by irrigation withdrawals and low-head hydro diversions have been identified as primary limiting factors for the Hood population. Degraded habitat quality resulting from transportation corridor development and maintenance is considered a primary threat for the Upper and Lower Gorge populations and for Hood juveniles. These limiting factors result from past and current land uses that include a mix of private, state, and federal forest land in the upper mainstem and headwater reaches of the Gorge subbasins, and transportation

[63] Gravel recruitment may have improved since the removal of Marmot and Little Sandy dams in 2009; however, the Oregon management unit plan also identifies gravel recruitment as a result of the city of Portland's water supply system in the Bull Run watershed as a secondary limiting factor for the Sandy fall Chinook populations (ODFW 2010, p. 116).

and rural residential land uses, with some urban development, in lower mainstem and tributary reaches. Highway and transportation corridors run parallel to the Columbia River shoreline, traversing all creek drainages in ways that restrict access and disconnect upland and lowland habitat processes. Upper Gorge fall Chinook salmon also face habitat issues caused by inundation from Bonneville Reservoir.

Habitat within the White Salmon subbasin was altered by the breaching of Condit Dam (in October 2011, with full removal in September 2012). Alterations include near-term negative effects from sediment release and scouring. Scientists and managers expect long-term positive effects as the result of restoration of natural flow regimes and sediment transport, but monitoring is needed to evaluate habitat and fish response to dam removal, and additional assessment of habitat limiting factors will be needed to refine understanding of limiting factors.

7.5.1.2 Estuary Habitat Limiting Factors[64]

Estuary habitat conditions are important for juvenile fall Chinook salmon, which spend considerable time rearing in the estuary. Water quantity issues related to altered hydrology and flow timing are identified as a primary limiting factor for all populations, as is impaired sediment and sand routing; these limiting factors are associated with hydroregulation at large storage reservoirs in the interior of the Columbia Basin, and, in the case of sediment issues, land uses both past and present. Much of the land surrounding the Columbia River estuary is in agricultural or rural residential use and has been extensively modified via dikes, levees, bank stabilization, and tide gates. Altered hydrology and sediment routing influence habitat-forming processes, the quantity and accessibility of habitats such as side channels and wetlands, the dynamics of the Columbia River plume, and the estuarine food web. Channel structure issues, in the form of reduced habitat complexity and diversity, and reduced access to peripheral and transitional habitats such as side channels and wetlands also are identified as primary limiting factors for juveniles from all populations. Again, simplification of channel structure is related to conversion of land to other uses—agricultural, rural residential, and as a transportation corridor—while juveniles' access to side channels and wetlands is impaired by these same land uses but also by flow alterations caused by mainstem dams.

Secondary limiting factors in the estuary that affect tule fall Chinook salmon are exposure to toxic contaminants (from urban, agricultural, and industrial sources) and elevated late summer and fall water temperatures, which are related to (1) land use

[64] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the ESU, the estuarine limiting factors in this section and in Table 7-7 reflect the determinations in the Oregon management unit plan, applied to all Lower Columbia River fall Chinook salmon populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

practices that impair riparian function or decrease streamflow, and (2) large hydropower reservoirs. Altered food web dynamics involving a transition from a macrodetrital-based food web to a microdetrital-based food web also are considered a secondary limiting factor for all populations.[65] These changes in the estuarine food web are caused primarily by increased microdetrital inputs from hydropower reservoirs and the loss of wetland habitats through diking and filling.

For the Coast stratum populations in particular, improvements to estuary habitat may be crucial. Habitat analysis indicates that populations in the Coast ecozone historically relied on wetland areas at the confluences of the tributaries and the mainstem Columbia (Northwest Fisheries Science Center 2010).

7.5.1.3 Hydropower Limiting Factors

Direct hydropower impacts are low on most Lower Columbia River fall Chinook salmon populations, with the exception of the Upper Cowlitz, the Sandy, and the Gorge stratum populations. Flow management operations at large storage reservoirs in the interior of the Columbia Basin (Grand Coulee, Dworshak, etc.) affect all juvenile Lower Columbia River fall Chinook salmon in the lower mainstem and estuary, and potentially in the plume—primarily by altering flow volume and timing. These alterations impair sediment routing, influence habitat-forming processes, reduce access to peripheral habitat, and change the dynamics of the Columbia River plume and the estuarine food web (see Section 7.5.1.2).[66] Moreover, the large reservoirs associated with mainstem dams contribute to elevated water temperatures downstream in late summer and fall. For the Upper Gorge, Hood, and White Salmon populations, which spawn above Bonneville Dam, passage issues at Bonneville and inundation of historical spawning habitat by Bonneville Reservoir are identified as secondary limiting factors.

There are no large tributary dams in the Coast ecozone, but tributary dams affect Cascade and Gorge fall Chinook salmon populations. In the Cascade fall Chinook stratum, impaired habitat access and passage caused by tributary hydropower are identified as a primary limiting factor for the Upper Cowlitz fall Chinook salmon population. The hatchery Barrier Dam in the Cowlitz subbasin prevents all volitional passage of anadromous fish above RM 49.5. Passage of downstream fry for the Sandy fall Chinook salmon population also was identified as a secondary limiting factor; however, the PGE Bull Run Hydroelectric Project (consisting of Marmot and Little Sandy dams) in the Sandy subbasin was removed in 2007-2008, so this limiting factor has been addressed for the Sandy fall Chinook population. There are no tributary hydropower facilities in the Coweeman, Toutle, Kalama, East Fork Lewis, Salmon Creek, or Washougal subbasins.[67] The Clackamas River Hydro Project was not identified as a

---

[65] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is unclear.

[66] It is likely that flow impacts of the hydropower system affect Lower Columbia River ESUs more through changes in habitat-forming processes (including impacts to the plume) and food web impacts than through changes in migratory travel time.

[67] However, the North Fork Toutle sediment retention structure currently blocks access to as many as 50 miles of habitat for anadromous fish.

hydropower threat for the Clackamas fall Chinook salmon population, but the project does affect downstream habitat; these impacts are accounted for under the tributary habitat limiting factor. In Washington, the Merwin, Yale, and Swift dams block passage to the Upper North Fork Lewis (beginning with Merwin Dam at RM 20). However, recovery efforts for the Lewis River fall Chinook salmon population are focused in the East Fork and lower North Fork Lewis subbasins, so the Merwin, Yale, and Swift dams are not identified as a limiting factor for fall Chinook salmon. Spawning and rearing habitats for the Lower Cowlitz and Lewis River fall Chinook salmon populations are adversely affected by flow regulation in the Cowlitz and Lewis river hydropower systems, respectively (LCFRB 2010a).

In the Gorge fall Chinook stratum, tributary hydropower impacts were identified as a primary limiting factor for the White Salmon fall Chinook salmon population (because, until recently, Condit Dam has blocked all upstream passage on the White Salmon River) and a secondary limiting factor for the Hood population (because of impaired access to historical spawning habitat). Powerdale Dam on the Hood River was removed in 2010, so that limiting factor has been addressed. Condit Dam was breached in October 2012 and completely removed in September 2012, so that limiting factor also has been addressed. Tributary hydropower is not a limiting factor for the Lower Gorge or Upper Gorge populations. However, for the three tule fall Chinook salmon populations that spawn above Bonneville Dam (the Hood, White Salmon, and Upper Gorge), passage issues at the dam and inundation of historical habitat by Bonneville Reservoir are secondary limiting factors.

7.5.1.4 Harvest Limiting Factors

Harvest-related mortality is identified as a primary limiting factor for all tule fall Chinook salmon populations. Tule fall Chinook salmon harvest occurs primarily in Alaskan and Canadian ocean fisheries regulated under the U.S.-Canada Pacific Salmon Treaty. Additional harvest occurs in U.S. ocean commercial, tribal, and recreational fisheries off the Washington Coast and in mainstem Columbia River gillnet and recreational fisheries. Harvest impacts were as high as 69 percent during the years 1983 to 1993. Since then they have been lowered steadily and significantly. For example, from 1999 to 2006, harvest rate averaged 48 percent; tule fall Chinook salmon harvest rates recently have been further reduced—to 38 percent in 2009 and 2010 and 37 percent in 2011 (NMFS 2008c). Harvest impacts on the Youngs Bay and Big Creek populations are higher—estimated by ODFW to average 75 and 65 percent, respectively, from 1997 to 2007—as a result of terminal fisheries targeting hatchery-origin fish in those subbasins. The Upper Gorge, Hood, and White Salmon populations also are subject to slightly higher harvest rates than the average for the ESU because they are intercepted in Zone 6 tribal fisheries above Bonneville Dam.

7.5.1.5 Hatchery-Related Limiting Factors

Most fall Chinook salmon currently returning to lower Columbia tributaries are produced in hatcheries operated to produce fish for harvest. Hatchery production has been reduced from its peak in the late 1980s but continues to threaten the productivity of Lower Columbia River fall Chinook salmon. Population-level effects resulting from hatchery fish interbreeding with natural-origin fish are a primary limiting factor for all populations. Hatchery straying, combined with past stock transfers, has likely altered the genetics of fall Chinook salmon populations and may have reduced diversity within the ESU. Out-of-ESU Rogue River bright fall Chinook salmon released into Youngs Bay to support terminal harvest have been recovered in the Grays River, potentially affecting genetics and diversity within that population. Productivity also has likely declined as a result of the influence of hatchery-origin fish. In addition, many scientists suspect that competition with or predation by hatchery-origin fall Chinook salmon affects natural population productivity.

Some scientists suspect that closely spaced releases of hatchery fish from all Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the estuary. NMFS (2011a) and LCFRB (2010a) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon in freshwater, estuarine, and nearshore ocean habitats.

7.5.1.6 Predation Limiting Factors

Direct mortality from predation is a secondary limiting factor for all fall Chinook salmon populations. Anthropogenic changes to habitat structure have increased predator abundance and effectiveness and led to increased predation by Caspian terns, double-crested cormorants, and various other seabird species in the Columbia River estuary and plume. Predation by non-salmonid fish (primarily northern pikeminnows) throughout the freshwater portions of the lower Columbia mainstem, but primarily at Bonneville Dam and hatchery release locations, is a secondary limiting factor for Upper Gorge and Hood juvenile tule fall Chinook salmon populations.

7.5.2 Fall Chinook Salmon Baseline Threat Impacts and Threat Reduction Targets

Table 7-8 shows the estimated impact on each Lower Columbia River fall Chinook salmon population resulting from potentially manageable threats, organized into six threat categories: tributary habitat degradation, estuary habitat degradation, hydropower, harvest, hatcheries, and predation. Both baseline and target impacts are shown, with the targets representing mortality levels that would be consistent with long-term recovery goals. Impact values indicate the percentage reduction in abundance and productivity that is attributable to human activities related to a particular threat category. The value associated with any particular threat category can be interpreted as the percent reduction in abundance and productivity from historical conditions if that threat category were the only one affecting the population. Cumulative values (both baseline and target) are multiplicative rather than additive. The table also shows the percentage improvements in population productivity and abundance (i.e., the percentage improvement in survival) that is needed to achieve the target impacts and corresponding population status.[68] For populations where the survival improvement needed is larger than 500 percent, Table 7-8 does not report the exact value, in part because the value is highly uncertain.[69]

As an example, the baseline status of the Grays/Chinook fall Chinook salmon population, circa 1999, has been severely reduced by the combined effects of multiple threats. The cumulative reduction in status was estimated at 92.6 percent from the multiplicative impacts of multiple threats acting across the salmon life cycle. Thus, current status is just 7.4 percent of the historical potential with no human impact. Tributary habitat, harvest, and hatchery impacts each accounted for reductions in population productivity of 40 percent or more, with corresponding reductions in abundance, spatial structure, and diversity. The Washington management unit plan identifies a recovery strategy involving significant reductions in the impact of several threats. For instance, the plan targets tributary habitat impacts to be reduced from the estimated baseline level of 40 percent to 16 percent (i.e., an approximately 120 percent improvement relative to baseline conditions). With the targeted reductions in individual impacts, the cumulative effect of all impacts would drop from 92.6 percent at baseline to 81.1 percent at the target status. This change would translate into a 150 percent improvement in survival relative to the baseline. Although the population would still be experiencing abundance and productivity that are 74.7 percent lower than historical conditions, the extinction risk at this mortality level would be estimated sufficient to meet the targets for this plan.

Oregon and Washington recovery planners used somewhat different definitions or methods to quantify the estimated impacts of anthropogenic threats. Baseline impacts for Washington populations reflect conditions prevalent at the time of ESA listing (circa 1999), while the baseline impacts for Oregon populations reflect conditions through 2004. Dam impacts for Washington populations reflect passage mortality, habitat loss caused by inundation, and loss of access to historical production areas; for Oregon populations, the estimates in the "Dams" column of Table 7-8 reflect direct upstream and downstream passage mortality only, with other dam impacts accounted for in the habitat and predation threat categories. Hatchery impacts for Washington populations were limited to not more than 50 percent per population, in accordance with Hatchery Scientific Review Group (HSRG) assessments of the potential for genetic effects (Hatchery Scientific Review Group 2009); Oregon recovery planners estimated that hatchery impacts were equivalent to one-half the rates at which hatchery fish were found on natural spawning grounds, based on analyzed relationships and reflecting

[68] The percentage of survival improvement needed is the percentage change in net impacts, is derived from information in the Washington and Oregon management unit plans, and is calculated as follows: $[(1-\text{Cumulative}_{\text{Target}})-(1-\text{Cumulative}_{\text{Baseline}})]/[1-\text{Cumulative}_{\text{Baseline}}] \times 100$. These values generally correspond to population improvement targets identified for Washington populations in LCFRB (2010). Comparable numbers are not explicitly reported in ODFW (2010) but are implicit in the modeling approach that Oregon recovery planners used to derive target impacts.

[69] For some populations—many of them small—the survival improvement needed is very large and highly uncertain because various other factors also are uncertain (i.e., the population's baseline persistence probability, the exact degree of impact of human activities on tributary habitat, and whether the population's response to reductions in impacts will be linear). In addition, very small populations do not necessarily follow predictable patterns in their response to changing conditions.

concern about genetic and ecological effects. Washington recovery planners derived estimates of impacts to tributary habitat using the Ecosystem Diagnosis and Treatment (EDT) model. Oregon recovery planners estimated the mortality associated with estuary habitat degradation, hydropower, harvest, hatcheries, and predation and assigned all remaining mortality (relative to the difference between the current modeled abundance and estimated historical abundance) to tributary habitat. In general, the tributary habitat values in Table 7-8 have the highest degree of uncertainty relative to the other threat categories and, for Oregon populations, may include causes of mortality associated with the other threat categories but not directly captured in those mortality estimates. (See Section 5.5 for more on the methodologies used to estimate baseline impacts.)

Estimates of threat impacts are useful in showing the relative magnitude of impacts on each population. Given the differences in methodologies, some values in Table 7-8 for Oregon and Washington populations are not necessarily directly comparable. Thus, values for Oregon populations are most directly comparable to those for other Oregon populations, and values for Washington populations are most directly comparable to those for other Washington populations. Regardless of differences in specific threat impact definitions and methods, the net effect of changes from all threats is useful in understanding the magnitude of population improvement needed to achieve the target population status.

The target impacts in Table 7-8 represent one of several possible combinations of threat reductions that could conceivably close the conservation gap and lead to a population achieving its target status. The particular threat reductions shown in Table 7-8 reflect policy decisions and the methodologies and assumptions used by the different recovery planning teams. (For a description of how target impacts were developed, see Section 5.6.) In estimating impacts, management unit recovery planners evaluated each threat category independently (i.e., values in the table reflect the mortality of Chinook salmon exposed to that particular category of threats, whether or not they are exposed to threats in other categories). The estimates of baseline threat impacts have high levels of uncertainty and in many cases should be considered working hypotheses that are testable as part of recovery plan implementation. Despite this uncertainty, it is the expert judgment of NMFS and management unit scientists that, based on the best available information at this time, the estimates of baseline threat impacts provide a reasonable estimate of the relative magnitude of different sources of anthropogenic mortality and serve as an adequate basis for designing initial recovery actions.[70] As more and better information is collected, it will be applied to recovery efforts in an adaptive management framework.

As shown in Table 7-8, the baseline impacts from harvest, hatcheries, and loss and degradation of tributary habitat are significant for every fall Chinook salmon population. Only for the Upper Cowlitz, Upper Gorge, and White Salmon populations does another threat category (hydropower) rise to the level of harvest, hatchery, and tributary habitat impacts. Estuarine habitat impacts likewise consistently affect all populations, although to a lesser degree than tributary habitat impacts.

---

[70] As implementation proceeds, research, monitoring, and evaluation and adaptive management will be key in helping to refine scientific understanding of the impact of threats on population persistence and of the extent to which management actions are reducing threats.

In the Coast and Cascade strata, much of the gains in fall Chinook salmon viability are targeted to be achieved through reductions in harvest, hatchery, and habitat impacts. This is the case for the Grays/Chinook, Elochoman/Skamokawa, Toutle, East Fork Lewis, Sandy, and Washougal populations. For the Scappoose population, target status is expected to be achieved primarily through reductions in hatchery and harvest impacts. In the Gorge stratum, some threat reductions are also targeted from hydropower actions, as the Upper Gorge, White Salmon, and Hood populations have been affected by dam passage issues at Bonneville, Powerdale, and Condit dams. (Powerdale Dam, on the Hood River, was removed in 2010; Condit Dam was breached in October 2011 and completely removed in September 2012).

Impacts from multiple threat categories will be needed for most populations if they are to achieve their target status. Exceptions are the Youngs Bay, Big Creek, Upper Cowlitz, and Salmon Creek populations. As stabilizing populations, the Youngs Bay, Upper Cowlitz, and Salmon Creek populations are not targeted for reductions in any threat impacts. (However, recovery actions will still be needed for these populations to remain at their baseline status of low [for Youngs Bay] or very low.) Both the Youngs Bay and Big Creek populations will be used to provide harvest opportunity through terminal fisheries targeting hatchery fish; consequently, the proportion of hatchery-origin spawners (pHOS) and harvest impacts in these populations are expected to remain high. The Salmon Creek population is not targeted for threat reductions because of the highly urbanized nature of the subbasin and the extent of habitat degradation there. In the Upper Cowlitz subbasin, spring Chinook salmon recovery efforts are the focus of the recovery strategy, so the Upper Cowlitz fall Chinook population is not targeted for improvement in status (although as of 2010, fall Chinook are being transported and released into the Upper Cowlitz).

Four of the 21 fall Chinook salmon populations are targeted for significant reductions in every threat category, including hydropower (in the form of dam removal or improvements in upstream and downstream passage). These populations are the Toutle, Upper Gorge, White Salmon, and Hood. Of these, the Toutle and Hood are designated as primary and the Upper Gorge and White Salmon as contributing. The Hood population is targeted for dramatic and almost certainly unattainable threat reductions (i.e., reducing all threat categories except hydropower to zero).[71]

Reductions in predation are also targeted to contribute to achieving recovery goals for fall Chinook salmon; however, net reductions in predation impacts are smaller than those for the habitat, hatcheries, and harvest categories because the impact of predation threats is less.

More information on threat reduction scenarios, including methodologies used to determine baseline and target impacts, is available in the management unit plans (ODFW 2010, pp. 151-177 and LCFRB 2010a, pp. 4-30 through 4-33, and 6-49 through 6-52).

[71] This is a function of the Oregon recovery planning team setting target status to meet recovery criteria, even if the criteria are likely to be unattainable because of intractable anthropogenic impacts. In addition, Oregon believes that the historical population structure designated in the Gorge stratum should be reassessed. For a discussion of this and other issues related to the Gorge strata and delisting criteria, see Sections 3.2.1 and 7.7.

Table 7-8

Impacts of Potentially Manageable Threats and Impact Reduction Targets Consistent with Recovery of LCR Fall Chinook Salmon Populations

Population	Impacts at Baseline[72]							Impacts at Target							% Survival Improvement Needed[80]
	T. Hab[73]	Est[74]	Dams[75]	Harv[76]	Hat[77]	Pred[78]	Cumulative[79]	T. Hab	Est	Dams	Harv	Hat	Pred	Cumulative	
Coast Fall															
Youngs Bay (OR)	0.72	0.32	0.00	0.75	0.45	0.07	0.9757	0.72	0.26	0.00	0.70	0.45	0.04	0.9672	30
Grays/Chinook (WA)	0.40	0.23	0.00	0.65	0.50	0.09	0.9264	0.16	0.09	0.00	0.26	0.20	0.03	0.5611	>500
Big Creek (OR)	0.80	0.32	0.00	0.65	0.45	0.06	0.9754	0.58	0.26	0.00	0.60	0.45	0.04	0.9344	170
Eloch/Skam (WA)	0.30	0.23	0.00	0.65	0.50	0.09	0.9142	0.21	0.17	0.00	0.46	0.35	0.06	0.7837	150
Clatskanie (OR)	0.99	0.32	0.00	0.60	0.45	0.07	0.9986	0.80	0.26	0.00	0.35	0.05	0.05	0.9132	>500
Mill/Aber/Germ (WA)	0.40	0.23	0.00	0.65	0.49	0.10	0.9258	0.29	0.17	0.00	0.47	0.35	0.07	0.8112	150
Scappoose (OR)	0.80	0.32	0.00	0.60	0.45	0.07	0.9722	0.78	0.26	0.00	0.35	0.05	0.05	0.9045	240
Cascade Fall															
Lower Cowlitz (WA)	0.70	0.23	0.00	0.65	0.50	0.10	0.9636	0.64	0.21	0.00	0.60	0.46	0.09	0.9441	50

72 Impact figures represent a percentage reduction in abundance and productivity that is attributable to human activities related to a particular threat category. Methods used to estimate impacts differ for Oregon and Washington populations. For example, baseline impacts reflect conditions circa 1999 for Washington populations and through 2004 for Oregon populations. Given the methodological differences, impact figures are not necessarily directly comparable. See Sections 5.5 and 5.6 for more on methodologies.

73 Reduction in tributary habitat production potential relative to historical conditions. Oregon and Washington used different methods to estimate historical abundance. Oregon's approach, which incorporates safety margins and includes causes of mortality that are not captured in the other five threat categories, tends to indicate a higher potential impact from tributary habitat loss and degradation than does Washington's.

74 Reduction in juvenile survival in the Columbia River estuary as a result of habitat changes (relative to historical conditions); excludes predation.

75 Reflects passage mortality, habitat loss caused by inundation, and loss of access to historical production areas for Washington populations; for Oregon populations, dam impacts reflect direct passage mortality only.

76 Includes direct and indirect mortality.

77 Reflects only the negative impacts of hatchery-origin fish, such as high pHOS and low PNI (proportion of natural influence), not the benefits of conservation hatchery programs.

78 Includes the aggregate predation rate in the Columbia River mainstem and estuary by northern pikeminnow, marine mammals, Caspian terns, and cormorants.

79 Cumulative values (both baseline and target) are multiplicative rather than additive and are equal to $(1-[(1-M_{thab})(1-M_{est})(1-M_{dams})(1-M_{harv})(1-M_{hatch})(1-M_{pred})])$. Minor differences from numbers in ODFW 2010 and LCFRB 2010a are due to rounding.

80 Survival improvements indicate the percentage improvement (rounded to the nearest 10) in population survival needed to achieve target impacts and are derived from the cumulative values (baseline and target), using the following equation: $[(1-Cumulative_{Target})-(1-Cumulative_{Baseline})]/[1-Cumulative_{Baseline}] \times 100$. These cumulative impact numbers are not explicitly reported in ODFW (2010) but are implicit in the modeling approach that Oregon recovery planners used to derive target impacts. For populations where the survival improvement needed is larger than 500 percent, this table does not report the exact value, for the reasons explained in Section 7.5.2. For the Oregon population designated as stabilizing (Youngs Bay), a survival improvement is shown because of improvements that are expected in tributary habitat, estuary conditions, and predation.

Table 7-8

Impacts of Potentially Manageable Threats and Impact Reduction Targets Consistent with Recovery of LCR Fall Chinook Salmon Populations

Population	Impacts at Baseline[72]							Impacts at Target							% Survival Improvement Needed[80]
	T. Hab[73]	Est[74]	Dams[75]	Harv[76]	Hat[77]	Pred[78]	Cumulative[79]	T. Hab	Est	Dams	Harv	Hat	Pred	Cumulative	
Upper Cowlitz (WA)	0.80	0.23	1.00	0.65	0.50	0.10	1.0000	0.80	0.23	1.00	0.65	0.50	0.10	1.000	0[81]
Toutle (WA)	0.60	0.23	0.05	0.65	0.50	0.10	0.9539	0.41	0.16	0.03	0.44	0.34	0.07	0.8348	260
Coweeman (WA)	0.50	0.23	0.00	0.65	0.23	0.10	0.9066	0.41	0.19	0.00	0.53	0.19	0.08	0.8326	80
Kalama (WA)	0.40	0.23	0.00	0.65	0.50	0.10	0.9272	0.31	0.18	0.00	0.51	0.39	0.08	0.8444	110
Lewis (WA)	0.40	0.23	0.00	0.65	0.50	0.11	0.9280	0.23	0.13	0.00	0.38	0.29	0.06	0.7228	290
Salmon Creek (WA)	0.90	0.23	0.00	0.65	0.50	0.11	0.9881	0.90	0.23	0.00	0.65	0.50	0.11	0.9880	0
Clackamas (OR)	0.82	0.32	0.00	0.60	0.45	0.07	0.9750	0.82	0.26	0.00	0.35	0.15	0.06	0.9308	180
Sandy (OR)	0.83	0.32	0.03	0.60	0.45	0.07	0.9771	0.57	0.26	0.00	0.35	0.15	0.06	0.8347	>500
Washougal (WA)	0.30	0.23	0.00	0.65	0.50	0.11	0.9161	0.20	0.15	0.00	0.43	0.33	0.07	0.7585	190
Gorge Fall															
L. Gorge — WA portion	0.70	0.23	0.30	0.65	0.50	0.11	0.9748	0.35	0.11	0.15	0.33	0.25	0.06	0.7677	>500
L. Gorge — OR portion	0.82	0.32	0.00	0.60	0.45	0.07	0.9750	0.59	0.26	0.00	0.35	0.30	0.06	0.8702	420
U. Gorge — WA portion	0.70	0.22	0.54	0.65	0.50	0.14	0.9838	0.35	0.11	0.27	0.33	0.25	0.07	0.8026	>500
U. Gorge — OR portion	0.80	0.32	0.13	0.65	0.45	0.09	0.9793	0.58	0.26	0.13	0.40	0.30	0.07	0.8944	410
White Salmon (WA)[82]	0.70	0.22	0.54	0.65	0.50	0.14	0.9838	0.35	0.11	0.27	0.33	0.25	0.07	0.8026	>500
Hood (OR)[83]	0.71	0.32	0.19	0.70	0.45	0.09	0.9760	0.00	0.00	0.10	0.00	0.00	0.00	0.1000	>500

81 The Upper Cowlitz population is a stabilizing population not targeted for improvements in any threat category. Because hydropower impacts are 100 percent for this population, the formula for percent survival improvement for these populations was modified to account for the 100 percent hydropower impacts (i.e., to avoid having to divide by zero).

82 Baseline and target impacts for the White Salmon population are from LCFRB (2010a).

83 Oregon's analysis indicates a low probability of meeting the delisting objective of high viability persistence probability for this population.

7.5.3 Fall Chinook Salmon Recovery Strategy

7.5.3.1 Strategy Summary

The recovery strategy for the tule fall component of the Lower Columbia River Chinook salmon ESU is designed to restore the Coast and Cascade tule strata to a high probability of persistence and to improve the persistence probability of all four Gorge-stratum populations. The strategy involves transitioning from decades of management that allowed habitat degradation and emphasized hatchery production of fish for harvest (without adequate regard to effects on natural production) to management that supports a naturally self-sustaining ESU. This transition will be accomplished by addressing all threat categories and sharing the burden of recovery across categories. The most crucial elements are as follows:

1. Protect and improve the Coweeman and Lewis populations, which are currently performing the best, by ensuring that habitat is protected and restored, that the proportion of hatchery-origin spawners (pHOS) is reduced, and that harvest rates allow for gains in productivity to translate into continued progress toward recovery.

2. Fill information gaps regarding the extent of natural production and the extent of hatchery-origin spawners.

3. Focus recovery efforts on populations that have the greatest prospects for improvement; determine whether efforts to reestablish populations are needed.

4. Protect existing high-functioning habitat for all populations.

5. Implement aggressive efforts to improve the quality and quantity of both tributary and estuarine habitat.

6. Implement aggressive efforts to reduce the influence of hatchery fish on natural-origin fish.

7. Adjust harvest as needed to ensure appropriate increases in natural-origin abundance.

8. Assess habitat quantity, quality, and distribution.

Transition strategies will be developed for each primary population that specify (1) timelines and strategies for reducing hatchery-origin spawners, (2) benchmarks for habitat improvement, (3) expected population response, and (4) harvest adjustments as needed to ensure appropriate increases in natural-origin abundance. These strategies will include adaptive management that provides a pathway for addressing critical uncertainties and that establishes benchmarks and adaptive actions if benchmarks are not met.

Transition strategies for non-primary populations will be developed to protect them from deterioration while moving them from high pHOS, with little or no natural production, through a period that addresses short-term demographic risks and reduces hatchery fractions while improving habitat conditions. Monitoring and evaluation will be critical in validating and, as appropriate, updating current assumptions regarding what is currently limiting the most poorly performing populations (i.e., assumptions about pHOS rates, the degree of local adaptation, the causes of the poor performance, and how the poorly performing populations contribute to the overall genetic diversity of their stratum and the ESU).

Very large improvements are needed in the persistence probability of most fall Chinook salmon populations if this component of the Lower Columbia River Chinook salmon ESU is to achieve recovery (see Table 7-4 for the target persistence probability for each fall Chinook salmon population and Figure 7-7 for the gaps between baseline and target status). Recovery prospects for fall Chinook salmon populations in the Gorge are constrained by very low abundance, limited habitat availability, and inundation of historically productive habitat by Bonneville Reservoir (LCFRB 2010a). As indicated in the delisting criteria (see Section 3.2), the recovery scenario for fall Chinook salmon does not meet the criteria for a high probability of persistence as defined by the WLC TRT; in addition, whether the recovery scenario for Gorge fall Chinook salmon can even be achieved is highly uncertain because of questions about the historical role of the Gorge populations and constrained opportunities for habitat restoration. To compensate for these limited recovery prospects, additional populations in the Coast and Cascade strata are prioritized for high persistence probabilities.

The recovery strategy for tule fall Chinook salmon is a long-term, "all-H" approach in which plan implementers begin work on all of the elements described above immediately and implement actions associated with each of the six threat categories simultaneously.[84] As part of a series of 5-year implementation schedules, management unit planners will work with NMFS staff to prioritize individual actions within each threat category, rather than across threat categories (see Chapter 11 for more on implementation). Recovery will require improvements in every threat category, even those improvements in Table 7-8 that are relatively small. Substantial actions are needed to improve tributary and estuarine habitat and reduce the effects of hatcheries, harvest, and hydropower; without significant improvements in all of these threat categories, the benefits of actions in any individual sector are unlikely to be fully realized and the expected threat reductions will not be achieved. Hatchery actions in particular are needed immediately to reduce impacts on natural-origin populations; however, the exact type and extent of actions will depend on the results of early monitoring to determine more clearly the actual pHOS rates among different populations. (Populations-specific pHOS rates are a critical uncertainty for fall Chinook salmon; see Section 7.5.3.8.) Harvest strategies also will be influenced by the results of monitoring. As natural production, abundance, and diversity eventually improve in populations that currently are performing poorly, harvest rates may need to be reevaluated to avoid impacts on these newly emerging weak stocks.

Monitoring and evaluation are particularly important in the short term to address critical uncertainties about Lower Columbia River tule Chinook salmon. Specific needs include improving information on fall Chinook escapements in the Clatskanie and

[84] Implementation of recovery actions to reduce threats in each category is already under way, although the scale of effort is less than that called for in this recovery plan.

Scappoose, identifying those habitat restoration strategies that have the most potential to improve production, and verifying assumptions about habitat conditions in key reaches in the priority populations (e.g., are we right to target fine sediment levels in spawning reaches as restoration priorities for poorly performing populations such as the Clatskanie and Elochoman/Skamokawa?).

The subsections below describe recovery strategies and near-term and long-term priorities for each threat category. For specific management actions in each threat category, linked to population and location, see the management unit plans (LCFRB 2010a, ODFW 2010, NMFS 2013).

7.5.3.2 Tributary Habitat Strategy

An aggressive, strategic approach is needed to protect and restore tributary and Columbia River estuary habitat, both of which are severely limiting for Lower Columbia River tule fall Chinook salmon. Fall Chinook salmon will benefit from the regional tributary strategy described in Section 4.1.2. The regional strategy is directed toward protecting and restoring high-quality, well-functioning salmon and steelhead habitat through a combination of (1) site-specific management actions that will protect habitat and provide benefits relatively quickly, (2) watershed-based actions designed to protect or restore habitat-forming processes and provide benefits over the long term, and (3) landscape-scale programmatic actions that affect a class of activities (such as stormwater management or forest practices) over multiple watersheds.

For fall Chinook salmon, the management unit plans set a high priority on reducing the impacts of sediment on survival to emergence and on improving juvenile rearing habitats, including reconnecting or restoring side channels and marsh habitats that are particularly critical to juvenile rearing of tule Chinook salmon. Priority site-specific actions will focus on protecting, restoring, or creating lowland floodplain function, riparian function, and stream habitat complexity. Priority restoration projects will include those to create or improve access to off-channel and side-channel habitat (alcoves, wetlands, floodplains, etc.) and restore riparian areas and instream habitat complexity; this includes improving recruitment of large wood to streams. Estuary/tributary confluence areas may also be a focus of site-specific actions, as habitat analysis indicates that substantial numbers of naturally produced juvenile Lower Columbia River fall Chinook salmon spend considerable time in such habitats (Cooney and Holzer 2010).

Near-term habitat actions should focus on implementing high-priority tributary actions that have already been identified, completing recovery plan implementation schedules, developing a prioritization and sequencing framework for habitat actions, and completing additional assessment work as part of developing the aforementioned transition strategy. This assessment effort should include identification of the amount and distribution of extant marsh-type habitats that are currently inaccessible for juvenile rearing in the tributaries used by Lower Columbia River tule Chinook salmon, along with identification of milestones or expected trends in improved habitat conditions in high-priority tributary and intertidal areas. The subsections below summarize additional, stratum-specific tributary habitat strategies for tule fall Chinook salmon.

Ultimately, restoration of adequate habitat for tules will be challenging because of the high proportion of habitat in private ownership.

Coast Fall Chinook Salmon Tributary Habitat Strategies

In implementing the Lower Columbia River fall Chinook salmon habitat strategy in the Coast fall stratum, considerations include the following:

- Lowland areas are primarily in agricultural or rural residential use. These areas have been extensively modified by dikes, levees, bank stabilization, and tide gates; efforts to protect and restore habitat complexity will be priorities here. Actions will include breaching, lowering, or relocating dikes and levees where possible to improve access to off-channel habitats for juvenile fall Chinook salmon, particularly in the Clatskanie, Scappoose, Grays, and Elochoman/Skamokawa subbasins (ODFW 2010, LCFRB 2010a).

- Upland areas are predominantly state and private timber land; these lands must be managed to protect and restore watershed processes (for example, through implementation of Washington's habitat conservation plan for state-owned forest land).

- Sediment source analyses and implementation of actions to reduce sediment will be needed in most Coast-stratum tributaries.

In addition to the actions described as part of the regional strategy for tributary habitat, the Washington management unit plan calls for restoring passage at culverts and other artificial barriers in the Elochoman/Skamokawa subbasin (LCFRB 2010a). The Oregon plan identifies a need to investigate whether headwater springs in the Youngs Bay, Big Creek, Clatskanie, and Scappoose subbasins are drying up as a result of land management practices.

Assuming that the impacts of other threats are reduced to the levels shown in Table 7-8, the scale of habitat improvements needed for the Coast fall Chinook stratum ranges from minimal in the Youngs Bay and Scappoose subbasins to a 20 to 30 percent increase in the productive capacity of tributary habitat in most subbasins. In the Grays subbasin, habitat productivity is targeted to increase by just over 60 percent.

Cascade Fall Chinook Salmon Tributary Habitat Strategies

In implementing the Lower Columbia River fall Chinook salmon habitat strategy in the Cascade stratum, considerations include the following:

- In the lower reaches of most Cascade subbasins, including the Lower Cowlitz, Coweeman, North Fork Lewis, East Fork Lewis, Toutle, Salmon Creek, and Clackamas, floodplains have been drastically altered or disconnected as a result of channel modification to facilitate and protect development, agricultural land, and, in some cases, gravel mining. Restoration of these areas will need to be balanced with the need to protect existing infrastructure and control flood risk.

- Upper portions of the East Fork Lewis, Washougal, Clackamas, and Sandy subbasins are primarily federal forest lands. Continued implementation of the Northwest Forest Plan will be crucial in protecting and restoring watershed processes in these areas.

- State or private forest land predominates in the upper portions of the Coweeman, Toutle, Kalama, North Fork Lewis, and Salmon Creek subbasins. These lands must be managed to protect and restore watershed processes (for example, through implementation of Washington's habitat conservation plan for state-owned forest land).

- The stratum includes the most heavily urbanized areas in the Columbia Basin. Managing the impacts of growth and development on watershed processes and habitat conditions will be key to the protection and improvement of habitat conditions for fall Chinook salmon in these areas.

In addition to the actions described as part of the regional strategy for tributary habitat, addressing passage barriers such as culverts will benefit fall Chinook salmon by restoring access to habitat in a number of locations, including the Lower Cowlitz, Kalama, and East Fork Lewis subbasins. (In some cases, additional assessment is needed to inventory and prioritize these blockages.) Addressing passage and sedimentation issues associated with the sediment retention structure on the North Fork Toutle River will be a key component for the Toutle population. Sediment issues in other watersheds will be addressed generally by restoring watershed processes and dealing with legacy road issues. In some cases (e.g., the Sandy), assessment to identify sediment sources is noted as a first step before additional actions can be taken. The Oregon management unit plan identifies a need to address flow issues in the Clackamas subbasin and incorporates a number of flow-related actions. In the Sandy subbasin, implementation of the city of Portland's Bull Run Water Supply habitat conservation plan will contribute significantly to the habitat improvements needed to achieve the recovery target.

Assuming that the impacts of other threats are reduced to the levels shown in Table 7-8, the scale of habitat improvements needed for Cascade fall Chinook stratum populations ranges from minimal (but with protection of well-functioning habitat) to just over 40 percent. The two stabilizing populations—Salmon Creek and Upper Cowlitz—are not targeted for improvements in habitat productivity, in the first case because production potential is low and in the second case because spring Chinook salmon recovery efforts in the Upper Cowlitz have been prioritized over fall Chinook salmon. The Lower Cowlitz is targeted for an 8 percent improvement in habitat productivity, and the Sandy, Toutle, Coweeman, Kalama, Washougal, and East Fork Lewis subbasins are targeted for habitat improvements on the order of 20 to 40 percent. Oregon estimated that, for the Clackamas population, existing habitat is adequate to achieve the targeted medium persistence probability, assuming that all other targeted threat reductions for that population are achieved. However, the Oregon plan notes that, because of multiple uncertainties, efforts should still be made to protect and restore habitat in the Clackamas subbasin.

Gorge Fall Chinook Salmon Tributary Habitat Strategies

In implementing the Lower Columbia River fall Chinook salmon habitat strategy in the Gorge stratum, considerations include the following:

- In the lower reaches of most Gorge tributary streams, floodplains have been drastically altered or disconnected as a result of channel modification to facilitate and protect development and transportation infrastructure. For the Lower Gorge population, site-specific actions will include addressing or mitigating the impacts of the highway and railroad transportation corridors that run parallel to the Columbia River shoreline, traversing all creek drainages in ways that restrict access and disconnect upland and lowland habitat processes.

- Gorge populations occur in watersheds that are largely federal, state, and private forest land. These lands must be managed to protect and restore watershed processes.

In addition to the actions described as part of the regional strategy for tributary habitat, the Oregon management unit plan identifies a number of actions to restore natural flows that have been disrupted by irrigation withdrawals in the Hood subbasin. Restoring floodplain connectivity and function is called for at locations below Bonneville Dam; however, there is little opportunity to implement floodplain measures above Bonneville Dam because much mainstem floodplain habitat was inundated by Bonneville Reservoir. For this reason, habitat efforts above the dam will rely on other strategies.

In the White Salmon subbasin, the breaching of Condit Dam in October 2011 (full removal was completed in September 2012) created near-term negative effects in the habitat below the dam and the habitat within the footprint of the former reservoir because of sediment release and scouring. Long-term effects are expected to be positive because of restored natural flow and sediment transport regimes. The White Salmon management unit plan outlines four broad tributary habitat strategies: (1) gain information to identify and prioritize habitat actions, (2) when the dam is removed, restore mainstem habitat, (3) protect and conserve natural ecological processes, and (4) improve habitat in upriver reaches (NMFS 2013). In the near-term, evaluating the effects of the dam breaching and removal on habitat and performing additional assessment of habitat limiting factors are high priorities.

Assuming that the impacts of other threats are reduced to the levels shown in Table 7-8, reductions in baseline tributary habitat impacts needed to meet target statuses range from 50 percent for the Lower and Upper Gorge and the White Salmon subbasins to a complete elimination of anthropogenically enhanced tributary habitat-related mortality in the Hood subbasin. (The Oregon management unit plan acknowledges that this is unattainable.)

7.5.3.3 Estuary Habitat Strategy

Estuarine habitat improvements are critical for Lower Columbia River fall Chinook salmon, which are severely limited by a paucity of intertidal marshes and similar estuarine wetlands that tules rely on for spawning, refuge, and extended rearing.

Improvements to estuary habitat may be especially important for Coast-stratum fall Chinook populations; outmigrant trapping and habitat analyses indicate that populations in the Coast ecozone historically relied on wetland areas at the confluences of the tributaries and the mainstem Columbia as juvenile rearing areas (Northwest Fisheries Science Center 2010). In addition, substantial numbers of naturally produced juvenile Lower Columbia River fall Chinook salmon spend significant time in estuary/tributary confluence habitats (Cooney and Holzer 2010).

Improving Columbia River estuary habitat as described in the regional estuary habitat strategy will benefit all Columbia Basin ESUs, including Lower Columbia River fall Chinook salmon. (For a summary of the regional estuarine habitat strategy, see Section 4.2.2.) The regional strategy reflects actions presented in the Oregon and Washington management unit plans to reduce estuarine habitat-related threats and is consistent with actions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). For fall Chinook salmon, the assessment process described as part of the regional strategy should include assessment of the tidal portions of tributaries and their confluence with the mainstem Columbia. (Recent NMFS modeling for selected Lower Columbia River tule populations indicates that such confluence habitat may be especially important for Coast- and Cascade-stratum populations [Northwest Fisheries Science Center 2010].) Developing implementation priorities for estuarine habitat actions also should include establishment of milestones or expected trends in improved habitat conditions in high-priority intertidal areas.

The *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) assumes that feasible estuarine habitat improvements and predation management measures could result in a maximum increase of 20 percent in the number of outmigrating juveniles leaving the Columbia River estuary. Oregon and Washington recovery planners set targets of reducing anthropogenically enhanced mortality in the estuary for fall Chinook salmon populations based on the estuary module and their own approaches to threat reductions (see ODFW 2010, Tables 6-13 and 6-21; LCFRB 2010a, Table 6-2).

Ultimately, restoring adequate habitat for tules in the Columbia River estuary will be challenging because of the high proportion of habitat in private ownership.

7.5.3.4 Hydropower Strategy

Because tule fall Chinook salmon are distributed low in tributary subbasins, reintroduction above tributary dam complexes is not critical to their recovery. However, the hydropower strategy includes actions to improve passage survival at tributary dams and reduce the effects of dam operation (e.g., flow management and water temperatures) on critical downstream habitats.

The strategy also includes measures to improve passage survival at Bonneville Dam for the Upper Gorge, Hood, and White Salmon populations and implementation of mainstem flow management operations designed to benefit spring migrants from the interior of the Columbia Basin; NMFS expects that these flow management operations will also improve survival in the estuary and, potentially, the plume for all Lower Columbia River salmon and steelhead populations. NMFS estimates that survival of

Lower Columbia River fall Chinook salmon passing Bonneville Dam was 95.1 percent for juveniles from 2002 to 2009 and 96.9 percent for adults from 2002 to 2007 (NMFS 2008a). NMFS expects that implementation of actions in the 2008 FCRPS Biological Opinion and its 2010 Supplement will improve juvenile fall Chinook salmon survival at Bonneville Dam by less than ½ percent, and that adult survival will be maintained at recent high levels (NMFS 2008a). Consequently, Oregon has not incorporated survival benefits from passage improvements at Bonneville into the hydropower threat reduction targets for Oregon populations above Bonneville.[85] The Washington management unit plan assumes that actions identified in the 2008 FCRPS Biological Opinion and its 2010 Supplement will aid adults and juveniles from all Lower Columbia River fall Chinook salmon populations originating above Bonneville Dam. For more on actions to improve mainstem dam passage, see the regional hydropower strategy in Section 4.3.2.

In its management unit plan, Oregon incorporated several actions addressing impacts of the Columbia River hydropower system that are not included in the FCRPS Biological Opinion and its 2010 Supplement but that Oregon maintains are needed to benefit Lower Columbia River salmon and steelhead populations that spawn above Bonneville Dam. The state of Oregon's position is that the FCRPS action agencies should conduct operations in addition to those incorporated in the FCRPS Biological Opinion to address the needs of ESA-listed salmon and steelhead. Oregon is a plaintiff in litigation against various federal agencies, including NMFS, challenging the adequacy of measures in the FCRPS Biological Opinion and its 2010 Supplement. NMFS does not agree with Oregon regarding the need for or likely efficacy of the additional actions Oregon proposed in that litigation, including the actions in the Oregon management unit plan that are not part of the FCRPS Biological Opinion and its 2010 Supplement. For more detail on these actions and NMFS' view of them, see the regional hydropower strategy in Section 4.3.2.

The subsections below summarize stratum-level hydropower strategies for fall Chinook salmon.

Coast Fall Chinook Salmon Hydropower Strategies

There are no tributary dams in the Coast ecozone, so the hydropower strategy for the Coast stratum is to implement the FCRPS flow management operations for spring migrants from the interior of the Columbia Basin; these flow management operations will also improve survival in the estuary and, potentially, the plume for all Lower Columbia River fall Chinook salmon populations.

Cascade Fall Chinook Salmon Hydropower Strategies

The primary element of the hydropower strategy for Cascade fall Chinook salmon is to address downstream impacts of operation of hydropower facilities in the Cowlitz and Lewis subbasins. These changes will be implemented under the terms of FERC relicensing orders for Tacoma Power's Cowlitz River Project in 2004 and for PacifiCorp and the Cowlitz PUD's Lewis River Hydroelectric Projects in 2002. In addition, the removal of PGE's Bull Run Hydroelectric Project (which consisted of Marmot and Little

---

[85] Hydropower-related threat reduction targets for Oregon populations above Bonneville Dam are associated with removal of Powerdale Dam on the Hood River.

Sandy dams) in the Sandy subasin in 2009 addressed downstream passage impacts for fry of the Sandy fall Chinook salmon population.

Recovery efforts for Chinook salmon in the Upper Cowlitz subbasin are focused on spring Chinook salmon, [86] while fall Chinook salmon recovery efforts are focused on the Lower Cowlitz population (targeted for medium-plus persistence probability) rather than on the Upper Cowlitz population (targeted to be maintained at very low persistence probability). Flow regimes from Cowlitz River hydropower system operations affect spawning and rearing habitat for the Lower Cowlitz fall Chinook salmon population, so the recovery strategy includes actions to maintain a flow regime, including minimum flow requirements, to enhance fall Chinook salmon spawning and rearing habitats in the Lower Cowlitz (LCFRB 2010a). While passage for fall Chinook salmon through the Cowlitz subbasin dams is not a primary focus of the recovery strategy, fall Chinook salmon are (in 2010) passed above Mayfield Dam into the Tilton subbasin and above Cowlitz Falls Dam into the Upper Cowlitz subbasin. Although the primary habitat for fall Chinook salmon in the Upper Cowlitz has been inundated, efforts are being made to reestablish some fall Chinook salmon spawning in the Upper Cowlitz.

In the Lewis subbasin, tule fall Chinook salmon occur in both the lower North Fork Lewis and the East Fork Lewis (where there are no hydropower dams), but the East Fork Lewis supports most of the production and, along with the lower North Fork, is the focus of recovery efforts.[87] As in the Cowlitz, hydroregulation on the Lewis River has altered the natural flow regime below Merwin Dam, affecting the quantity and quality of fall Chinook salmon spawning and rearing habitat. The Washington management unit plan includes a measure to operate the Lewis hydrosystem to provide appropriate flows for salmon spawning and rearing habitat. The operational plan for the Lewis River dams, in conjunction with fish management plans, should include flow regimes—including minimum flow and ramping rate requirements—that enhance the lower river habitat for fall Chinook salmon (LCFRB 2010a). Passage at the Lewis River dams is not part of the recovery strategy for Lewis River fall Chinook salmon.

Gorge Fall Chinook Salmon Hydropower Strategies

Tributary hydropower impacts for the White Salmon and Hood populations have been addressed by removing Condit and Powerdale dams, respectively. Condit Dam, operated on the White Salmon River by PacifiCorp, was breached in October 2011 and completely removed in September 2012, under the terms of a 1999 decommissioning agreement and a 2006 Biological Opinion. Removal reopens access to four miles of historical fall Chinook salmon habitat (55 percent of historical spawning habitat is above the dam) (NMFS 2013). Natural escapement and production will be monitored for 4 to 5 years; if adequate recolonization has not occurred by that time, appropriate hatchery adults and/or juveniles may be released into the White Salmon River. Powerdale Dam, on the Hood River and also operated by PacifiCorp, was removed in 2010 under the

[86] Barrier Dam and Mayfield Dam in the Cowlitz Basin prevent all volitional passage of anadromous fish above RM 49.5.
[87] In the North Fork Lewis Basin, three dams (Merwin, Yale, and Swift), beginning with Merwin Dam at RM 20, block passage to the upper North Fork Lewis.

terms of a settlement agreement reached in 2003. Benefits to fall Chinook salmon in the Hood River will include improved upstream and downstream migration; removal of the dam is expected to reduce hydropower-related impacts for the Hood fall Chinook salmon population from 18.7 percent to 13 percent (ODFW 2010). Tributary dams do not affect the Lower Gorge or Upper Gorge populations.

Actions in the 2008 FCRPS Biological Opinion and its 2010 Supplement will also provide slight improvements in juvenile survival for the three Gorge fall Chinook salmon populations that spawn above Bonneville Dam (see the regional hydropower strategy in Section 4.3.2).

7.5.3.5 Harvest Strategy

Consistent with the regional harvest strategy (see Section 4.5.2), the harvest strategy for Lower Columbia River fall Chinook salmon focuses on refining harvest management to further reduce impacts to naturally produced fish while maintaining harvest opportunities that target hatchery-produced fish. Harvest on Lower Columbia River tule Chinook salmon has been reduced from average highs of 69 percent during the years 1983 to 1993 to an average of 48 percent from 1999 to 2006, 38 percent in 2009 and 2010, and 37 percent in 2011 (NMFS 2008c). These changes have contributed to the harvest reductions called for in the Oregon and Washington management unit plans, both of which envision further reductions through a strategy of implementing mark-selective fisheries when feasible as a tool to sustain important fisheries, implementing abundance-based management when feasible, and applying weak-stock management principles.[88]

In terms of needed additional reductions, the Oregon management unit plan did not recommend specific harvest rates; instead, in its analyses it used 35 percent as a modeled, long-term average harvest rate and assumed that harvest actions such as abundance-based, weak-stock management and mark-selective commercial fisheries would be implemented. The Washington management unit plan recommends a phased harvest strategy involving lower near-term rates to reduce population risks until habitat improvements are achieved. Modeling in the Washington management unit plan shows a scenario in which harvest rates would be managed for benchmarks of 38 to 49 percent for the period between 1999 (the time of listing) and the year 2010, and rates of 33 to 38 percent from 2011 to 2022. (The benchmark range is a target to be met within the designated period and will be used to assess progress toward recovery. With respect to tule Chinook salmon, the 1999-2010 benchmark range of 38 to 49 percent was met by rates of 38 to 49 percent over most of the period.) The modeling also projects that harvest rates eventually would increase as the benefits of other recovery actions are realized and natural production improves. These modeling results are planning targets and not predictions of future harvest rates; managers will establish future harvest rates based on observed indicators in Lower Columbia River fall Chinook salmon populations.

NMFS' recent modeling (Northwest Fisheries Science Center 2010), which addressed all primary tule populations except the Toutle, indicates that, in the Cascade stratum, the Lewis, Washougal, and Coweeman populations would benefit somewhat from

---

[88] A critical question regarding weak stock management principles is how and when tule harvest will be based on the populations in the Coast stratum.

additional harvest reductions but would be at low demographic risk at harvest rates of up to 38 percent. In the Coast stratum, the Clatskanie, Scappoose, and Elochoman/Skamokawa populations appear to be sustained by hatchery straying under current conditions and modeling indicates they would be at high risk in the absence of hatchery augmentation, even at very low harvest rates. The Mill/Abernathy/Germany population would be at intermediate risk at intermediate harvest levels. Because few population-specific landscape habitat maps are available, the NMFS analysis applied tributary habitat assumptions derived for the East Fork Lewis River to all populations. Under that assumption set, the Hood population appears to be self-sustaining at a harvest rate of around 20 percent; however, the Oregon management unit plan discusses the unique nature of the Hood River drainage, including the dynamic nature of sediment conditions caused by glacial inputs and other factors, and is more pessimistic about the status of that population (ODFW 2010). The uncertainty in all of these predictions is substantial. The Oregon and Washington management unit plans both highlight the need for improved estimates of current spawning levels and habitat conditions for Lower Columbia River fall Chinook salmon populations. The Oregon management unit plan identifies evaluating and potentially updating available data series for the Clatskanie, Scappoose, and Hood River fall Chinook salmon populations as high-priority technical tasks. Incorporating drainage-specific tributary habitat information may substantially alter model projections.

NMFS will ensure that best available science continues to be used to determine harvest rates that, when combined with other threat reduction strategies, are likely to achieve positive growth rates and move populations to their target status over the long term. Near-term actions will evaluate and describe options for employing mark-selective fishing strategies in order to sustain fisheries while reducing fishery impacts on naturally produced Lower Columbia River tule Chinook salmon populations. Near-term actions also will include investigation of one or more options for predicting the abundance of natural-origin Lower Columbia River tule Chinook salmon (including the use of prior year returns) and incorporating abundance-driven management principles into Lower Columbia River tule harvest management.

The current harvest strategy is based on the assumption (supported by the results of Northwest Fisheries Science Center 2010 modeling) that the productivity of the poorly performing populations in the Coast stratum is so low that their extinction risk would remain high regardless of harvest rates. The Hood tule population presents an additional challenge for several reasons. First, there is a relatively high degree of uncertainty associated with the specific assumptions regarding current tributary habitat conditions incorporated into NMFS' modeling for the Hood population. In addition, the population's baseline persistence probability in these model runs is very low, the population is targeted for high persistence probability, and—because of harvest impacts in Zone 6 fisheries above Bonneville Dam—the Hood population is subject to exploitation rates higher than those for the Coast and Cascade strata.[89] In the future, as productivity begins to improve in populations that currently are performing poorly, NMFS, co-managers, and the management unit leads will evaluate whether harvest needs to be adjusted. Additional information will be needed to understand how harvest

[89] Harvest management provisions in Zone 6 have been established through the year 2017 under the *US v. Oregon* process. Harvest in Zone 6 is limited primarily by constraints on upriver fall Chinook and steelhead.

and other threats are affecting the ability of tule populations to achieve their recovery targets and appropriate strategies will need to be developed.

In ESA evaluations of hatchery and harvest actions, NMFS expects to analyze the combinations of effects of multiple actions when appropriate. For example, where hatchery production clearly is intended to support harvest, the synergistic effects of artificial production and harvest will need to be analyzed at the juvenile and adult life stages. This should include ecological interactions as well as genetic and other considerations.

Coast Fall Chinook Salmon Harvest Strategies

The ESU-level harvest strategy described above is expected to reduce harvest impacts on most populations in this stratum. As part of the strategy to direct harvest impacts away from other Lower Columbia River fall Chinook salmon populations, terminal fisheries targeting hatchery fish in Youngs Bay and Big Creek will continue, and those populations will continue to be subject to higher harvest rates than other fall Chinook salmon populations. Still, implementation of the ESU-level harvest strategy is expected to reduce harvest impacts on the Youngs Bay and Big Creek populations from 75 and 65 percent, respectively, to 70 and 60 percent (ODFW 2010).

Cascade Fall Chinook Salmon Harvest Strategies

The ESU-level harvest strategy described above is expected to reduce harvest impacts on all populations in this stratum.

Gorge Fall Chinook Salmon Harvest Strategies

The ESU-level harvest strategy described above is expected to reduce harvest impacts on all populations in this stratum.

7.5.3.6 Hatchery Strategy

The regional hatchery strategy described in Section 4.4.2 summarizes goals and approaches relevant to Lower Columbia River fall Chinook salmon. In general, pHOS will be reduced through a combination of removal of excess hatchery-origin fish at weirs,[90] shifts in production levels or locations, changes in hatchery practices, and mark-selective harvest. Some programs will be shifted to formal integrated programs, in which genetic hatchery impacts are reduced through inclusion of natural-origin fish in the broodstock. Because pHOS and its impact on the productivity of naturally spawning fish are key uncertainties for fall Chinook salmon, the management unit recovery plans propose monitoring to determine with more certainty the actual pHOS, while simultaneously moving ahead with actions to reduce the influence of hatchery fish to levels appropriate to each population (i.e., populations with a higher target persistence probabilities will be targeted for lower levels of influence), using techniques tailored to

[90] The ecological risks of weirs will also be considered. The Recovery Implementation Science Team (RIST) discussed potential benefits and ecological risks associated with use of weirs (Recovery Implementation Science Team 2009).

the circumstances of each population.[91] Transition schedules will recognize the differences between populations such as the Washougal, where strays are largely from a within-population tributary hatchery program, and the Lewis, where hatchery strays are also from an adjacent facility but presumably are present at much lower numbers than in some populations. Near-term priorities include conducting more detailed assessments of current spawning escapements and hatchery proportions in the Clatskanie and Scappoose populations, both of which are designated as primary. The historical-to-current spawner data series for these two populations are highly uncertain. Near-term priorities also include continuing the efforts already under way to shift production and install and operate weirs. In addition, NMFS believes that there is a need for studies of the potential effects hatchery introgression on productivity (such studies are rare for fall Chinook salmon). Long-term priorities include achieving the recovery targets for each population and reducing reliance on hatchery production for harvest or risk reduction as natural productivity improves.

Details of how the hatchery strategy will be implemented in each fall Chinook salmon stratum will be developed as part of the transition schedules, but the subsections below provide some information.

Coast Fall Chinook Salmon Hatchery Strategies

The preliminary intent of the Coast-stratum hatchery strategy includes maintaining the Youngs Bay and Big Creek subbasins as areas of hatchery production to support terminal fisheries targeting hatchery fish; consequently, pHOS in the Youngs Bay and Big Creek populations is expected to remain high, and the populations are targeted to be maintained at low persistence probabilities. Some fall Chinook salmon hatchery production will be shifted from Big Creek to Youngs Bay in an effort to reduce hatchery-origin spawners in the Clatskanie and, to a lesser degree, Scappoose subbasins. Existing weirs in both Youngs Bay and Big Creek will be used to pass natural-origin fish into sanctuary areas. The Clatskanie and Scappoose subbasins will remain areas where no hatchery fish are released. If pHOS in the Clatskanie remains higher than 10 percent, a trap may be installed to sort hatchery fish within 15 years.[92]

The Grays/Chinook, Mill/Abernathy/Germany, and Elochoman/Skamokawa subbasins also are expected to be maintained as areas where no hatchery fall Chinook salmon are released. No hatchery fall Chinook salmon have been released in the Grays subbasin since 1998 and none from the Abernathy fall Chinook salmon program since 1995. The Elochoman hatchery was closed in 2009. The proportion of hatchery-origin spawners in each subbasin needs to be reduced; hatchery strays in the Grays subbasin are believed to come primarily from the Rogue River bright fall Chinook stock used to produce fish for the Select Area fishery in Youngs Bay. As of late 2011, weirs were in use in the Grays, Washougal, Elochoman, Coweeman, and Toutle rivers to separate hatchery- from natural-origin fish.

---

[91] For example, ODFW has established a target of 10 percent or less hatchery-origin spawners in natural spawning areas for populations targeted for high probability of persistence. WDFW will establish similar targets in its Conservation and Sustainable Fisheries Plan.

[92] The Oregon management unit plan did not incorporate an explicit contingency plan for the Scappoose basin.

Cascade Fall Chinook Salmon Hatchery Strategies

Currently, no hatchery fish are released into the Coweeman, Lewis, or Salmon Creek subbasins in Washington or into the Clackamas or Sandy subbasins in Oregon, although fall Chinook salmon populations in these watersheds are affected by hatchery-origin spawners that stray from other areas within the Lower Columbia subdomain. These areas are expected to be maintained as areas with no hatchery releases, and recovery actions will focus on reducing the proportion of hatchery-origin spawners (pHOS) to levels appropriate to each population depending on its target status.

As of 2010, fall Chinook salmon were being released into the Upper Cowlitz subbasin as part of a reintroduction strategy, although they are not the focus of the recovery effort in that subbasin. In the Lower Cowlitz, Toutle, Kalama, and Washougal, hatchery programs currently produce and release fall Chinook salmon that are intended to support harvest, in part as mitigation for fall Chinook salmon production lost as a result of multiple factors in the Columbia Basin. In these programs hatchery recovery efforts will focus initially on developing integrated hatchery programs through actions such as separate management of hatchery and natural subpopulations, control of hatchery-origin fish into natural spawning areas, incorporation of natural-origin fish into hatchery broodstock (LCFRB 2010a). Specific approaches to broodstock and targets for proportions of hatchery-origin spawners and natural-origin broodstock will be developed for each population depending on its target status.

In the Sandy subbasin, stray rates already have been reduced significantly from baseline levels and currently are lower than the 30 percent identified for recovery (ODFW 2010). Further reductions in pHOS may be difficult.

Gorge Fall Chinook Salmon Hatchery Strategies

Hatchery strategies for Gorge fall Chinook salmon will consist largely of changes in fishery enhancement programs to reduce hatchery impacts on natural-origin spawners. Actions may include separate management of hatchery and natural subpopulations and control of hatchery-origin fish into natural spawning areas. Specific targets for proportions of hatchery-origin spawners will be developed for each population depending on its target status.

For the Lower Gorge population, ODFW may install a weir and trap to reduce pHOS by separating natural- from hatchery-origin adults at Eagle Creek and Tanner Creek in Oregon. There are no hatcheries operating in the Washington Lower Gorge tributaries.

For the Upper Gorge population, Oregon will consider placing a trap at Herman Creek to sort hatchery fish. For the Washington portion of the Upper Gorge population and the White Salmon population, fall Chinook salmon from four federal hatcheries will continue to be released to provide for fishery enhancement (LCFRB 2010a).

7.5.3.7 Predation Strategy

The regional predation strategy (see Section 4.6.2) involves reducing predation by birds, fish, and marine mammals and will benefit all Lower Columbia River ESUs, including tule fall Chinook salmon.

7.5.3.8 Critical Uncertainties

Each aspect of the fall Chinook salmon recovery strategy has a number of critical uncertainties. For all ESUs, there are uncertainties regarding how habitat actions will translate into changes in productivity and capacity (Roni et al. 2011). Prioritizing and identifying next steps in resolving uncertainties is a near-term priority. Critical uncertainties specific to Lower Columbia River fall Chinook salmon include the following:

- Current level of natural productivity, hatchery fractions, sources of hatchery strays, loss and gain of reproductive fitness, and ecological interactions between hatchery-origin fish and natural-origin fish
- Effects of hatchery-origin fish on natural productivity at the population level, and whether there are density-dependent and/or predation effects in the Columbia River estuary
- Response in natural productivity to reductions in pHOS, and the time frame of that response
- Effectiveness of integrated hatchery programs in restoring the productivity of natural populations; availability of sufficient numbers of naturally produced fish for incorporation in the hatchery broodstock; validity of assumptions concerning natural fitness of hatchery-origin fish produced using natural broodstock
- Historical role of the Gorge populations and appropriate persistence probabilities, and abundance and productivity targets, for these populations
- Most effective recovery strategy for populations whose genetic diversity is low and that may not be locally adapted
- Appropriate stock to use (especially in terms of run timing) if reintroduction is necessary
- Effect of the distribution of intertidal habitats on the life history strategies of fall Chinook salmon[93]
- Locations of priority habitats for restoration, especially with respect to the distribution of intertidal habitats

---

[93] Recent modeling by NMFS (Northwest Fisheries Science Center 2010) for selected LCR tule populations indicates that "confluence habitat" (i.e., the tidal portions of tributaries and their confluence with the mainstem Columbia) may be especially important for coastal and Cascade populations.

These critical uncertainties represent preliminary priorities identified by Oregon and Washington recovery planners and NMFS Northwest Regional Office and Northwest Fisheries Science Center staff during a November 2010 workshop. They are preliminary priorities only (and are not in ranked order); as described in Chapter 10, additional discussion among recovery planners and NMFS staff will be needed to finalize future research priorities for Lower Columbia River fall Chinook salmon.

The management unit plans identify more comprehensive critical uncertainties and research, monitoring, and evaluation needs that, along with the list above, will provide the basis for these future discussions. The White Salmon and Washington management unit plans have discrete sections on critical uncertainties for all of the ESUs in general (see Section 8.3 of NMFS 2013, pp. 8-4 through 8-6, and Section 9.6 of LCFRB 2010a, pp. 9-68 through 9-73), while the Oregon management unit plan embeds relevant critical uncertainties within subsections on monitoring and evaluation needs related to the four VSP parameters and five ESA listing factors (see Sections 8.4 and 8.5, respectively, of ODFW 2010). In addition, in June 2010, the *Lower Columbia Fish Recovery Board completed the Research, Monitoring, and Evaluation Program for Lower Columbia Salmon and Steelhead* as a companion to its recovery plan (LCFRB 2010b). This document also describes critical uncertainties. The list above also does not include critical uncertainties that apply to multiple ESUs; these will be discussed and considered as decisions are made in implementation. In addition, the critical uncertainties above are of a technical nature; there are also many critical uncertainties related to social, political, and economic issues.

Critical uncertainties are one element of research, monitoring, and evaluation (RME) and adaptive management, which will be key components of the fall Chinook salmon recovery strategy (see Chapter 10 for more discussion of RME and adaptive management for this recovery plan).

Monitoring and evaluation are particularly important in the short term to address critical uncertainties about Lower Columbia River tule Chinook salmon, identify those habitat restoration strategies that have the most potential to improve production, and verify assumptions about habitat conditions in key reaches in the priority populations (e.g., are we right to target fine sediment levels in spawning reaches as restoration priorities for poorly performing populations such as the Clatskanie and Elochoman/Skamokawa?).

7.6 Late-Fall Chinook Salmon Analysis: Limiting Factors, Threat Reductions, and Recovery Strategies

7.6.1 Late-Fall Chinook Salmon Limiting Factors

Table 7-9 and the text that follows summarize baseline limiting factors and threats for Lower Columbia River late-fall Chinook salmon strata based on population-specific limiting factors and threats identified in the management unit plans. In cases where conditions have changed significantly since the management unit plans' analyses of limiting factors and threats (e.g., if harvest rates have dropped or a dam is no longer present), this is noted in the text. Unless noted otherwise, NMFS agrees that the management unit plans' identification of limiting factors provide a credible hypothesis for understanding population performance and identifying management actions.

Because the individual management unit plans used somewhat different terms in identifying limiting factors, NMFS has translated those terms into standardized and more general terminology taken from a NMFS "data dictionary" of possible ecological concerns that could affect salmon and steelhead (Hamm 2012; see Section 5.4 and Appendix H). In addition, in Table 7-9 NMFS has rolled up the population-specific limiting factors to the stratum level—a process that also has resulted in some loss of specificity.

In addition, each management unit plan used a different approach for identifying limiting factors and threats (see Section 5.3). One difference relevant to the crosswalk is that while the Oregon management unit plan identified primary and secondary limiting factors for each population in each threat category,[94] the Washington management unit plan categorized limiting factors in this way only for habitat-related limiting factors, and the estuary module did not. For the crosswalk and this table, NMFS assigned primary and secondary status to non-habitat limiting factors for Washington populations (based on the Washington management unit plan's quantification of threat impacts and the professional judgment of Lower Columbia Fish Recovery Board's staff and consultants). It is likely that some apparent distinctions in results between Washington and Oregon populations are artifacts of differences in limiting factor assessment methodologies and not an actual difference in conditions or their effects on salmon and steelhead populations. In addition, there is not necessarily a bright line between primary and secondary limiting factor designations. Nevertheless, NMFS believes that the designations are useful, particularly for looking across ESUs and populations and identifying patterns (see Chapter 4).

The management unit plans provide more detail on limiting factors and threats affecting Lower Columbia River late-fall Chinook salmon, including magnitude, spatial scale, and relative impact, (see LCFRB 2010a, Chapter 3 and various sections of Volume II, and ODFW 2010, pp. 116-128). For a regional perspective on limiting factors and threats that affect multiple salmon and steelhead ESUs, see Chapter 4 of this recovery plan. For a description of the data dictionary, the approach NMFS used to correlate management unit terms for limiting factors with the standardized NMFS terminology at the population scale, and the approach for rolling up from the population to the stratum scale, see Section 5.4 and Appendix H.

Management unit recovery planners in Oregon and Washington recognized that six major categories of manageable threats—tributary habitat, estuary habitat, hydropower, harvest, hatcheries, and predation—were useful as an organizing construct for grouping limiting factors, quantifying impacts on population productivity, and determining how much different categories of threats would need to be reduced to close the gap between baseline and target population status. Planners in both Washington and Oregon quantified the impacts of each of these major threat categories on population status, along with a reduction in each impact that would be consistent with achieving population target status. The results of that analysis are presented in Section 7.6.2 and provide a related but slightly different perspective on limiting factors. The threat

[94] In the Oregon management unit plan, primary limiting factors are those that have the greatest impact and secondary limiting factors have a lesser but still significant impact.

reduction targets also allow actions to be scaled to achieve a specific impact reduction, and to be linked to monitoring and performance benchmarks.

Table 7-9

Baseline Limiting Factors and Threats Affecting LCR Late-Fall Chinook Salmon: Stratum-Level Summary

Ecological Concern	Threat(s)	VSP Parameters Affected	Cascade Late Fall
Tributary Habitat Limiting Factors			
Riparian Condition	Past and/or current land use practices	All	Primary for Sandy juveniles, secondary for NF Lewis juveniles
Channel Structure and Form	Past and/or current land use practices/ transportation corridor	All	Primary for Sandy juveniles, secondary for NF Lewis juveniles
Peripheral and Transitional Habitats: Side Channel and Wetland Conditions	Past and/or current land use practices/ transportation corridor	All	Primary for Sandy juveniles, secondary for NF Lewis juveniles
Peripheral and Transitional Habitats: Floodplain Conditions	Past and/or current land use practices/ transportation corridor	All	Primary for Sandy juveniles, secondary for NF Lewis juveniles
Sediment Conditions	Past and/or current land use practices/ transportation corridor	All	Secondary for juveniles in both populations
Water Quality (Temperature)	Land uses that impair riparian function/decrease streamflow, dams	A,P,D	Secondary for juveniles in NF Lewis
Water Quantity (Flow)	Dams, land use, irrigation, municipal, and hatchery withdrawals	All	Secondary for juveniles in both populations
Estuary Habitat Limiting Factors[95]			
Toxic Contaminants	Agricultural chemicals, urban and industrial practices	A,P,D	Secondary for juveniles in both populations
Food[96] (Shift from macrodetrital- to microdetrital-based food web)	Dam reservoirs	All	Secondary for juveniles in both populations

[95] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the ESU, the estuarine limiting factors in this table and Section 7.5.1.2 reflect the determinations in the Oregon management unit plan, applied to all Lower Columbia River late-fall Chinook salmon populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

[96] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is unclear.

Table 7-9

Baseline Limiting Factors and Threats Affecting LCR Late-Fall Chinook Salmon: Stratum-Level Summary

Ecological Concern	Threat(s)	VSP Parameters Affected	Cascade Late Fall
Peripheral and Transitional Habitats: Estuary Condition	Past and/or current land use practices/transportation corridor, mainstem dams	All	Secondary for juveniles in both populations
Channel Structure and Form	Past and/or current land use practices/ transportation corridor	All	Secondary for juveniles in both populations
Sediment Conditions	Past and/or current land use practices/transportation corridor , dams	All	Primary for juveniles in both populations
Water Quality (Temperature)	Land uses that impair riparian function/decrease streamflow, dam reservoirs	A,P,D	Secondary for juveniles in both populations
Water Quantity (Flow)	Columbia River mainstem dams	All	Primary for juveniles in both populations
Hydropower Limiting Factors			
Habitat Quantity (Access)	Bonneville Dam	All	
Habitat Quantity (Access)	Tributary dams	All	Secondary for Sandy juveniles
Harvest Limiting Factors			
Direct Mortality	Fisheries	A,D	Primary for adults in both populations
Hatchery Limiting Factors			
Food[97]	Smolts from all Columbia Basin hatcheries competing for food and space in the estuary	All	Secondary for juveniles in both populations
Population Diversity	Stray hatchery fish interbreeding with wild fish	A,P,D	Primary for Sandy adults
Predation Limiting Factors			
Direct Mortality	Land use	A,P,D	Secondary for juveniles in both populations
Direct Mortality	Dams	A,P,D	

7.6.1.1 Tributary Habitat Limiting Factors

Degraded riparian conditions caused by land uses past and present are a primary limiting factor for the Sandy late-fall Chinook salmon population and a secondary factor for the North Fork Lewis population. So, too, are channel structure and form issues, in the form of reductions in habitat complexity, diversity, and connectivity; changes in channel structure and form have resulted from past and current land uses, including the

[97] Some scientists suspect that closely spaced releases of hatchery fish from all Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the estuary. NMFS 2011a and LCFRB (2010) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon in freshwater, estuarine, and nearshore ocean habitats.

transportation corridor. Sediment conditions are a secondary limiting factor for both populations. The high density of forest and rural roads in the Lower Columbia subdomain contributes to an abundance of fine sediment in tributary streams used by late-fall Chinook salmon. The resulting excess fine sediment covers spawning gravel, limiting egg development and incubation.

Water quality—specifically elevated water temperature—is a secondary limiting factor for juveniles from the North Fork Lewis population of late-fall Chinook salmon. Water quantity issues related to altered hydrology and flow timing have been identified as secondary limiting factors for both populations. Impaired side channel and wetland conditions along with degraded floodplain habitat also have significant negative impacts on Lower Columbia River late-fall Chinook salmon, warranting mention as a primary limiting factor for the Sandy population and a secondary factor for the North Fork Lewis population.

7.6.1.2 Estuary Habitat Limiting Factors[98]

Estuary habitat conditions are important for juvenile late-fall Chinook salmon, which spend considerable time rearing in the estuary. Water quantity issues related to altered hydrology and flow timing are identified as a primary limiting factor for both late-fall populations, as is impaired sediment and sand routing; these limiting factors are associated with hydroregulation at large storage reservoirs in the interior of the Columbia Basin, and, in the case of sediment issues, land uses both past and present. Much of the land surrounding the Columbia River estuary is in agricultural or rural residential use and has been extensively modified via dikes, levees, bank stabilization, and tide gates. Altered hydrology and sediment routing influence habitat-forming processes, the quantity and accessibility of habitats such as side channels and wetlands, the dynamics of the Columbia River plume, and the estuarine food web.

Channel structure issues, in the form of reduced habitat complexity and diversity, are identified as a secondary limiting factor for juveniles from both populations, as is lack of access to peripheral and transitional habitats such as side channels and wetlands. Again, simplification of channel structure is related to conversion of land to other uses—agricultural, rural residential, and as a transportation corridor—while juveniles' access to side channels and wetlands is impaired by these same land uses but also by flow alterations caused by mainstem dams. Other secondary limiting factors in the estuary that affect both late-fall bright populations are exposure to toxic contaminants (from urban, industrial, and agricultural sources) and elevated late summer and fall water

---

[98] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the ESU, the estuarine limiting factors in this section and in Table 7-9 reflect the determinations in the Oregon management unit plan, applied to all Lower Columbia River late-fall Chinook salmon populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

temperatures, which are related to (1) land use practices that impair riparian function or decrease streamflow, and (2) large hydropower reservoirs. Altered food web dynamics involving a transition from a macrodetrital-based food web to a microdetrital-based food web also are considered a secondary limiting factor for both populations.[99] These changes in the estuarine food web are caused primarily by increased microdetrital inputs from hydropower reservoirs and the loss of wetland habitats through diking and filling.

7.6.1.3 Hydropower Limiting Factors

Flow management operations at large storage reservoirs in the interior of the Columbia Basin (Grand Coulee, Dworshak, etc.) affect all juvenile Lower Columbia River late-fall Chinook salmon in the lower mainstem and estuary, and potentially in the plume—primarily by altering flow volume and timing. These alterations impair sediment routing, influence habitat-forming processes, reduce access to peripheral habitat, and change the dynamics of the Columbia River plume and the estuarine food web (see Section 7.6.1.2).[100] Moreover, the large reservoirs associated with mainstem dams contribute to elevated water temperatures downstream in late summer and fall. Tributary hydropower impacts in the form of impaired habitat access and passage were identified as a secondary limiting factor for Sandy late-fall Chinook salmon, with downstream fry passage being impaired by PGE's Bull Run Hydroelectric Project (consisting of Marmot and Little Sandy dams). This project was removed in 2009, so this limiting factor has been addressed. In the Lewis subbasin, the Lewis River hydroelectric project's effects on flow, sediment transport, and large wood supply were identified as limiting factors.

7.6.1.4 Harvest Limiting Factors

Harvest-related mortality is identified as a primary limiting factor for both populations. Harvest rates historically were around 54 percent but have dropped to approximately 36 percent since listing. The majority of the harvest affecting late-fall Chinook salmon takes place in ocean fisheries, although there is some harvest in non-treaty fisheries in the mainstem Columbia River below Bonneville Dam, and in the North Fork Lewis River.

7.6.1.5 Hatchery-Related Limiting Factors

Population-level effects resulting from stray hatchery fish interbreeding with natural-origin fish are identified as a secondary limiting factor for the Sandy population, which has an average pHOS of 25 percent. The North Fork Lewis population is largely uninfluenced by hatchery effects.

---

[99] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is unclear.

[100] It is likely that flow impacts of the hydropower system affect Lower Columbia River ESUs more through changes in habitat-forming processes (including impacts to the plume) and food web impacts than through changes in migratory travel time.

Some scientists suspect that closely spaced releases of hatchery fish from all Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the estuary. NMFS (2011a) and LCFRB (2010a) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of both populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon in freshwater, estuarine, and nearshore ocean habitats.

7.6.1.6 Predation Limiting Factors

Direct mortality from predation is a secondary limiting factor for all Cascade Chinook salmon populations, including late-fall Chinook salmon. Anthropogenic changes to the structure of habitat have increased predator abundance and effectiveness and led to increased predation by Caspian terns, double-crested cormorants, and various other seabird species in the Columbia River mainstem, estuary, and plume.

7.6.2 Late-Fall Chinook Salmon Baseline Threat Impacts and Threat Reduction Targets

Table 7-10 shows the estimated impact on each Lower Columbia River late-fall Chinook salmon population resulting from potentially manageable threats, organized into six threat categories: tributary habitat degradation, estuary habitat degradation, hydropower, harvest, hatcheries, and predation. Both baseline and target impacts are shown, with the targets representing mortality levels that would be consistent with long-term recovery goals. Impact values indicate the percentage reduction in abundance and productivity that is attributable to human activities related to a particular threat category. The value associated with any particular threat category can be interpreted as the percent reduction in abundance and productivity from historical conditions if that threat category were the only one affecting the population. Cumulative values (both baseline and target) are multiplicative rather than additive. The table also shows the percentage improvement in productivity and abundance (i.e., improvement in population survival) that is needed to achieve the target impacts and corresponding population status.[101]

As an example, the baseline status of the Sandy late-fall Chinook salmon population has been reduced by the combined effects of multiple threats. The cumulative reduction in status was estimated at 90.8 percent from the multiplicative impacts of multiple threats acting across the salmon life cycle. Thus, current status is just 9.2 percent of the historical potential with no human impact. Tributary and estuary habitat, harvest, and hatchery impacts each accounted for reductions in population productivity of 20 percent or more,

---

[101] The percentage of survival improvement needed is the percentage change in net impacts, is derived from information in the Washington and Oregon management unit plans, and is calculated as follows: [(1-$Cumulative_{Target}$)-(1-$Cumulative_{Baseline}$)]/[1-$Cumulative_{Baseline}$] x 100. These values generally correspond to population improvement targets identified for Washington populations in LCFRB (2010). Comparable numbers are not explicitly reported in ODFW (2010) but are implicit in the modeling approach that Oregon recovery planners used to derive target impacts.

with corresponding reductions in abundance, spatial structure, and diversity. The Oregon management unit plan identifies a recovery strategy involving significant reductions in the impact of several threats. For instance, the plan targets tributary habitat impacts to be reduced from the estimated baseline level of 23 percent to 17 percent (i.e., an approximately 8 percent improvement relative to baseline conditions). With the targeted reductions in individual impacts, the cumulative effect of all impacts would drop from 90.8 percent at baseline to 61.6 percent at the target status. This change would translate into a 310 percent improvement in survival relative to the baseline. Although the population would still be experiencing abundance and productivity that are 74.7 percent lower than historical conditions, the extinction risk at this mortality level would be estimated sufficient to meet the targets for this plan.

Oregon and Washington recovery planners used somewhat different definitions or methods to quantify the estimated impacts of anthropogenic threats. Baseline impacts for the Washington population reflect conditions prevalent at the time of ESA listing (circa 1999), while the baseline impacts for the Oregon population reflect conditions through 2004. Dam impacts for the Washington population reflect passage mortality, habitat loss caused by inundation, and loss of access to historical production areas; for the Oregon population, the estimate of impacts in the "Dams" column of the Table 7-10 reflects direct upstream and downstream passage mortality only, with other dam impacts accounted for in the habitat and predation threat categories. Hatchery impacts for the Washington population were limited to not more than 50 percent per population, in accordance with Hatchery Scientific Review Group (HSRG) assessments of the potential for genetic effects (Hatchery Scientific Review Group 2009); for the Oregon population, recovery planners used hatchery impact rates equivalent to one-half the rates at which hatchery fish were found on natural spawning grounds, based on analyzed relationships and reflecting concern about genetic and ecological effects. Washington recovery planners derived estimates of impacts to tributary habitat using the Ecosystem Diagnosis and Treatment (EDT) model. Oregon recovery planners estimated the mortality associated with estuary habitat degradation, hydropower, harvest, hatcheries, and predation and assigned all remaining mortality (relative to the difference between the current modeled abundance and estimated historical abundance) to tributary habitat. In general, the tributary habitat values in Table 7-10 have the highest degree of uncertainty relative to the other threat categories and, for Oregon populations, may include causes of mortality associated with the other threat categories but not directly captured in those mortality estimates. (See Section 5.5 for more on the methodologies used to estimate baseline impacts.)

Estimates of threat impacts are useful in showing the relative magnitude of impacts on each population. Given the differences in methodologies, some values in Table 7-10 for the Oregon and Washington populations are not necessarily directly comparable. Regardless of differences in specific threat impact definitions and methods, the net effect of changes from all threats is useful in understanding the magnitude of population improvement needed to achieve the target population status.

The target impacts in Table 7-10 represent one of several possible combinations of threat reductions that could conceivably close the conservation gap and lead to a population achieving its target status. The particular threat reductions shown in Table 7-10 reflect policy decisions and the methodologies and assumptions used by the different recovery planning teams. (For a description of how target impacts were developed, see Section 5.6.) In estimating impacts, management unit recovery planners evaluated each threat category independently (i.e., values in the table reflect the mortality of Chinook salmon exposed to that particular category of threats, whether or not they are exposed to threats in other categories). The estimates of baseline threat impacts have high levels of uncertainty and in many cases should be considered working hypotheses that are testable as part of recovery plan implementation. Despite this uncertainty, it is the expert judgment of NMFS and management unit scientists that, based on the best available information at this time, the estimates of baseline threat impacts provide a reasonable estimate of the relative magnitude of different sources of anthropogenic mortality and serve as an adequate basis for designing initial recovery actions.[102] As more and better information is collected, it will be applied to recovery efforts in an adaptive management framework.

Both the North Fork Lewis and Sandy populations are currently considered viable; however, the recovery scenario calls for the persistence probability of the Sandy population to be raised from high to very high. This will be accomplished primarily through reductions in harvest and hatchery impacts. As with spring and fall Chinook salmon, recent actions have substantially reduced harvest impacts on late-fall Chinook salmon over baseline conditions, but additional reductions in harvest impacts are called for to achieve the target status for the Sandy population. More modest reductions in the tributary and estuarine habitat, hydropower, and predation threat categories are expected to support the gains achieved through reductions in harvest and hatchery impacts.

[102] As implementation proceeds, research, monitoring, and evaluation and adaptive management will be key in helping to refine scientific understanding of the impact of threats on population persistence and of the extent to which management actions are reducing threats.

Table 7-10

Impacts of Potentially Manageable Threats and Impact Reduction Targets Consistent with Recovery of LCR Late-fall Chinook Salmon Populations

Population	Impacts at Baseline[103]							Impacts at Target							% Survival Improvement Needed[111]
	T. Hab[104]	Est[105]	Dams[106]	Harv[107]	Hat[108]	Pred[109]	Cumulative[110]	T. Hab	Est	Dams	Harv	Hat	Pred	Cumulative	
Cascade Late Fall															
NF Lewis (WA)	0.10	0.23	0.16	0.50	0.05	0.11	0.7539	0.10	0.23	0.16	0.50	0.05	0.11	0.7539	0
Sandy (OR)	0.23	0.31	0.03	0.50	0.25	0.07	0.9074	0.17	0.26	0.00	0.30	0.05	0.06	0.6161	310

103 Impact figures represent a percentage reduction in abundance and productivity that is attributable to human activities related to a particular threat category. Methods used to estimate impacts differ for Oregon and Washington populations. For example, baseline impacts reflect conditions circa 1999 for Washington populations and through 2004 for Oregon populations. Given the methodological differences, impact figures are not necessarily directly comparable. See Sections 5.5 and 5.6 for more on methodologies.

104 Reduction in tributary habitat production potential relative to historical conditions. Oregon and Washington used different methods to estimate historical abundance. Oregon's approach, which incorporates safety margins and includes causes of mortality that are not captured in the other five threat categories, tends to indicate a higher potential impact from tributary habitat loss and degradation than does Washington's.

105 Reduction in juvenile survival in the Columbia River estuary as a result of habitat changes (relative to historical conditions); excludes predation.

106 Reflects passage mortality, habitat loss caused by inundation, and loss of access to historical production areas for Washington populations; for Oregon populations, dam impacts reflect direct passage mortality only.

107 Includes direct and indirect mortality.

108 Reflects only the negative impacts of hatchery-origin fish, such as high pHOS and low PNI (proportion of natural influence), not the benefits of conservation hatchery programs.

109 Includes the aggregate predation rate in the Columbia River mainstem and estuary by northern pikeminnow, marine mammals, Caspian terns, and cormorants.

110 Cumulative values (both baseline and target) are multiplicative rather than additive and are equal to $(1-[(1-M_{thab})(1-M_{est})(1-M_{dams})(1-M_{harv})(1-M_{hatch})(1-M_{pred})])$. Minor differences from numbers in ODFW 2010 are due to rounding.

111 Survival improvements indicate the percentage improvement (rounded to the nearest 10) in population survival needed to achieve target impacts and are derived from the cumulative values (baseline and target), using the following equation: $[(1\text{-Cumulative}_{Target})-(1\text{-Cumulative}_{Baseline})]/[1\text{-Cumulative}_{Baseline}] \times 100$. These cumulative impact numbers are not explicitly reported in ODFW (2010) but are implicit in the modeling approach that Oregon recovery planners used to derive target impacts.

7.6.3 Late-Fall Chinook Salmon Recovery Strategy

7.6.3.1 Strategy Summary

The recovery strategy for the late-fall component of the Lower Columbia River Chinook salmon ESU is designed to maintain the two healthy populations (North Fork Lewis and Sandy) and raise the persistence probability of the Sandy population from high to very high. Key elements of the strategy are as follows:

1. Implement the regional hatchery strategy. Minimize the impacts of hatchery releases of steelhead, coho, and spring Chinook salmon on late-fall Chinook salmon. Continue the current practice of not releasing hatchery fall Chinook salmon into the North Fork Lewis River.

2. Reduce harvest impacts on the Sandy late-fall population by using the same harvest strategies identified for tule fall Chinook salmon. Continue to manage fisheries to meet the spawning escapement goal for the Lewis River late-fall population and consider reassessing the goal as new data are acquired.

3. Implement actions in the regional tributary and estuary habitat strategy designed to benefit tule fall Chinook salmon. Implement the stratum-level tributary habitat strategies designated for tule fall Chinook.

Improving the persistence of the Sandy population will be accomplished primarily through reductions in harvest and hatchery impacts. As with spring and tule fall Chinook salmon, recent actions have substantially reduced harvest impacts on late-fall Chinook salmon over baseline conditions, but additional reductions in harvest impacts are called for to achieve the target status for the Sandy population.

7.6.3.2 Late-Fall Chinook Salmon Tributary and Estuarine Habitat Strategy

In general, tributary and estuary habitat actions designed to benefit tule fall Chinook salmon will benefit the two late-fall Chinook salmon populations. Actions include those in the regional tributary and estuary habitat strategies (see Sections 4.1.2 and 4.2.2) and the stratum-level tributary habitat strategies described in Section 7.5.3.2.

7.6.3.3 Late-Fall Chinook Salmon Hydropower Strategy

Tributary hydropower impacts, which had baseline effects on the Sandy late-fall population, have been addressed by the removal of PGE's Marmot and Little Sandy dams (ODFW 2010). The hydropower strategy also includes implementation of mainstem flow management operations designed to benefit spring migrants from the interior of the Columbia Basin; NMFS expects that these flow management operations will also improve survival in the estuary and, potentially, the plume for all Lower Columbia River salmon and steelhead populations. (See the regional hydropower strategy in Section 4.3.2).

7.6.3.4 Late-Fall Chinook Salmon Harvest Strategy

Late-fall Chinook salmon are captured in many of the same ocean fisheries as their early fall run counterparts, although overall, inshore recreational and net harvest impacts are somewhat less for late-run fall Chinook salmon. Fisheries are managed to meet a spawning escapement goal for Lower Columbia River bright fall Chinook salmon that is based on the North Fork Lewis river population. In recent years, this escapement goal has been 5,700 natural adult late-fall Chinook salmon. Under the recovery strategy, ocean and freshwater fisheries would continue to employ escapement goal management for Lewis River late-fall Chinook salmon. The escapement goal may be reassessed as new data are acquired (LCFRB 2010a). Consistent with the regional harvest strategy (see Section 4.5.2), the Oregon management unit plan targets a reduction in harvest impacts for the Sandy late-fall Chinook salmon population from 50 percent to 30 percent and expects that this reduction would be achieved through the same harvest strategies identified for tule fall Chinook salmon.

7.6.3.5 Late-Fall Chinook Salmon Hatchery Strategy

The regional hatchery strategy described in Section 4.4.2 summarizes goals and approaches relevant to Lower Columbia River late-fall Chinook salmon. Lewis River naturally spawning late-fall Chinook salmon are the healthiest Chinook salmon population in the lower Columbia Basin and have been largely uninfluenced by hatchery production. Hatchery late-fall Chinook salmon are not released into the North Lewis River and releases should not be considered in the future. Hatchery releases of steelhead, coho, and spring Chinook salmon, either from the hatchery harvest program or from the upper Lewis natural reintroduction program, must include strategies to minimize impacts to rearing naturally produced fall and late-fall Chinook salmon. Hatchery strays have had a lesser, though still key, effect on the Sandy late-fall Chinook salmon population, with stray rates at one time averaging 24 percent but currently assumed to be less than 10 percent (lower than the hatchery threat reduction target for the Sandy late-fall population) (ODFW 2010).

7.6.3.6 Late-Fall Chinook Salmon Predation Strategy

The regional predation strategy (see Section 4.6.2) involves reducing predation by birds, fish, and marine mammals and will benefit all Lower Columbia River ESUs, including late-fall Chinook salmon.

7.6.3.7 Critical Uncertainties

For all ESUs, there are uncertainties regarding how habitat actions will translate into changes in productivity and capacity (Roni et al. 2011). In addition, the following are critical uncertainties specific to the Lower Columbia River late-fall Chinook salmon recovery strategy:

- Evaluate assumptions about harvest: are impacts on the Sandy late fall Chinook salmon population lower than those on the tules because of run timing differences?

- Adequacy of the spatial distribution of the North Fork Lewis population to maintain the population at a high probability of persistence

These critical uncertainties represent preliminary priorities identified by Oregon and Washington recovery planners and NMFS Northwest Regional Office and Northwest Fisheries Science Center staff during a 2010 workshop. They are preliminary priorities only; as described in Chapter 10, additional discussion among recovery planners and NMFS staff will be needed to finalize future research and monitoring priorities for Lower Columbia River Chinook salmon.

The management unit plans identify more comprehensive critical uncertainties and research, monitoring, and evaluation needs that, along with the list above, will provide the basis for these future discussions. The Washington management unit plan has a discrete section on critical uncertainties for all of the ESUs in general (see Section 9.6 of LCFRB 2010a, pp. 9-68 through 9-73), while the Oregon management unit plan embeds relevant critical uncertainties within subsections on the four VSP parameters and five ESA listing factors (see Sections 8.4 and 8.5, respectively, of ODFW 2010). In addition, in June 2010, the Lower Columbia Fish Recovery Board completed its *Research, Monitoring, and Evaluation Program for Lower Columbia Salmon and Steelhead* as a companion to its recovery plan (LCFRB 2010b). This document also describes critical uncertainties. The list above also does not include critical uncertainties that apply to multiple ESUs; these will be discussed and considered as decisions are made in implementation. In addition, the critical uncertainties above are of a technical nature; there are also many critical uncertainties related to social, political, and economic issues.

Critical uncertainties are one element of research, monitoring, and evaluation (RME) and adaptive management, which Chapter 10 discusses in depth. RME and adaptive management will be key components of the Lower Columbia River late-fall Chinook salmon recovery strategy.

7.7 Delisting Criteria Conclusion for LCR Chinook Salmon

The requirement for determining that a species no longer requires the protection of the ESA is that the species is no longer in danger of extinction or likely to become endangered within the foreseeable future, based on evaluation of the listing factors specified in ESA section 4(a)(1). To remove the Lower Columbia River Chinook salmon ESU from the Federal List of Endangered and Threatened Wildlife and Plants (that is, to delist the ESU or DPS), NMFS must determine that the ESU, as evaluated under the ESA listing factors, is no longer likely to become endangered.

The ESA requires that recovery plans, to the maximum extent practicable, incorporate objective, measurable criteria that, 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). The recovery criteria in this plan (both biological and threats criteria) meet this statutory requirement.

As described in Section 7.3, if the scenario in Table 7-4 were achieved, it would exceed the WLC TRT's stratum-level viability criteria in the Coast and Cascade fall strata, the

Cascade spring stratum, and the Cascade late-fall stratum. However, the scenario for the Gorge fall and Gorge spring strata does not meet WLC TRT criteria because, within each stratum, the scenario targets only one population (the Hood) for high persistence probability, instead of two (see Table 7-11).[112] Exceeding the WLC TRT criteria in the Cascade fall and spring Chinook strata was intentional on the part of local recovery planners to compensate for uncertainties about meeting the WLC TRT's criteria in the Gorge fall and spring strata. In addition, multiple spring Chinook salmon populations are prioritized for aggressive recovery efforts to balance risks associated with the uncertainty of success in reintroducing spring Chinook salmon populations above tributary dams in the Cowlitz and Lewis systems.

Table 7-11
LCR Chinook Salmon Recovery Scenario Scores Relative to WLC TRT Viability Criteria

Species	Number of Primary Populations					Stratum Average Criteria			
		Coast	Cascade	Gorge	Total		Coast	Cascade	Gorge
Fall Chinook	n ≥ high	4	4	1	9	Avg. score	2.36	2.35	2.25*
	TRT criterion (n ≥ 2) met?	Yes	Yes	No		TRT criterion (avg. ≥ 2.25) met?	Yes	Yes	*
Late-Fall Chinook	n ≥ high	--	2	--	2	Avg. score	--	4.00	--
	TRT criterion (n ≥ 2) met?	--	Yes	--		TRT criterion (avg. ≥ 2.25) met?	--	Yes	--
Spring Chinook	n ≥ high	--	4	1	5	Avg. score	--	2.36	2.75*
	TRT criterion (n ≥ 2) met?	--	Yes	No		TRT criterion (avg. ≥ 2.25) met?	--	Yes	*

*Stratum does not meet WLC TRT criterion for number of populations at high or higher probability of persistence.

Source: Based on LCFRB 2010a, Table 4-7

Recovery planners' uncertainty about meeting WLC TRT criteria in the Gorge fall and spring Chinook salmon strata is based on questions about available habitat and anthropogenic impacts that are unlikely to change in the near future (e.g., inundation of habitat by Bonneville Reservoir) and on questions regarding Gorge strata and population delineations and historical role (LCFRB 2010a, ODFW 2010). These questions include whether the Gorge populations were highly persistent historically, whether they functioned as independent populations within their stratum in the same way that the

[112] As discussed in Section 2.5.4, the TRT's criteria for high probability of stratum persistence require that two or more populations be viable and that the average score for all populations in the stratum be 2.25 or higher.

Coast and Cascade populations did, and whether the Gorge stratum itself should be considered a separate stratum from the Cascade stratum.

As discussed in Section 3.2, NMFS has considered the WLC TRT's viability criteria (from McElhany et al. 2003 and 2006 and summarized in Table 2-3), the additional recommendations in McElhany et al. (2007), the recovery scenarios and population-level abundance and productivity goals developed by the management unit planners, and the questions management unit planners raised regarding the historical role of the Gorge strata.

NMFS has concluded that the WLC TRT's criteria adequately describe the characteristics of an ESU that meet or exceed the requirement for determining that a species no longer needs the protection of the ESA. These criteria provide a framework within which to evaluate specific recovery scenarios. NMFS has evaluated the recovery scenario in the management unit plans for Lower Columbia River Chinook salmon (summarized in Table 3-1 of this recovery plan) and the associated population-level abundance and productivity goals (see Section 7.3).

Regarding the divergence of the scenario from the WLC TRT's criteria, the TRT noted in its revised viability criteria (McElhany et al. 2006) the need for case-by-case evaluations of the continuum of ESU-level risk associated with some strata not meeting their criteria. In commenting on the recovery scenarios presented in the interim Washington management unit plan[113]—and by extension the recovery scenarios presented in Table 3-1 of this plan—the WLC TRT stated that achieving the recovery scenarios would improve the status of the Gorge strata, even if the TRT's criteria for those strata were not met. The TRT also noted that targeting the Cascade strata for very high persistence (above the minimum TRT criteria) would help lower ESU extinction risk. In addition, the TRT noted that the Gorge and Cascade strata are relatively similar compared to the Cascade and Coast strata. Also significant in the TRT's view was that options for recovery of the Gorge stratum would be preserved, in case future conditions or analyses were to require high stratum persistence for ESU viability (McElhany et al. 2006, p. 9).

Based on the information provided by the WLC TRT and the management unit recovery planners, NMFS concludes that the recovery scenarios in Table 3-1 and the associated population-level abundance and productivity goals in Section 7.3 represent one of multiple possible scenarios that would meet biological criteria for delisting. The similarities between the Gorge and Cascade strata, coupled with compensation in the Cascade stratum for not meeting TRT criteria in the Gorge stratum, would provide an ESU no longer likely to become endangered. NMFS endorses the recovery scenario and population-level goals found in the management unit plans for Lower Columbia River Chinook salmon (summarized in Table 3-1 and Section 7.3) as one of multiple possible scenarios consistent with delisting.

NMFS also agrees with the management unit planners that the historical role of the Gorge populations and stratum merits further examination. The extent to which

[113] In February 2006, NMFS approved the December 2004 version of the Washington management unit plan as an interim regional recovery plan for Lower Columbia River Chinook salmon and steelhead and Columbia River chum salmon. In May 2010, the LCFRB completed a revision of its 2004 plan (LCFRB 2010a), which is incorporated into this ESU-level recovery plan as Appendix B.

compensation in the Cascade stratum is ultimately considered necessary to achieve an acceptably low risk at the ESU level will depend on how questions regarding the historical role of the Gorge populations are resolved.

NMFS therefore has developed the following delisting criteria for the Lower Columbia River Chinook salmon ESU (NMFS has amended the WLC TRT's criteria to incorporate the concept that each stratum should have a probability of persistence consistent with its historical condition, thus allowing for resolution of questions regarding the Gorge strata):

1. All strata that historically existed have a high probability of persistence or have a probability of persistence consistent with their historical condition. High probability of stratum persistence is defined as:

    a. At least two populations in the stratum have at least a 95 percent probability of persistence over a 100-year time frame (i.e., two populations with a score of 3.0 or higher based on the TRT's scoring system).

    b. Other populations in the stratum have persistence probabilities consistent with a high probability of stratum persistence (i.e., the average of all stratum population scores is 2.25 or higher, based on the TRT's scoring system). (See Section 2.6 for a brief discussion of the TRT's scoring system.)

    c. Populations targeted for a high probability of persistence are distributed in a way that minimizes risk from catastrophic events, maintains migratory connections among populations, and protects within-stratum diversity.

    A probability of persistence consistent with historical condition refers to the concept that strata that historically were small or had complex population structures may not have met Criteria A through C, above, but could still be considered sufficiently viable if they provide a contribution to overall ESU viability similar to their historical contribution.

2. The threats criteria described in Section 3.2.2 have been met.

8. Columbia River Chum Salmon

8.1 Chum Salmon Biological Background

8.1.1 Chum Salmon Life History and Habitat

Columbia River chum salmon (*Oncorhynchus keta*) once were widely distributed throughout the lower Columbia Basin and spawned in the mainstem Columbia and the lower reaches of most lower Columbia River tributaries. Historically, spawning occurred as far upstream as the Umatilla and Walla Walla rivers, but it now is restricted largely to tributary and mainstem areas downstream of Bonneville Dam (LCFRB 2010a, NMFS 2013). Although chum salmon are strong swimmers, they rarely pass river blockages and waterfalls that pose no hindrance to other salmon or steelhead (ODFW 2010); thus, they spawn in low-gradient, low-elevation reaches and side channels (LCFRB 2010a). Chum salmon enter fresh water close to the time of spawning. They need clean gravel for spawning, and spawning sites typically are associated with areas of upwelling water. For example, in 1999 chum salmon were discovered spawning along the Washington shoreline near the I-205 Glen Jackson Bridge, where upwelling occurs. In addition, a significant proportion of chum salmon returning to Hamilton Creek spawn in a spring-fed channel, and portions of the Grays River and Hardy Creek populations spawn in the area of springs (LCFRB 2010a).

Adult chum salmon returning to the Columbia River at the present time are virtually all fall-run fish, entering fresh water from mid-October through November and spawning from early November to late December (see Figure 8-1) (LCFRB 2010a). There is also evidence that a summer-run chum salmon population returned historically to the Cowlitz River, and fish displaying this life history are occasionally observed there (Ford 2011, Myers et al. 2006).

Various physical and biotic factors affect the time it takes for eggs to incubate, hatch, and emerge as alevins from the gravel, but water temperature is believed to have the most influence on embryonic development; lower water temperatures can prolong the time required from fertilization to hatching by 1.5 to 4.5 months (NMFS 2013). Chum salmon fry emerge from March through May (LCFRB 2010a), typically at night (ODFW 2010), and are believed to migrate promptly downstream to the estuary for rearing. Chum salmon fry are capable of adapting to seawater soon after emergence from gravel (LCFRB 2010a). Their small size at emigration is thought to make chum salmon susceptible to predation mortality during at this life stage (LCFRB 2010a).

Given the minimal time chum salmon spend in their natal streams, the period of estuarine residency appears to be a critical phase in their life history and may play a major role in determining the size of returning adults (NMFS 2013). Chum and ocean-type Chinook salmon usually spend more time in estuaries than do other anadromous salmonids (Dorcey et al. 1978 and Healey et al. 1982, as cited in NMFS 2013)—weeks or months, rather than days or weeks (NMFS 2011a). Shallow, protected habitats such as salt marshes, tidal creeks, and intertidal flats serve as significant rearing areas for juvenile chum salmon during estuarine residency (LCFRB 2010a).

Juvenile chum salmon rear in the Columbia River estuary from February through June before beginning long-distance ocean migrations (LCFRB 2010a). Chum salmon remain in the North Pacific and Bering Sea for 2 to 6 years, with most adults returning to the Columbia River as 4-year-olds (ODFW 2010). All chum salmon die after spawning.

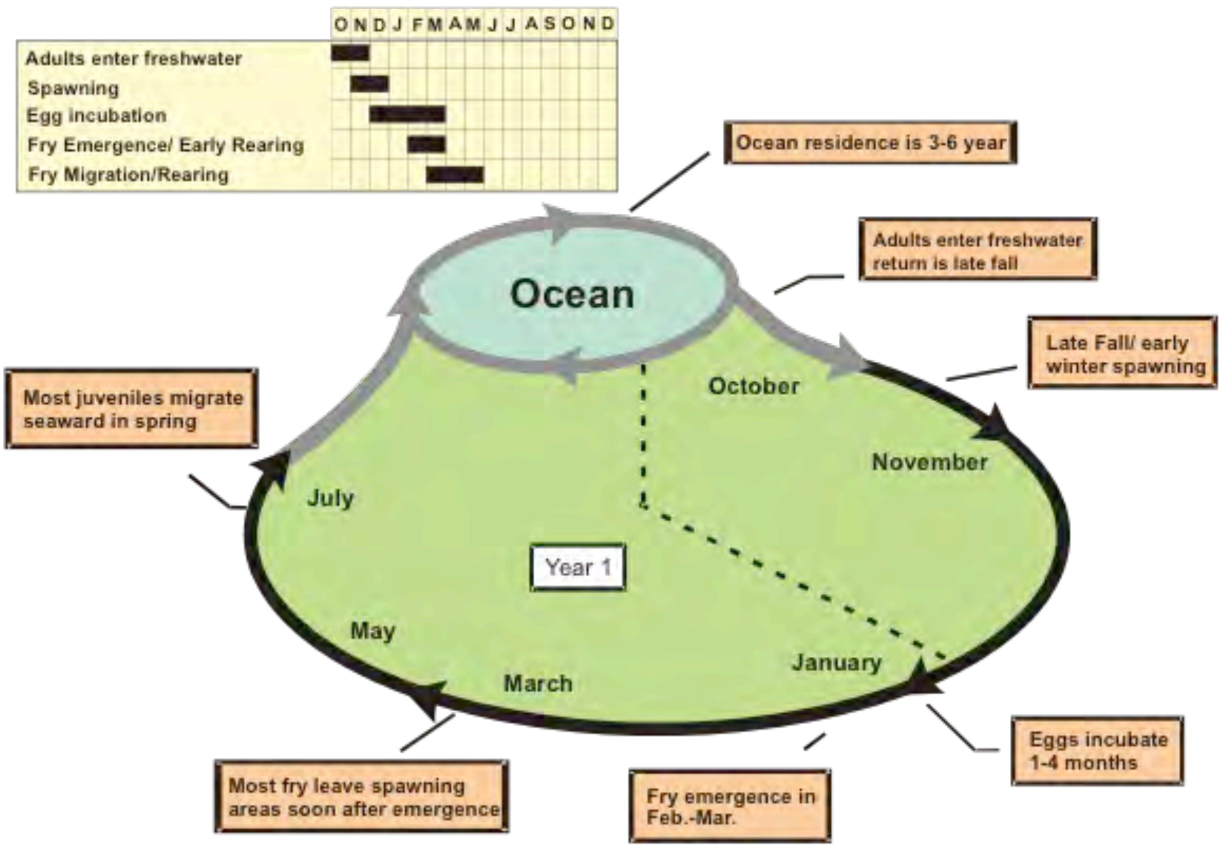

Figure 8-1. *Life Cycle of Columbia River Chum Salmon*

(Source: LCFRB 2010a)

8.1.2 Historical Distribution and Population Structure of Columbia River Chum Salmon

The Columbia River chum salmon ESU historically consisted of 17 independent populations. Of these, 16 were fall-run populations and one was a summer-run population that returned to the Cowlitz River.[1] Table 8-1 lists these populations and

[1] Recent genetic studies indicate the historical existence of a summer-run chum population in the Cowlitz subbasin (Ford 2011). Based on earlier information about the possible existence of this population (see Myers et al. 2006), the Washington management unit plan recognized the need to protect and restore the full range of diversity in this ESU, and incorporated actions to recover summer-run chum in the Cowlitz subbasin to a medium probability of persistence. The WLC TRT defines a stratum as a group of populations sharing major life history characteristics (e.g., run timing) and ecological zones and representing a major diversity component within an ESU (McElhany et al. 2003). It remains unclear whether summer-run chum salmon in the Cowlitz River represent a separate stratum from Cascade fall-run chum or the early

indicates core populations (which historically were highly productive) and genetic legacy populations (which represent important historical genetic diversity). Figure 8-2 shows the geographical distribution of Columbia River chum salmon strata and populations.

The Columbia River chum salmon ESU includes fish from three artificial propagation programs in Washington: the Chinook River (Sea Resources Hatchery), Grays River, and Washougal River/Duncan Creek chum salmon hatchery programs (70 *Federal Register* 37176). These programs produce fry for efforts to supplement natural populations (LCFRB 2010a). In 2010, the Oregon Department of Fish and Wildlife initiated a new chum salmon hatchery program, which NMFS has not yet evaluated for inclusion in the ESU, at Big Creek Hatchery to develop chum salmon for reintroduction into lower Columbia River tributaries in Oregon (76 *Federal Register* 50448, Jones 2011).

Table 8-1
Historical Columbia River Chum Salmon Populations

Stratum	Historical Populations	Core or Genetic Legacy Populations
Coast	Youngs Bay (OR)	Core
	Grays/Chinook (WA)	Core, genetic legacy
	Big Creek (OR)	Core
	Elochoman/Skamakowa (WA)	Core
	Clatskanie (OR)	
	Mill/Abernathy/Germany (WA)	
	Scappoose (OR)	
Cascade	Cowlitz - fall (WA)	Core
	Cowlitz - summer (WA)	Core
	Kalama (WA)	
	Lewis (WA)	Core
	Salmon Creek (WA)	
	Clackamas (OR)	Core
	Sandy (OR)	
	Washougal (WA)	
Gorge	Lower Gorge (WA & OR)	Core, genetic legacy
	Upper Gorge[2] (WA & OR)	

Source: Myers et al. (2006), McElhany et al. (2003).

component of broadly distributed run timing. In its 2011 5-year review, the NMFS Northwest Fisheries Science Center concluded that available information suggests adding the summer-run chum population to the Cascade stratum of the Columbia River chum ESU (Ford 2011). This approach is consistent with the Washington management unit plan's approach. Organizationally within this ESU-level recovery plan, Cowlitz summer chum are included in the Cascade chum stratum.

[2] Includes White Salmon population.

8.2 Baseline Population Status of Columbia River Chum Salmon

Over the last century, Columbia River chum salmon returns have collapsed from hundreds of thousands to just a few thousand per year. Of the 17 populations that historically made up this ESU, 15 of them (six in Oregon and nine in Washington) are so depleted that either their baseline probability of persistence is very low or they are extirpated or nearly so (LCFRB 2010a, ODFW 2010, Ford 2011).[3] All three strata in the ESU fall significantly short of the WLC TRT criteria for viability.

Currently almost all natural production occurs in just two populations: the Grays/Chinook and the Lower Gorge (see Figure 8-2).The Grays/Chinook population has a moderate persistence probability, and the Lower Gorge population has a high probability of persistence (LCFRB 2010a). The Lower Gorge population meets abundance and productivity criteria for very high levels of viability, but the distribution of spawning habitat (i.e., spatial structure) for the population has been significantly reduced (LCFRB 2010a); spatial structure may need to be improved, at least in part, through better performance from the Oregon portion of the population.

The very low persistence probabilities or possible extirpations of most chum salmon populations are due to low abundance, productivity, spatial structure, and diversity. Habitat loss has severely reduced the distribution of suitable chum salmon habitats, with accompanying reductions in abundance and productivity. Limited distribution also increases risk to the ESU from local disturbances. Although hatchery production of chum salmon has been limited and hatchery effects on diversity are thought to have been relatively small,[4] diversity has been greatly reduced at the ESU level because of presumed extirpations and the low abundance in the remaining populations (fewer than 100 spawners per year for most populations) (LCFRB 2010a). For additional discussion of Columbia River chum salmon population status, see the management unit plans (LCFRB 2010a, pp. 6-33 through 6-35; ODFW 2010, pp. 57-58; and NMFS 2013, p. 4-3) and Ford (2011).

---

[3] As described in Section 2.5 and 2.6, the WLC TRT recommended methods for evaluating the status of Lower Columbia River salmon and steelhead populations. The TRT's approach is based on evaluating the population parameters of abundance, productivity, spatial structure, and diversity and then integrating those assessments into an overall assessment of population persistence probability. As also described in Section 5.1, management unit recovery planners evaluated their respective populations' baseline status in a manner generally consistent with the WLC TRT's approach, with the baseline period being either circa 1999 (for Washington populations) or 2006-2008 (for Oregon populations). Unless otherwise noted, NMFS and the management unit planners believe that those assessments accurately the status of the population at that time; the assessments are the basis for the summaries presented here and are consistent with the conclusions of the Northwest Fisheries Science Center in its *Status Review Update for Pacific Salmon and Steelhead Listed under the Endangered Species Act* (Ford 2011). New information on population status will continue to accumulate over time and will be taken into account as needed to reflect the best available science regarding a population's status.

[4] LCFRB 2010a reports that the proportion of hatchery-origin spawners for most Washington populations is 3 percent or less. The exception is the Grays/Chinook population, which has a pHOS of 54 percent (LCFRB 2010a) because a conservation hatchery program is being used to supplement natural production in that population.

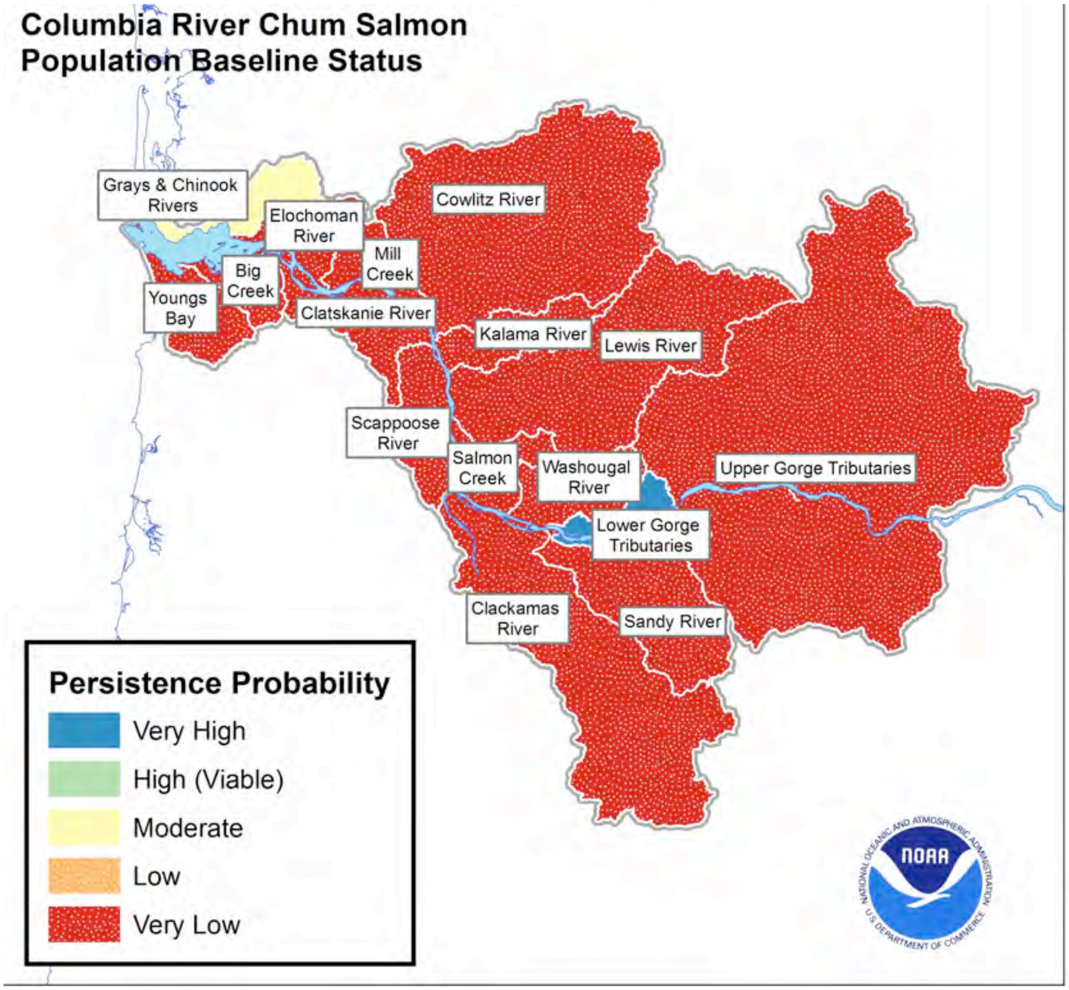

Figure 8-2. *Baseline Status of Historical Columbia River Chum Salmon Populations*

8.3 Target Status and Conservation Gaps for Chum Salmon Populations

Table 8-2 shows the baseline and target status and historical and target abundance for Washington Columbia River chum salmon population, along with target status and abundance for Oregon populations.[5] Local recovery planners coordinated with NMFS in making decisions about the target status for each population, taking into consideration opportunities for improvement in view of historical production, current habitat conditions and potential, and the desire to accommodate objectives such as maintaining harvest opportunities. Oregon did not identify abundance targets for chum salmon populations because quantitative data for use in calculating abundance targets and conservation gaps are not available. In Table 8-2, NMFS has included placeholder abundance targets for Oregon chum salmon populations based on the minimum

[5] Because quantitative data on the status of Oregon chum populations are lacking, ODFW (2010) variously refers to these populations as extirpated, nearly extirpated, functionally extirpated, or extremely depressed. It is often difficult to distinguish between a population that is truly extirpated and one that is not entirely extirpated but is at significant short-term risk. This ESU-level plan refers to Oregon chum salmon populations as very high risk or extirpated or nearly so.

abundance thresholds presented in McElhany et al. 2006 and 2007. The minimum abundance threshold (MAT) represents a lower bound estimate for average population size associated with a given persistence level. Minimum abundance thresholds take into account environmental variation, genetic issues, ecosystem functions, catastrophic risk, and other biological and ecological factors that affect the relationship between abundance and persistence probability and that may not be explicitly addressed in the viability curve analysis. McElhany et al. (2007) advised that, before a population is assigned to a particular risk category, the population should exceed the viability curve criterion, minimal abundance threshold, and any qualitative TRT criteria.[6] (Note: the target statuses in Table 8-2 are the same as the persistence probabilities in the recovery scenario presented in Table 3-1 in Section 3.1.3.)

Very large improvements are needed in the persistence probability of almost all chum salmon populations if the ESU is to achieve recovery (see Figure 8-3): nine of the eleven historical populations in Washington have very low baseline persistence probabilities, as do all six historical Oregon populations; it is possible that some populations are extirpated. Of the 17 historical populations, nine are targeted for high or better persistence probability. Some level of recovery effort will be needed for every population to arrest or reverse continuing long-tem declining trends; this is true for stabilizing populations, which are expected to remain at their baseline status, and for the ESU's two best-performing populations—the Grays/Chinook and Lower Gorge—which have baseline persistence probabilities of medium and high, respectively. For these latter two populations, meeting recovery objectives will require significant improvement in spatial structure. The Grays/Chinook will need improvements in diversity as well.

In the Coast stratum, five of seven populations are targeted for high or very high persistence probability. These include the Grays/Chinook and Elochoman/Skamakowa, which historically were among the most productive populations in the stratum. (The Grays/Chinook also is one of only two genetic legacy populations in the ESU.) However, two other Coast stratum populations that also historically were highly productive—Youngs Bay and Big Creek—are expected to remain at their baseline status of very low persistence probability to allow for incidental harvest of chum salmon that may occur in terminal fisheries that target hatchery coho and Chinook (ODFW 2010).

Of eight populations in the Cascade stratum, three—the Lewis, Sandy, and Washougal—are targeted for high or high-plus persistence probability; in the case of the Lewis, this is in part because it is a core population, meaning that historically it was one of the most productive in the stratum. Chum salmon in the Cowlitz and the Clackamas subbasins also are core populations.[7] However, extensive diking in the Longview/Kelso area limits the recovery prospects for chum salmon in the Cowlitz subbasin, and the Oregon chum recovery strategy does not require both the Clackamas and Sandy

---

[6] Minimum abundance thresholds are also specific to historical population size. Estimates of historical watershed size available to chum salmon populations are not available at this time, so the minimum abundance thresholds in Table 8-2 reflect the upper end of the range of the minimum abundance threshold for the small size category of chum salmon populations.

[7] The WLC TRT also indicated that the Cowlitz, including fall and summer-run fish, was likely an important component of the genetic legacy of the ESU (McElhany et al. 2003). As discussed above, preserving the summer component of the Columbia River chum ESU is an important recovery objective.

populations to be viable.[8] Thus the target status for the Cowlitz and Clackamas populations is medium. The Salmon Creek population is expected to remain at its baseline persistence probability of very low because of severe habitat degradation in that subbasin and the historically small size of the population.

In the Gorge stratum, which contains two populations, the Lower Gorge population (a core and genetic legacy population) is targeted for high persistence probability, and the Upper Gorge population is targeted for medium probability of persistence. The management unit recovery planners did not consider it feasible to achieve a higher persistence probability for the latter population. Challenges include the small amount of historical and current habitat (and thus the limited options for restoration); anthropogenic impacts that are unlikely to change in the near future (e.g., inundation of historical spawning habitat by Bonneville Reservoir and roads that restrict access to habitat); high uncertainty in the data and analyses for small populations[9]; and the possibly inaccurate designation of population structure for this stratum. The Oregon management unit plan states that most of these issues are related to the population structure designation and suggests re-evaluating the Gorge stratum population structure for all species (ODFW 2010). As discussed in Section 3.2.1, NMFS agrees that such an evaluation is needed.

If the scenario in Table 8-2 were achieved, it would slightly exceed the WLC TRT's stratum-level viability criteria in the Coast and Cascade strata. However, the scenario would not meet criteria in the Gorge stratum because only one Gorge population (the Lower Gorge) would be viable, instead of two. Exceeding the criteria in the Coast and Cascade strata was intentional on the part of local recovery planners to compensate for high levels of uncertainty about recovery prospects in the Gorge stratum (LCFRB 2010a). (Delisting criteria for the Columbia River chum ESU are described in Section 3.2 and below in Section 8.7.)

Figure 8-3 displays the population-level conservation gaps for Columbia River chum salmon graphically. The conservation gap reflects the magnitude of improvement needed to move a population from its baseline status to the target status. For additional discussion of the status targets and conservation gaps for Columbia River chum salmon populations, see the management unit plans (LCFRB 2010a, pp. 6-33 through 6-37, ODFW 2010 pp. 148-150, and NMFS 2013 p. 3-12).

---

[8] Oregon recovery planners set the desired status for chum salmon populations based on having half of the Oregon populations in a stratum reaching low extinction risk and the others improving significantly.
[9] In the method used by the WLC TRT and management unit planners to establish abundance goals, target abundance is based to some extent on the gap between current and historical abundance. If the historical abundance of Gorge chum salmon populations has been significantly overestimated, then the abundance needed to achieve their target status may also be overestimated (ODFW 2010).

Table 8-2

Baseline and Target Persistence Probability and Abundance of Columbia River Chum Salmon Populations

			Baseline Persistence Probability[10]					Abundance		
Stratum	Population	Contribution	A&P	S	D	Net[11]	Target Persistence Probability	Historical	Baseline[12]	Target[13]
Coast	Youngs Bay (OR) [C]	Stabilizing	--[14]	--	--	VL	VL	--	--	<500
	Grays/Chinook (WA) [C, GL]	Primary	VH	M	H	M	VH	10,000	1,600	1,600
	Big Creek (OR) [C]	Stabilizing	--	--	--	VL	VL	--	--	<500
	Elochoman/Skamakowa (WA) [C]	Primary	VL	H	L	VL	H	16,000	< 200	1,300
	Clatskanie (OR)	Primary	--	--	--	VL	H	--	--	1,000
	Mill/Abernathy/Germany (WA)	Primary	VL	H	L	VL	H	7,000	< 100	1,300
	Scappoose (OR)	Primary	--	--	--	VL	H	--	--	1,000
Cascade	Cowlitz - fall (WA) [C]	Contributing	VL	H	L	VL	M	195,000	< 300	900
	Cowlitz - Summer (WA) [C]	Contributing	VL	L	L	VL	M	--	--	900
	Kalama (WA)	Contributing	VL	H	L	VL	M	20,000	< 100	900

10 A&P = Abundance and productivity, S = spatial structure, and D = genetic and life history diversity. Net = overall persistence probability of the population. VL = very low, L = low, M = moderate, H = high, VH = very high.

11 All Oregon populations are considered to have a very low baseline persistence probability.

12 Baseline abundance was estimated as described in Section 5.1 and does not equal observed natural-origin spawner counts. The baseline is a modeled abundance that represents 100-year forward projections under conditions representative of a recent baseline period using a population viability analysis that is functionally equivalent to the risk analyses in McElhany et al. (2007). Washington numbers reflect fishery impacts prevalent in the period immediately prior to listing in 1999.

13 Oregon did not identify abundance targets for chum salmon populations because quantitative data for use in calculating abundance targets and conservation gaps are not available. In this table, NMFS has included placeholder abundance targets for Oregon chum salmon populations based on the minimum abundance thresholds presented in McElhany et al. 2006 and 2007. The minimum abundance threshold (MAT) represents a lower bound estimate for average population size associated with a given persistence level. Minimum abundance thresholds take into account environmental variation, genetic issues, ecosystem functions, catastrophic risk, and other biological and ecological factors that affect the relationship between abundance and persistence probability and that may not be explicitly addressed in the viability curve analysis. McElhany et al. (2007) advised that, before a population is assigned to a particular risk category, the population should exceed the viability curve criterion, minimal abundance threshold, and any qualitative TRT criteria.

14 " – " indicates that no data are available from which to make a quantitative assessment.

Table 8-2

Baseline and Target Persistence Probability and Abundance of Columbia River Chum Salmon Populations

			Baseline Persistence Probability[10]					Abundance		
Stratum	**Population**	**Contribution**	**A&P**	**S**	**D**	**Net[11]**	**Target Persistence Probability**	**Historical**	**Baseline[12]**	**Target[13]**
	Lewis (WA) [C]	Primary	VL	H	L	VL	H	125,000	< 100	1,300
	Salmon Creek (WA)	Stabilizing	VL	L	L	VL	VL	--	< 100	--
	Clackamas (OR) [C]	Contributing	--	--	--	VL	M	--	--	500
	Sandy (OR)	Primary	--	--	--	VL	H	--	--	1,000
	Washougal (WA)	Primary	VL	H	L	VL	H+	18,000	< 100	1,300
Gorge	Lower Gorge (WA & OR) [C, GL]	Primary	VH	H	VH	H	VH	6,000	2,000	2,000
	Upper Gorge (WA & OR)	Contributing	VL	L	L	VL	M	11,000	< 50	900

C = Core populations, meaning those that historically were the most productive.

G = Genetic legacy populations, which best represent historical genetic diversity.

Source: LCFRB (2010a) and ODFW (2010).

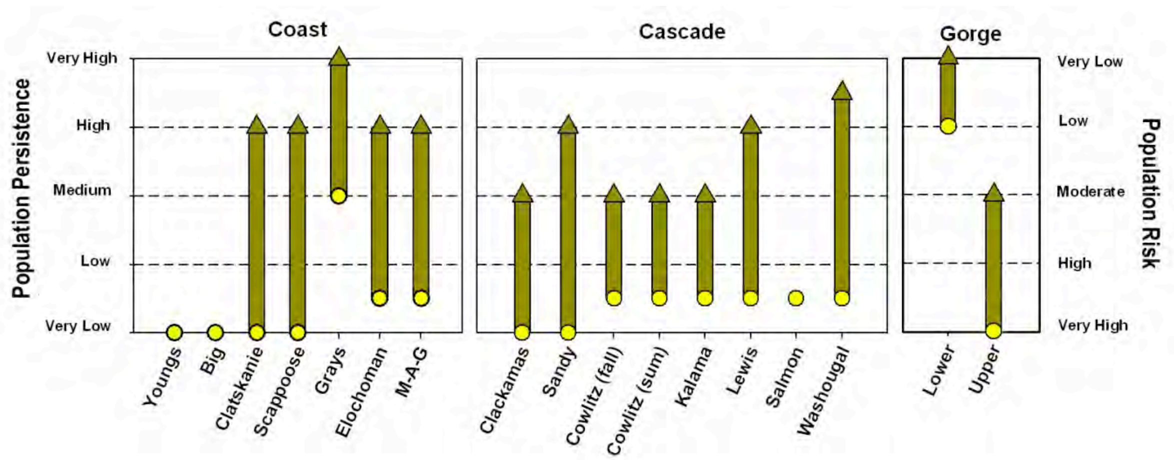

Figure 8-3. *Conservation Gaps for Columbia River Chum Salmon Populations: Difference between Baseline and Target Status*

Source: LCFRB 2010a.

8.4 Limiting Factors and Threats for Columbia River Chum Salmon

Columbia River chum salmon have been—and continue to be—affected by loss and degradation of spawning and rearing habitat, the impacts of mainstem hydropower dams on upstream access and downstream habitats, and the legacy effects of historical harvest; together, these factors have reduced the persistence probability of all populations. Under baseline conditions, constrained spatial structure at the ESU level (related to conversion, degradation, and inundation of habitat) contributes to very low abundance and low genetic diversity in most populations and increases risk to the ESU from local disturbances.

Table 8-3 and the text that follows summarize baseline limiting factors and threats for Columbia River chum salmon strata based on population-specific limiting factors and threats identified in the management unit plans. In cases where conditions have changed significantly since the management unit plans' analyses of limiting factors and threats (e.g., if harvest rates have dropped or a dam is no longer present), this is noted in the text. Unless otherwise noted, NMFS agrees that the management unit plans' identification of limiting factors provide a credible hypothesis for understanding population performance and indentifying management actions.

Because the individual management unit plans used somewhat different terms in identifying limiting factors, NMFS has translated those terms into standardized and more general terminology taken from a NMFS "data dictionary" of possible ecological concerns that could affect salmon and steelhead (Hamm 2012; see Section 5.4). In addition, in Table 8-3 NMFS has rolled up the population-specific limiting factors (see Appendix H) to the stratum level—a process that has resulted in some loss of specificity.

In addition, each management unit plan used a different approach for identifying limiting factors and threats (see Section 5.3). One difference relevant to the crosswalk is that while the Oregon management unit plan identified primary and secondary limiting factors for each population in each threat category,[15] the Washington management unit plan categorized limiting factors in this way only for habitat-related limiting factors, and the estuary module did not use the primary and secondary terminology. For the crosswalk and this table, NMFS assigned primary and secondary status to non-habitat limiting factors for Washington populations (based on the Washington management unit plan's quantification of threat impacts and the professional judgment of Lower Columbia Fish Recovery Board's staff and consultants). It is likely that some apparent distinctions in results between Washington and Oregon populations are artifacts of differences in limiting factor assessment methodologies and not an actual difference in conditions or their effects on salmon and steelhead populations. In addition, there is not necessarily a bright line between primary and secondary limiting factor designations. Nevertheless, NMFS believes that the designations are useful, particularly for looking across ESUs and populations and identifying patterns (see Chapter 4).

The management unit plans provide more detail on limiting factors and threats affecting each Columbia River chum salmon population, including magnitude, spatial scale, and relative impact (see LCFRB 2010a, Chapter 3 and various sections of Volume II; ODFW 2010, pp. 141-146; and NMFS 2013, Chapter 5). For a regional perspective on limiting factors and threats that affect multiple salmon and steelhead ESUs, see Chapter 4 of this recovery plan. For a description of the data dictionary, the approach NMFS used to correlate management unit terms for limiting factors with the standardized NMFS terminology at the population scale, and the approach for rolling up from the population to the stratum scale, see Section 5.4 and Appendix H.

Management unit recovery planners in Oregon and Washington recognized that six major categories of manageable threats—tributary habitat, estuary habitat, hydropower, harvest, hatcheries, and predation—were useful as an organizing construct for grouping limiting factors, quantifying impacts on population productivity, and determining how much different categories of threats would need to be reduced to close the gap between baseline and target population status. Planners in both Washington and Oregon quantified the impacts of each of these major threat categories on population status, along with a reduction in each impact that would be consistent with achieving population target status. The results of that analysis are presented in Section 8.5 and provide a related but slightly different perspective on limiting factors. The threat reduction targets also allow actions to be scaled to achieve a specific impact reduction, and to be linked to monitoring and performance benchmarks.

[15] In the Oregon management unit plan, primary limiting factors are those that have the greatest impact and secondary limiting factors have a lesser but still significant impact.

Table 8-3

Baseline Limiting Factors and Threats Affecting Columbia River Chum Salmon: Stratum-Level Summary

Ecological Concern	Threat(s)	VSP Parameters Affected	Coast	Cascade	Gorge
Tributary Habitat Limiting Factors[16]					
Riparian Condition	Past and/or current land use practices	All	Primary for WA juveniles	Primary for WA juveniles	Primary for Lower and Upper Gorge adults and juveniles
Channel Structure and Form	Past and/or current land use practices/ transportation corridor	All	Primary for WA juveniles	Primary for WA juveniles	Primary for Lower and Upper Gorge adults and juveniles
Peripheral and Transitional Habitats: Side Channel and Wetland Conditions	Past and/or current land use practices/ transportation corridor	All	Primary for WA juveniles	Primary for WA juveniles	Primary for Lower and Upper Gorge adults and juveniles
Peripheral and Transitional Habitats: Floodplain Conditions	Past and/or current land use practices/ transportation corridor	All	Primary for WA juveniles	Primary for WA juveniles	Primary for Lower and Upper Gorge adults and juveniles
Sediment Conditions	Past and/or current land use practices/ transportation corridor	All	Primary for WA juveniles; secondary for OR juveniles	Primary for Cowlitz, Kalama, and Washougal juveniles; secondary for OR juveniles	
Water Quality (Temperature)	Land uses that impair riparian function/decrease streamflow, dams	A,P,D		Primary for Kalama, Lewis, and Salmon Creek juveniles	
Water Quantity (Flow)	Dams, land use, and water withdrawals for irrigation, municipal uses, and hatchery operations	All	Secondary for juveniles in all populations	Primary for Cowlitz and Kalama juveniles; secondary for juveniles in all other populations	Secondary for Lower and Upper Gorge juveniles

[16] Tributary habitat limiting factors in this table primarily reflect those identified in the Washington management unit plan. This is because chum salmon do not migrate far up tributaries and Oregon recovery planners categorized chum salmon limiting factors occurring in areas of tidal influence in the lower reaches of tributaries as estuarine. Thus, the relative paucity of tributary habitat limiting factors for Oregon chum salmon populations is an artifact of differences in limiting factor assessment methodologies between the two states and not an actual difference in the extent of tributary habitat limiting factors or their effects on chum salmon populations.

Table 8-3

Baseline Limiting Factors and Threats Affecting Columbia River Chum Salmon: Stratum-Level Summary

Ecological Concern	Threat(s)	VSP Parameters Affected	Coast	Cascade	Gorge
Estuary Habitat Limiting Factors[17]					
Toxic Contaminants	Agricultural chemicals, urban and industrial practices	A,P,D	Secondary for juveniles in all populations		
Food[18] (Shift from macrodetrital- to microdetrital-based food web)	Dam reservoirs	All	Secondary for juveniles in all populations		
Peripheral and Transitional Habitats: Estuary Condition	Past and/or current land use practices, transportation corridor, mainstem dams	All	Primary for juveniles in all populations		
Channel Structure and Form	Past and/or current land use practices/ transportation corridor	All	Primary for juveniles in all populations		
Sediment Conditions	Past and/or current land use practices/transportation corridor, dams	All	Primary for juveniles in all populations		
Water Quality (Temperature)	Land uses that impair riparian function/decrease streamflow, dam reservoirs	A,P,D	Secondary for juveniles in all populations		
Water Quantity (Flow)	Columbia River mainstem dams	All	Primary for juveniles in all populations		

[17] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the ESU, the estuarine limiting factors in this table and Section 8.4.2 reflect the determinations in the Oregon management unit plan, applied to all Columbia River chum salmon populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

[18] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is unclear.

Table 8-3

Baseline Limiting Factors and Threats Affecting Columbia River Chum Salmon: Stratum-Level Summary

Ecological Concern	Threat(s)	VSP Parameters Affected	Coast	Cascade	Gorge
Hydropower Limiting Factors					
Habitat Quantity (Access)	Bonneville Dam	All			Primary for Upper Gorge adults and juveniles
Habitat Quantity (Inundation)	Bonneville Dam	All			Primary for Upper Gorge adults and juveniles
Hatchery Limiting Factors					
Food	Smolts from all Columbia Basin hatcheries competing for food and space in the estuary	All			
Population Diversity	Stray hatchery fish interbreeding with wild fish	A,P,D	Secondary for Grays/Chinook adults		
Predation Limiting Factors					
Direct Mortality	Dams	A,P,D			Secondary for Upper Gorge juveniles
Direct Mortality	Hatchery fish	A,P,D	Secondary for juveniles in all populations[19]		

8.4.1 Tributary Habitat Limiting Factors

The pervasive loss of critical spawning, incubation, and rearing habitat is a primary limiting factor for chum salmon throughout the Lower Columbia subdomain. Chum salmon typically spawn in upwelling areas of clean gravel beds in mainstem and side-channel portions of low-gradient reaches above tidewater. These habitats have been practically eliminated in most systems through a combination of channel alteration and sedimentation that is attributable largely to past and current land uses; these include historical and current forest management, agriculture, rural residential uses, urban development, and gravel extraction. Low-elevation stream reaches have been directly affected by extensive channelization, diking, wetland conversion, stream clearing, and gravel extraction. Impaired watershed processes continue to limit chum salmon habitat through effects on floodplain and wetland habitat conditions and connectivity, riparian conditions and function, and channel structure.

Impaired side channel and wetland conditions, along with degraded floodplain habitat are identified as primary limiting factors for all Washington populations and the two Gorge populations. Channel structure and form issues and degraded riparian conditions also are considered primary limiting factors for juveniles in all Washington populations and for juveniles and adults in the two Gorge populations. Sediment conditions are

[19] Chum salmon fry from all populations may experience predation to varying degrees by hatchery-origin coho, steelhead, and Chinook smolts, although differences in life history patterns may moderate effects and the significance of these interactions is unknown.

identified as a primary limiting factor for all Washington populations in the Coast stratum and for the Cowlitz, Kalama, and Washougal populations in the Cascade stratum, and they are considered a secondary limiting factor for the Oregon portion of the Coast and Cascade strata.[20] In addition, water quality—specifically, elevated water temperature brought about through land use and hydropower reservoirs—is a primary factor for Kalama, Lewis, and Salmon Creek juveniles. Water quantity issues related to altered hydrology and flow timing have been identified as a primary limiting factor for juveniles in the Cowlitz and Kalama populations and as a secondary limiting factor for juveniles in all other chum populations.

In the Coast stratum, tributary habitat limiting factors are largely the same as those described above for the ESU as a whole and are attributable largely to past and current land uses. Lower reaches are mostly in agricultural and rural residential use and have been extensively modified by bank stabilization, levees, and tide gates. Private and state forest land predominates in the upper reaches of Coast ecozone subbasins. The high density of unimproved rural roads throughout the area leads to an abundance of fine sediment in tributary streams that covers spawning gravel and increases turbidity. In the Youngs Bay and Big Creek subbasins, hatchery weirs are identified as secondary limiting factors because they block access to historically productive spawning and rearing habitat for chum salmon.

In the Cascade stratum, tributary habitat limiting factors are largely the same as those described above for the ESU as a whole, with the addition of road crossings that impede chum salmon passage; this has been identified as a secondary limiting factor in the Clackamas and Sandy subbasins. Land uses that have limited the productivity of tributary habitat in this stratum include forest management and timber harvest, agriculture, rural residential and urban development, and gravel extraction. A mix of private, state, and federal forest land predominates in the upper mainstem and headwater tributaries of the Cascade subbasins, while the lower mainstem and tributary reaches of most subbasins are characterized by agricultural and rural residential land use, with some urban development, especially in the Salmon Creek and lower Clackamas subbasins.

In the Gorge stratum, habitat-related limiting factors result from past and current land uses; these include a mix of private, state, and federal forest land in the upper mainstem and headwater reaches of the Gorge subbasins, plus transportation and rural residential land uses, with some urban development, in lower mainstem and tributary reaches. Highway and transportation corridors run parallel to the Columbia River shoreline, traversing all creek drainages in ways that restrict access and disconnect upland and lowland habitat processes. The associated habitat degradation is considered a primary limiting factor for the Upper and Lower Gorge chum salmon populations. The Upper Gorge population also is significantly affected by habitat loss caused by inundation from

---

[20] Tributary habitat limiting factors for chum salmon populations primarily reflect those identified in the Washington management unit plan. This is because chum salmon do not migrate far up tributaries and Oregon recovery planners categorized chum salmon limiting factors occurring in areas of tidal influence in the lower reaches of tributaries as estuarine. Thus, the apparent lack of tributary habitat limiting factors for Oregon populations is an artifact of differences in limiting factor assessment methodologies between the two states and not an actual difference in the extent of tributary habitat limiting factors or their effects on chum salmon populations.

Bonneville Reservoir; it is likely that significant amounts of historical spawning and rearing habitat for this population have been inundated.

8.4.2 Estuary Habitat Limiting Factors[21]

Estuary habitat conditions are important for juvenile chum salmon, which leave their natal streams as fry and spend considerable time rearing in the estuary. Water quantity issues related to altered hydrology and flow timing are identified as a primary limiting factor for all populations, as is impaired sediment and sand routing; these limiting factors are associated with hydroregulation at large storage reservoirs in the interior of the Columbia Basin, and, in the case of sediment issues, land uses both past and present. Much of the land surrounding the Columbia River estuary is in agricultural or rural residential use and has been extensively modified via dikes, levees, bank stabilization, and tide gates. Altered hydrology and sediment routing influence habitat-forming processes, the quantity and accessibility of habitats such as side channels and wetlands, the dynamics of the Columbia River plume, and the estuarine food web. Channel structure issues, in the form of reduced habitat complexity and diversity, and reduced access to peripheral and transitional habitats such as side channels and wetlands also are identified as primary limiting factors for juveniles from all populations. Again, simplification of channel structure is related to conversion of land to other uses—agricultural, rural residential, and as a transportation corridor—while juveniles' access to side channels and wetlands is impaired by these same land uses but also by flow alterations caused by mainstem dams.

Secondary limiting factors in the estuary that affect chum salmon are exposure to toxic contaminants (from urban, agricultural, and industrial sources) and elevated late summer and fall water temperatures, which are related to (1) land use practices that impair riparian function or decrease streamflow, and (2) large hydropower reservoirs.[22] Altered food web dynamics involving a transition from a macrodetrital-based food web to a microdetrital-based food web also are considered a secondary limiting factor for all populations.[23] These changes in the estuarine food web are caused primarily by

---

[21] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the ESU, the estuarine limiting factors in this section and in Table 8-3 reflect the determinations in the Oregon management unit plan, applied to all Columbia River chum salmon populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

[22] Although the management unit plans identified temperature impacts as a secondary limiting factor for juveniles in all populations, the timing of juvenile chum salmon migration and rearing raises questions about the significance of this limiting factor; see Section 8.4.3.

[23] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is unclear.

increased microdetrital inputs from hydropower reservoirs and the loss of wetland habitats through diking and filling.

8.4.3 Hydropower Limiting Factors

Flow management operations at large storage reservoirs in the interior of the Columbia Basin (Grand Coulee, Dworshak, etc.) affect all juvenile Columbia River chum salmon in the lower mainstem and estuary, and potentially in the plume—primarily by altering flow volume and timing. These alterations impair sediment routing, influence habitat-forming processes, reduce access to peripheral habitat, and change the dynamics of the Columbia River plume and the estuarine food web (see Section 8.4.2).[24] Moreover, the large reservoirs associated with mainstem dams contribute to elevated water temperatures downstream in late summer and fall. Although the management unit recovery plans identified temperature impacts of the hydropower system as a secondary limiting factor for all juvenile chum salmon, juvenile chum salmon are rearing in and migrating through the mainstem in February through July, with peak presence in May(Dawley et al. 1986, McCabe et al. 1986, Roegner et al. 2004, Bottom et al. 2008, cited in Figure 2.2 of Carter et al. 2009). Thus, it is unlikely that elevated mainstem temperatures are having a significant impact on juvenile chum salmon.

For the Upper Gorge population, which spawns above Bonneville Dam, passage issues at Bonneville and inundation of historical spawning habitat by Bonneville Reservoir are identified as primary limiting factors.[25] For the Lower Gorge population, the availability of tailrace spawning habitat is affected by flows from the Columbia River hydropower system, with winter and early spring flows being critical to prevent dewatering of redds before emergence.

There are no large tributary dams in the Coast ecozone. In the Cascade and Gorge ecozones, tributary dams are not identified as a primary or secondary limiting factor. Large dam complexes in the Cowlitz and Lewis systems may be affecting chum salmon spawning and rearing conditions by altering habitat-forming processes downstream, but the significance of these effects is unknown (and LCFRB 2010a does not explicitly identify such effects as limiting factors).

8.4.4 Harvest Limiting Factors

Historical high harvest rates of chum salmon may have compounded the effects of habitat losses during the last century, but harvest mortality is not considered a baseline or current limiting factor for Columbia River chum salmon. Commercial chum salmon fisheries were closed or drastically reduced in the 1950s. Harvest impacts are limited to illegal harvest and incidental take in lower river commercial gillnet and recreational fisheries (LCFRB 2010a). Commercial fisheries for Chinook and coho salmon occur

---

[24] It is likely that flow impacts of the hydropower system affect Lower Columbia River ESUs more through changes in habitat-forming processes (including impacts to the plume) and food web impacts than through changes in migratory travel time.

[25] In the 2008 FCRPS Biological Opinion and its 2010 Supplement, NMFS assumed that survival of adult chum passing Bonneville Dam is 96 to 97 percent, based on data for Snake River Fall Chinook salmon (NMFS 2008f and 2010a). It is likely that significant areas of historical chum spawning habitat were inundated by Bonneville Reservoir.

before adult chum salmon return in the late fall. Harvest-related mortality of chum salmon has been less than 5 percent per year since 1993 (LCFRB 2010a) and has averaged 1.6 percent annually since 1998 (ODFW 2010).

8.4.5 Hatchery-Related Limiting Factors

Chum salmon have never been subject to significant hatchery production in the Columbia River for fishery mitigation programs. Hatchery-related factors were not identified as limiting for any Oregon chum salmon population. ODFW began releasing chum salmon into the Big Creek subbasin in 2011 as part of a reintroduction program, using Grays River chum salmon as broodstock. In Washington, conservation hatchery programs are being used to supplement natural production in the Grays/Chinook and Lower Gorge populations. Population-level effects resulting from stray hatchery fish interbreeding with natural-origin fish were identified as a secondary limiting factor for the Grays/Chinook chum salmon, where analysis by the regional Hatchery Scientific Review Group estimated an 11 percent reduction in productivity; however, the HSRG analysis did not consider the positive demographic effects of increased natural spawning abundance through hatchery supplementation. Conservation hatchery programs are identified as a key component of reintroduction and recovery efforts for chum salmon populations in Oregon and Washington.

It is possible that juvenile chum salmon rearing in the estuary are affected by hatchery-origin Chinook, steelhead, and coho juveniles. Potentially detrimental interactions include competition for food and space. However, differences in life history patterns may moderate effects, and the significance of interactions is unknown. NMFS (2011a) and LCFRB (2010a) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon and steelhead in freshwater, estuarine, and nearshore ocean habitats.

8.4.6 Predation Limiting Factors

Predation by hatchery smolts in the estuary is identified as a secondary limiting factor for all Columbia River chum salmon. Chum salmon fry from all populations may experience predation by hatchery-origin coho, steelhead, and Chinook smolts, although differences in life history patterns may moderate effects, and the significance of interactions is unknown. In addition, predation by non-salmonid fish is identified as a secondary limiting factor for the Upper Gorge population. Although the extent of chum salmon production above Bonneville is unknown, fish spawning above the dam would experience predation by pikeminnow above and below Bonneville Dam and by walleye and smallmouth bass in the reservoir behind the dam.

8.5 Baseline Threat Impacts and Reduction Targets

Table 8-4 shows the estimated impact on each Washington Columbia River chum salmon population resulting from potentially manageable threats, organized into six threat categories: tributary habitat degradation, estuary habitat degradation, hydropower, harvest, hatcheries, and predation. Both baseline and target impacts are shown, with the targets representing levels that would be consistent with long-term recovery goals. Impact values indicate the percentage reduction in abundance and productivity that is attributable to human activities related to a particular threat category. The value associated with any particular threat category can be interpreted as the percent reduction in abundance and productivity from historical conditions if that threat category were the only one affecting the population. The table also shows the overall percentage improvement that is needed to achieve the target impacts and corresponding population status.[26] These cumulative values across all threat categories (both baseline and target) are multiplicative rather than additive. Both the Oregon and Washington management unit plans use cumulative survivals across threat categories to illustrate the overall level of improvement needed. Each plan assumes that there is a direct proportional relationship between the projected changes in cumulative survival and the required changes in natural-origin spawner abundance and productivity. For populations where the survival improvement needed is larger than 500 percent, Table 8-4 does not report the exact value, in part because the value is highly uncertain.[27]

As an example, the baseline status of the Elochoman/Skamakowa chum salmon population, circa 1999, has been severely reduced by the combined effects of multiple threats. The cumulative reduction in status was estimated at 93.3 percent from the multiplicative impacts of multiple threats acting across the salmon life cycle. Thus, current status is just 6.7 percent of the historical potential with no human impact. Tributary and estuary habitat impacts each accounted for reductions in population productivity of 25 percent or more, with corresponding reductions in abundance, spatial structure, and diversity. The Washington management unit plan identifies a recovery strategy involving significant reductions in the impact of habitat-related threats. For instance, the plan targets tributary habitat impacts to be reduced from the estimated baseline level of 90 percent to 45 percent (i.e., an approximately 100 percent improvement relative to baseline conditions). With the targeted reductions in individual impacts, the cumulative effect of all impacts would drop from 93.3 percent at baseline to 55 percent at the target status. This change would translate into a more than 500 percent improvement in survival relative to the baseline. Although the population would still be experiencing abundance and productivity that are 74.7 percent lower than historical conditions, the extinction risk at this mortality level would be estimated sufficient to meet the targets for this plan.

---

[26] The percentage improvement (rounded to the nearest 10) in population survival needed to achieve target impacts is taken from Table 6-7 of LCFRB (2010a). For populations where the survival improvement needed is larger than 500 percent, this table does not report the exact value, for the reasons explained in Section 8.5.

[27] For some populations—many of them small—the survival improvement needed is very large and highly uncertain because various other factors also are uncertain (i.e., the population's baseline persistence probability, the exact degree of impact of human activities on tributary habitat, and whether the population's response to reductions in impacts will be linear). In addition, very small populations do not necessarily follow predictable patterns in their response to changing conditions.

Baseline impacts reflect conditions prevalent at the time of ESA listing (circa 1999). Dam impacts reflect passage mortality, habitat loss caused by inundation, and loss of access to historical production areas. Hatchery impacts were limited to not more than 50 percent per population, in accordance with Hatchery Scientific Review Group (HSRG) assessments of the potential for genetic effects (Hatchery Scientific Review Group 2009). Washington recovery planners derived estimates of impacts to tributary habitat using the Ecosystem Diagnosis and Treatment (EDT) model. In general, the tributary habitat values in Table 8-4 have the highest degree of uncertainty relative to the other threat categories. (See Section 5.5 for more on the methodologies used to estimate baseline impacts.)

Estimates of threat impacts are useful in showing the relative magnitude of impacts on each population. Given the differences in methodologies, some values in Table 8-4 for Oregon and Washington populations are not necessarily directly comparable. Thus, values for Oregon populations are most directly comparable to those for other Oregon populations, and values for Washington populations are most directly comparable to those for other Washington populations. Regardless of differences in specific threat impact definitions and methods, the net effect of changes from all threats is useful in understanding the magnitude of population improvement needed to achieve the target population status.

The target impacts in Table 8-4 represent one of several possible combinations of threat reductions that could conceivably close the conservation gap and lead to a population achieving its target status. The particular threat reductions shown in Table 8-4 reflect policy decisions and the methodologies and assumptions used by the management unit recovery planners. (For a description of how target impacts were developed, see Section 5.6.) In estimating impacts, management unit recovery planners evaluated each threat category independently (i.e., values in the table reflect the mortality of chum salmon exposed to that particular category of threats, whether or not they are exposed to threats in other categories). The estimates of baseline threat impacts have high levels of uncertainty and in many cases should be considered working hypotheses that are testable as part of recovery plan implementation. Despite this uncertainty, it is the expert judgment of NMFS and management unit scientists that, based on the best available information at this time, the estimates of baseline threat impacts provide a reasonable estimate of the relative magnitude of different sources of anthropogenic mortality and serve as an adequate basis for designing initial recovery actions.[28] As more and better information is collected, it will be applied to recovery efforts in an adaptive management framework.

As shown in Table 8-4, most of the gains in the viability of Washington chum salmon populations are targeted to be achieved by improving tributary and estuarine habitat. Because potentially manageable harvest, hatchery, and predation impacts on chum salmon already are relatively low, there is little opportunity to further reduce threats in these sectors. Hydropower actions also are projected to benefit the Upper Gorge population, which is affected by Bonneville Dam and its reservoir.

---

[28] As implementation proceeds, research, monitoring, and evaluation and adaptive management will be key in helping to refine scientific understanding of the impact of threats on population persistence and of the extent to which management actions are reducing threats.

Oregon recovery planners did not develop current and target threat impacts for chum salmon populations because quantitative information for use in calculating baseline or target threat impacts or the likelihood of recovery goals being achieved was not available (ODFW 2010). Recovery planners developed a chum salmon recovery strategy that involves identifying specific habitat needs and proceeding with reintroduction, initially in the Coast stratum (see Appendix I of ODFW 2010).

More information on threat reduction scenarios, including methodologies to determine baseline and target impacts, is available in the management unit plans (ODFW 2010 p. 152 and LCFRB 2010a pp. 4-30 through 4-33 and 6-37 through 6-40).

Table 8-4

Impacts of Potentially Manageable Threat, and Impact Reduction Targets Consistent with Recovery of Columbia River Chum Salmon (Washington Populations Only[29])

Washington Population	Impacts at Baseline[30]							Impacts at Target							% Survival Improvement Needed[38]
	T. Hab[31]	Est[32]	Dams[33]	Harv[34]	Hat[35]	Pred[36]	Cumul-ative[37]	T. Hab	Est	Dams	Harv	Hat	Pred	Cumul-ative	
Coast															
Grays/Chinook	0.80	0.25	0.00	0.05	0.11	0.03	0.8770	0.80	0.25	0.00	0.05	0.11	0.03	0.8770	0%
Eloch/Skam	0.90	0.25	0.00	0.05	0.03	0.03	0.9330	0.45	0.13	0.00	0.03	0.01	0.02	0.5497	>500%
Mill/Ab/Germ	0.90	0.25	0.00	0.05	0.03	0.03	0.9330	0.45	0.13	0.00	0.03	0.01	0.02	0.7497	>500%
Cascade															
Cowlitz (Fall)	0.96	0.25	0.00	0.05	0.02	0.03	0.9729	0.48	0.13	0.00	0.03	0.01	0.02	0.5742	>500%
Cowlitz (Summer)	0.96	0.25	0.00	0.05	0.02	0.03	0.9729	0.48	0.13	0.00	0.03	0.01	0.02	0.5742	>500%
Kalama	0.90	0.25	0.00	0.05	0.01	0.03	0.9316	0.45	0.13	0.00	0.03	0.00	0.02	0.5451	>500%
Lewis	0.90	0.25	0.00	0.05	0.01	0.03	0.9316	0.45	0.13	0.00	0.03	0.01	0.02	0.5497	>500%
Salmon Creek	0.98	0.25	0.00	0.05	0.01	0.03	0.9863	0.98	0.25	0.00	0.05	0.01	0.03	0.9863	0%
Washougal	0.96	0.25	0.00	0.05	0.01	0.03	0.9863	0.48	0.13	0.00	0.03	0.01	0.02	0.5742	>500%

29 Oregon populations are not included in this table because data are not available to quantify the baseline or target threat impacts for these populations.
30 Impact figures represent a percentage reduction in abundance and productivity that is attributable to human activities related to a particular threat category. See Sections 5.5 and 5.6 for information on methodologies.
31 Reduction in tributary habitat production potential relative to historical conditions.
32 Reduction in juvenile survival in the Columbia River estuary as a result of habitat changes (relative to historical conditions); excludes predation.
33 Reflects passage mortality, habitat loss caused by inundation, and loss of access to historical production areas.
34 Includes direct and indirect mortality.
35 Reflects only the negative impacts of hatchery-origin fish, such as high pHOS and low PNI (proportion of natural influence), not the benefits of conservation hatchery programs.
36 Includes the aggregate predation rate in the Columbia River mainstem and estuary by northern pikeminnow, marine mammals, Caspian terns, and cormorants.
37 Cumulative values (both baseline and target) are multiplicative rather than additive and are equal to $(1-[(1-M_{thab})(1-M_{est})(1-M_{dams})(1-M_{harv})(1-M_{hatch})(1-M_{pred})])$.
38 Survival improvements indicate the percentage improvement (rounded to the nearest 10) in population survival needed to achieve target impacts and are taken from Table 6-7 of LCFRB (2010a). For populations where the survival improvement needed is larger than 500 percent, this table does not report the exact value, for the reasons explained in Section 8.5.

Table 8-4

Impacts of Potentially Manageable Threat, and Impact Reduction Targets Consistent with Recovery of Columbia River Chum Salmon (Washington Populations Only[29])

Washington Population	Impacts at Baseline[30]							Impacts at Target							% Survival Improvement Needed[38]
	T. Hab[31]	Est[32]	Dams[33]	Harv[34]	Hat[35]	Pred[36]	Cumul-ative[37]	T. Hab	Est	Dams	Harv	Hat	Pred	Cumul-ative	
Gorge															
Lower Gorge—WA portion	0.40	0.25	0.30	0.05	0.01	0.03	0.7126	0.40	0.25	0.30	0.05	0.01	0.03	0.7126	0%
Upper Gorge—WA portion	0.97	0.25	0.96	0.05	0.01	0.03	0.9992	0.49	0.13	0.48	0.03	0.00	0.02	0.7807	>500%

8.6 ESU Recovery Strategy for Columbia River Chum Salmon

This section describes the recovery strategy for Columbia River chum salmon. A general summary of the ESU-level strategy is presented first. This is followed by subsections on each of the threat categories and critical uncertainties that pertain to the strategy. Where appropriate, stratum-specific strategies are described for each threat category.

8.6.1 Strategy Summary

The ESU recovery strategy for Columbia River chum salmon focuses on improving tributary and estuarine habitat conditions, reducing or mitigating hydropower impacts, and reestablishing chum salmon populations where they may have been extirpated. The goal of the strategy is to increase the abundance, productivity, diversity, and spatial structure of chum salmon populations such that the Coast and Cascade chum salmon strata are restored to a high probability of persistence and the persistence probability of the two Gorge populations is improved (including achieving a high persistence probability for the Lower Gorge population). The ESU recovery strategy has the following main elements:

1. Protect and improve the Grays/Chinook and Lower Gorge populations, which together produce the majority of Columbia River chum salmon (LCFRB 2010a) and are the only populations in the ESU not currently at very high risk of extinction.

2. Identify, protect, and restore chum salmon spawning habitat in lower mainstem and off-channel areas of large rivers and streams that are fed by upwelling from intergravel flows or springs. Restore hydrologic, riparian, and sediment processes (e.g., large woody debris recruitment) that support the accumulation of spawning gravel and reduce inputs of fine sediment.

3. Restore off-channel and side-channel habitats (alcoves, wetlands, floodplains, etc.) in the Columbia River estuary, where chum salmon fry rely on peripheral and transitional habitats for extended estuarine rearing.

4. Use hatchery reintroduction as appropriate in reestablishing chum salmon populations and continue using supplementation to enhance the abundance of the Grays/Chinook and Lower Gorge populations.

Restoring tributary spawning and estuary rearing habitat is essential in the recovery of Columbia River chum salmon. Although the recovery strategy includes other components, no other factor can effectively bring about recovery (LCFRB 2010a).

The Oregon management unit plan's description of a systematic, adaptive approach to chum salmon recovery can be viewed as a template for the ESU. The approach involves (1) identifying, assessing, and protecting existing chum salmon habitat, especially in currently productive areas, (2) restoring spawning and rearing habitat in all ecozones as needed to support recovered populations,[39] (3) reestablishing populations in selected subbasins, (4) monitoring to evaluate the program and allow for adaptive management, and (5) applying successful techniques elsewhere (see ODFW 2010, Appendix I). Oregon intends to focus initial efforts on the Clatskanie and Scappoose populations and then, based on results in those populations, expand efforts to populations in the Cascade and Gorge ecozones. Washington intends to focus initial efforts on the Elochoman-Skamokawa, Mill/Abernathy/Germany, Lewis, and Washougal populations.

Reestablishing chum salmon populations could occur through recolonization or hatchery reintroduction. Recolonization is the process of fish from other populations straying into a subbasin and spawning successfully; this may lead to the establishment of self-sustaining, locally adapted populations. If chum salmon abundances are so low that recolonization cannot occur, hatchery reintroduction may have a higher likelihood of success. For either method to be successful, the factors that led to extirpation will need to have been addressed—thus the emphasis on habitat assessment and restoration.

As part of a series of 3- to 5-year implementation schedules, management unit planners will work with NMFS staff to prioritize individual actions within each threat category, rather than across threat categories (see Chapter 11 for more on implementation).

Key critical uncertainties that need to be addressed to support implementation of near-term actions for chum salmon relate to current population status, estuarine habitat requirements, the extent and location of currently or potentially suitable habitat, and the effectiveness of hatchery reintroduction compared to natural recolonization (see Section 8.6.8).

The subsections below describe recovery strategies and near-term and long-term priorities for each threat category. For specific management actions in each threat category, linked to population and location, see the management unit plans (LCFRB 2010a, ODFW 2010, NMFS 2013).

8.6.2 Tributary Habitat Strategy

Tributary habitat protection and improvement are essential to the recovery of Columbia River chum salmon, which will benefit from the regional tributary habitat strategy described in Section 4.1.2. The regional strategy is directed toward protecting and restoring high-quality, well-functioning salmon and steelhead habitat through a combination of (1) site-specific management actions that will protect habitat and provide benefits relatively quickly, (2) watershed-based actions that will repair habitat-forming processes and provide benefits over the long term, and (3) landscape-scale programmatic actions that affect a class of activities (such as stormwater management or forest practices) over multiple watersheds. The management unit plans set a high priority on identifying and improving chum salmon spawning habitat, reducing the impacts of sediment on survival to emergence, and improving juvenile rearing habitat.[40] Because of a lack of habitat data in Oregon specific to chum salmon, physical

[39] Recovery plan implementers will look for opportunities to combine chum habitat restoration efforts with those for fall Chinook, to increase efficiency.

[40] Because chum salmon leave tributary habitat at a very early age, improving estuarine habitats will also be essential to improving juvenile rearing habitats for chum salmon.

assessments are needed to identify areas for reintroduction, estimate carrying capacity, and identify habitat in need of immediate restoration. Key habitats to be protected or restored for chum salmon include lower mainstem and off-channel areas of large rivers and streams fed by upwelling from intergravel flows or springs. Protecting key production areas in the Grays River and Columbia River mainstem will be critical.

Near-term habitat improvements will depend on implementation of high-priority tributary actions that are identified in the management unit plans, completion of recovery plan implementation schedules—including a prioritization and sequencing framework for additional habitat actions—and completion of additional assessment work. The Oregon management unit plan recommends that physical habitat surveys be initiated as soon as possible to determine the quality and quantity of chum salmon spawning habitat for the entire historical range of chum salmon in Oregon if funding is available but with priority given to areas of high intrinsic habitat potential in the Scappoose and Clatskanie subbasins if funds are limited (ODFW 2010, Appendix I).

Priority site-specific actions for chum salmon will focus on protecting, restoring, or creating lowland floodplain function, riparian function, and stream habitat complexity. Priority restoration projects will include those to create or improve access to off-channel and side-channel habitat (alcoves, wetlands, floodplains, etc.) and restore riparian areas and instream habitat complexity; this includes improving recruitment of large wood to streams. The Washington management unit plan also identifies the creation of chum salmon spawning channels as a priority short-term action. The subsections below summarize additional, stratum-specific tributary habitat strategies for Columbia River chum salmon.

Ultimately, restoration of adequate habitat for chum salmon will be challenging because of the high proportion of habitat in private ownership.

8.6.2.1 Coast-Stratum Tributary Habitat Strategies

In implementing the Columbia River chum salmon strategy in the Coast stratum, considerations include the following:

- Protecting the existing production areas in the Grays River will be key. The Grays/Chinook chum salmon population is a core and genetic legacy population and one of only two populations in the ESU with appreciable natural production.

- Lowland areas are primarily in agricultural or rural residential use. These areas have been extensively modified by dikes, levees, bank stabilization, and tide gates; efforts to protect and restore habitat complexity will be priorities here. Actions will include breaching, lowering, or relocating dikes and levees where possible to improve access to off-channel habitats for juvenile chum salmon, particularly in the Clatskanie, Scappoose, Grays, and Mill/Abernathy/Germany, and Elochoman/Skamokowa subbasins (ODFW 2010, LCFRB 2010a).

- Upland areas are predominantly state and private timber land; these lands must be managed to protect and restore watershed processes.

- Physical habitat surveys are needed to determine the quality and quantity of chum salmon spawning habitat within high intrinsic potential areas of the Scappoose and Clatskanie subbasins. Assessments should include evaluations of gravel quality, hyporheic flow, upwelling, and water quality conditions (temperature, suspended sediments dissolved oxygen, etc.).

- Sediment source analyses and implementation of actions to reduce sediment will be needed in most Coast-stratum tributaries.

In addition to the actions described as part of the regional strategy for tributary habitat, the Oregon plan identifies a need to investigate whether headwater springs in the Youngs Bay, Big Creek, Clatskanie, and Scappoose subbasins are drying up as a result of land management practices. The Oregon management unit plan also emphasizes the almost universal deficiency of large woody debris in the Coast ecozone as a contributing factor to the inability of individual stream systems to sort and store gravel suitable for use by chum salmon.

Assuming that the impacts of other threats are reduced to the levels shown in Table 8-4, habitat improvements of up to 50 percent will be needed for some Washington Coast-stratum chum salmon populations. Significant habitat actions will be needed in all areas to protect existing habitats. Habitat improvement targets for Oregon chum salmon populations were not quantified because of a lack of baseline habitat and population data for chum salmon.

8.6.2.2 Cascade-Stratum Tributary Habitat Strategies

In implementing the Columbia River chum salmon habitat strategy in the Cascade stratum, considerations include the following:

- In the lower reaches of most Cascade subbasins, including the Lower Cowlitz, North Fork Lewis, East Fork Lewis, Salmon Creek, and Clackamas, floodplains have been drastically altered or disconnected as a result of channel modification to facilitate and protect development, agricultural land, and, in some cases, gravel mining. Restoration of these areas will need to be balanced with the need to protect existing infrastructure and control flood risk. Restoring floodplain function and habitat complexity in these areas is crucial in restoring chum salmon spawning and rearing habitat.

- Upper portions of the East Fork Lewis, Washougal, Clackamas, and Sandy subbasins are primarily federal forest lands. Continued implementation of the Northwest Forest Plan will be crucial in protecting and restoring watershed processes in these areas.

- State or private forest land predominates in the upper portions of the Kalama, North Fork Lewis, and Salmon Creek subbasins. These lands must be managed to protect and restore watershed processes.

- The stratum includes the most heavily urbanized areas in the Columbia Basin. Managing the impacts of growth and development on watershed processes and habitat conditions will be key to the protection and improvement of habitat conditions for chum salmon in these areas.

- Physical habitat surveys are needed to determine the quality and quantity of chum salmon spawning habitat within areas of high intrinsic potential. Assessments should include evaluations of gravel quality, hyporheic flow, upwelling, and water quality conditions (temperature, suspended sediments dissolved oxygen, etc.).

Sediment issues will be addressed generally by restoring watershed processes and dealing with legacy road issues. In some cases (e.g., the Sandy), assessment to identify sediment sources is noted as a first step before additional actions can be taken. The Oregon management unit plan also includes actions to address flow issues in the Clackamas subbasin and roadway-related passage issues in lower Sandy river tributaries. Implementation of the city of Portland's Bull Run Water Supply habitat conservation plan will include habitat restoration in the Sandy River delta and lower reaches that will improve habitat for chum salmon.

Assuming that the impacts of other threats are reduced to the levels shown in Table 8-4, the scale of habitat improvements needed for Washington Cascade chum salmon populations ranges from minimal for the Salmon Creek population to a 50 percent reduction in habitat impacts in other Washington populations. Habitat improvement targets for Oregon chum salmon populations were not quantified because of a lack of baseline habitat and population data for chum salmon.

8.6.2.3 Gorge-Stratum Tributary Habitat Strategies

In implementing the Columbia River chum salmon habitat strategy in the Gorge stratum, considerations include the following:

- It is likely that significant amounts of historical chum spawning habitat for the Upper Gorge population have been inundated by Bonneville Reservoir.

- In the lower reaches of most Gorge streams, floodplains have been drastically altered or disconnected as a result of channel modification to facilitate and protect development and transportation infrastructure. For the Upper Gorge population, site-specific actions will include addressing or mitigating the impacts of the highway and railroad transportation corridors that run parallel to the Columbia River shoreline, traversing all creek drainages in ways that restrict access and disconnect upland and lowland habitat processes.

- Upper portions of some Gorge tributaries are largely federal, state, and private forest land. These lands must be managed to protect and restore watershed processes.

- Physical habitat surveys are needed to determine the quality and quantity of chum salmon spawning habitat within areas of high intrinsic potential. Assessments should include evaluations of gravel quality, hyporheic flow, upwelling, and water quality conditions (temperature, suspended sediments dissolved oxygen, etc.).

Restoring floodplain connectivity and function is called for at locations below Bonneville Dam; however, there is little opportunity to implement these floodplain measures above Bonneville Dam because much floodplain habitat was inundated by Bonneville Reservoir. For this reason, habitat efforts above the dam will rely on other strategies.

Assuming that the impacts of other threats are reduced to the levels shown in Table 8-4, reductions in baseline tributary habitat impacts needed to meet target statuses range from minimal for the Upper Gorge population to a 50 percent reduction in habitat impacts for the Washington portion of the Lower Gorge population. Habitat improvement targets for Oregon chum salmon populations were not quantified because of a lack of baseline habitat and population data for chum salmon.

8.6.3 Estuary Habitat Strategy

Estuarine habitat improvements are likely to be critical for Columbia River chum salmon, which leave their natal tributaries at a very early age and are thought to be severely limited by a paucity of intertidal marshes and similar estuarine wetlands needed for refuge and extended rearing. Habitat analysis for fall Chinook salmon indicates that populations in the Coast ecozone historically relied on wetland areas at the confluences of the tributaries and the mainstem Columbia (Northwest Fisheries Science Center 2010); because the habitat needs of fall Chinook and chum salmon appear to overlap considerably, some NMFS scientists have suggested that these same confluence areas may also be significant for chum salmon.

Improving Columbia River estuary habitat as described in the regional estuary habitat strategy will benefit all Columbia Basin ESUs, including Columbia River chum salmon. (For a summary of the regional estuarine habitat strategy, see Section 4.2.2.) The regional strategy reflects actions presented in the Oregon and Washington management unit plans to reduce estuarine habitat-related threats and is consistent with actions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). For Columbia River chum salmon, the assessment process described as part of the regional strategy should include assessment of the tidal portions of tributaries and their confluence with the mainstem Columbia. Developing implementation priorities for estuarine habitat actions also should include establishment of milestones or expected trends in improved habitat conditions in high-priority intertidal areas.

The *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) assumes that feasible estuarine habitat improvements and predation management measures could result in a maximum increase of 20 percent in the number of outmigrating juveniles leaving the Columbia River estuary. Washington recovery planners set targets of reducing anthropogenically enhanced mortality in the estuary for chum salmon populations based on the estuary module and their own approach to threat reductions (LCFRB 2010a, Table 6-7). Oregon did not quantify baseline and target threat impacts for chum salmon populations because data were inadequate to do so.

Ultimately, restoring adequate habitat for chum salmon in the Columbia River estuary will be challenging because of the high proportion of habitat in private ownership.

8.6.4 Hydropower Strategy

Chum salmon are expected to benefit from the regional hydropower strategy (see Section 4.3.2), which involves improving passage survival at Bonneville Dam for the Upper Gorge populations and, specifically for chum salmon, ensuring adequate flows in the Bonneville Dam tailrace and downstream throughout migration, spawning, incubation, and emergence. In addition, NMFS expects that implementation of mainstem flow management operations designed to benefit spring migrants from the interior of the Columbia Basin will also improve survival in the estuary and, potentially, the plume for all Lower Columbia River salmon and steelhead populations. Because Columbia River chum salmon are distributed low in tributary subbasins, reintroduction above tributary dam complexes is not part of the recovery strategy.

NMFS estimates that survival of Columbia River chum salmon passing Bonneville Dam was 95.1 percent for juveniles from 2002 to 2009 and 96.9 percent for adults from 2002 to 2007 (NMFS 2008a). NMFS expects that implementation of actions in the 2008 FCRPS Biological Opinion and its 2010 Supplement will improve juvenile chum salmon survival at Bonneville Dam by less than ½ percent, and that adult survival will be maintained at recent high levels (NMFS 2008a). Consequently, Oregon has not incorporated survival benefits from passage improvements at Bonneville into the hydropower threat reduction targets for Oregon populations above Bonneville.[41] The Washington management unit plan assumes that actions identified in the 2008 FCRPS Biological Opinion and its 2010 Supplement will aid adults and juveniles from all chum salmon populations originating above Bonneville Dam.

FCRPS Biological Opinion actions also will provide adequate conditions for chum salmon spawning in the mainstem Columbia River in the area of the Ives Island complex and/or access to the Hamilton and Hardy Creeks to protect spawning areas for the Lower Gorge population.

For information on how hydropower operations will improve the survival of chum salmon in the Columbia River estuary, see the regional hydropower strategy in Section 4.3.2.

In its management unit plan, Oregon incorporated several actions addressing impacts of the Columbia River hydropower system that are not included in the FCRPS Biological Opinion and its 2010 Supplement but that Oregon maintains are needed to benefit Lower Columbia River salmon and steelhead populations that spawn above Bonneville Dam. The state of Oregon's position is that the FCRPS action agencies should conduct operations in addition to those incorporated in the FCRPS Biological Opinion to address the needs of ESA-listed salmon and steelhead. Oregon is a plaintiff in litigation against various federal agencies, including NMFS, challenging the adequacy of measures in the FCRPS Biological Opinion and its 2010 Supplement. NMFS does not agree with Oregon

---

[41] Hydropower-related threat reduction targets for Oregon populations above Bonneville Dam are associated with removal of Powerdale Dam on the Hood River.

regarding the need for or likely efficacy of the additional actions Oregon proposed in that litigation, including the actions in the Oregon management unit plan that are not part of the FCRPS Biological Opinion and its 2010 Supplement. For more detail on these actions and NMFS' view of them, including their potential to benefit chum salmon, see the regional hydropower strategy in Section 4.3.2.

The subsections below summarize stratum-level hydropower strategies for chum salmon.

8.6.4.1 Coast-Stratum Hydropower Strategies

There are no tributary dams in the Coast ecozone, so the hydropower strategy for the Coast stratum is to implement the flow management operations designed to benefit spring migrants from the interior of the Columbia Basin; these flow management operations will also improve survival in the estuary and, potentially, the plume for all Lower Columbia River salmon and steelhead populations.

8.6.4.2 Cascade-Stratum Hydropower Strategies

Tributary dams in the Cascade ecozone are not identified as limiting factors for Cascade chum salmon populations, so the hydropower strategy for the Cascade stratum is to implement the mainstem hydropower actions that are expected to improve estuarine and, potentially, plume survival for all Columbia River chum salmon populations. The quantity and quality of spawning and rearing habitat for chum salmon in the North Fork Lewis and Cowlitz are affected by the rate at which water is discharged at Merwin and Mayfield dams, respectively. The operational plans for the Lewis and Cowlitz dams, in conjunction with fish management plans, should include flow regimes (minimum flow and ramping rate requirements, etc.) that enhance the lower river habitat for chum salmon.

8.6.4.3 Gorge-Stratum Hydropower Strategies

Tributary dams do not affect the Lower Gorge or Upper Gorge populations. Reductions in passage impacts at Bonneville Dam, as outlined in the 2008 FCRPS Biological Opinion and its 2010 Supplement (NMFS 2008f and 2010a), are expected to provide slight benefits to the Upper Gorge population, and the FCRPS will be operated to provide adequate conditions for chum salmon spawning in the mainstem Columbia River below Bonneville Dam (i.e., the Lower Gorge population). For more information, see the regional hydropower strategy in Section 4.3.2.

8.6.5 Harvest Strategy

The harvest strategy for chum salmon is to avoid significant increases in the current very low incidental fishery impacts by continuing to limit mainstem and tributary recreational fisheries for other species (primarily hatchery late-fall Chinook and coho) in times and areas where chum salmon are present. The Washington management unit plan identifies targets for reductions in impacts of all threat categories based on a strategy of equitable sharing of the recovery burden. Thus, the Washington plan describes fishery impact reductions from the 5 percent baseline rate for chum salmon at the time of listing. However, the current incidental fishery impact rate of 2 percent or less per year meets impact reduction targets identified in the Washington management unit plan (LCFRB 2010a).

8.6.6 Hatchery Strategy

The hatchery recovery strategy for Columbia River chum salmon is to use hatcheries to supplement and reduce risks to natural populations as appropriate, and to use hatchery reintroduction as appropriate to reestablish populations where they have been extirpated or nearly so. Reintroduction using hatchery chum salmon would be coordinated with habitat protection and restoration and triggered by a determination that natural chum salmon abundances are so low that recolonization would likely not be successful. Steps in the reintroduction strategy are to identify and obtain suitable broodstock, identify facilities for use in the conservation hatchery program, identify production goals and program duration, identify artificial production techniques, and identify release strategies for the reintroduction program. Experimental supplementation and reintroduction programs will be accompanied by aggressive monitoring and evaluation programs.

8.6.6.1 Coast-Stratum Hatchery Strategy

In the Coast stratum, the hatchery strategy is to continue the existing hatchery supplementation program and expand supplementation or reintroduction to other populations as deemed appropriate. The Grays River hatchery program produces chum salmon to augment natural production and reduce extinction risks to naturally spawning Grays River chum salmon. This program occurs in conjunction with habitat restoration efforts in the Grays subbasin. The program also is considered an important safety net for chum in the lower Columbia in general (LCFRB 2010a, Volume II).

Oregon also recently initiated a chum salmon hatchery program at its Big Creek hatchery, using Grays River fish as broodstock. Chum salmon from this program were first released into the Big Creek subbasin in 2011 as part of a reintroduction program. The Oregon management unit plan's chum salmon recovery strategy focuses initially on the Coast stratum. This is because the Coast-stratum subbasins are believed to have been less altered by human development than subbasins in other strata; thus Coast-stratum subbasins provide the best opportunity to test hypotheses regarding re-establishing self-sustaining chum salmon populations. (Oregon will use lessons learned from chum salmon recovery efforts in the Coast stratum to inform efforts to improve or create habitat and to reestablish chum salmon throughout the ESU.)

No hatchery chum salmon are currently released into other Coast-stratum subbasins, although other reintroduction or supplementation programs may be developed.

8.6.6.2 Cascade-Stratum Hatchery Strategy

In the Cascade stratum, the hatchery strategy is to develop supplementation or reintroduction programs for Cascade-stratum populations as deemed appropriate. Currently, no hatchery chum salmon are released in the Cascade stratum. (The Washougal hatchery produces chum salmon for an enhancement program to assist in rebuilding of the Lower Gorge chum salmon population). The Washington management unit plan notes that for the Cascade populations, one potential hatchery strategy is to develop a chum salmon broodstock using natural returns or some other appropriate population but does not lay out any timelines or decision points for that strategy. The Oregon management unit plan will focus efforts first in the Coast stratum and use lessons learned there to inform efforts to improve or create habitat and to reestablish chum salmon throughout the ESU.

8.6.6.3 Gorge-Stratum Hatchery Strategy

In the Gorge stratum, the hatchery strategy is to continue the existing hatchery supplementation program and expand supplementation or reintroduction as deemed appropriate. Currently, no hatchery chum salmon are produced in the Gorge stratum; however, the Washougal hatchery produces chum salmon for an enhancement program to assist in rebuilding the Lower Gorge population. This program uses chum salmon spawning in the Ives Island area for broodstock with a goal of enhancing chum salmon returns to Duncan Creek. The program occurs in conjunction with habitat restoration efforts in Duncan Creek. This program also acts as a safety net in the event that mainstem Columbia flow operations severely limit the natural spawning of chum salmon in Hamilton and Hardy creeks and in the Ives Island area below Bonneville Dam. The Washington management unit plan also notes the possibility of using a conservation hatchery program for the Upper Gorge population. The Oregon management unit plan will focus chum salmon recovery efforts first in the Coast stratum and use lessons learned there to inform efforts to improve or create habitat and to reestablish chum salmon throughout the ESU.

8.6.7 Predation Strategy

The regional predation strategy (see Section 4.6.2) involves reducing predation by birds, fish, and marine mammals and will benefit all Lower Columbia ESUs, including Columbia River chum salmon.

8.6.8 Critical Uncertainties

Each aspect of the chum salmon recovery strategy has a number of critical uncertainties, including the overarching questions of why some chum salmon populations are performing better than others and what the implications of these differences are with respect to recovery. To answer these questions, additional data are needed on chum salmon population characteristics, habitat usage and availability, interspecies predation on chum salmon juveniles, and hatchery reintroductions of chum salmon. In addition, for all ESUs there are uncertainties regarding how habitat actions will translate into changes in productivity and capacity (Roni et al. 2011). Prioritizing and identifying next steps in resolving uncertainties is a near-term priority. Critical uncertainties specific to the Columbia River chum salmon recovery strategy include the following:

- Historical role of the Gorge populations and appropriate target persistence probabilities, and abundance and productivity targets for them.

- Total adult spawning escapement, adult productivity, juvenile survival, and life history diversity of Columbia River chum salmon populations;
- Chum salmon's estuarine habitat requirements and how they overlap with those of fall Chinook
- Extent to which chum salmon use intertidal estuary-tributary "confluence" habitats and, if so, whether they are the same habitats used by fall Chinook
- Current extent of suitable or potentially suitable chum salmon habitat
- Best locations for restoration of chum salmon spawning habitat
- Effectiveness (both short term and long term) of constructed chum salmon spawning channels as a restoration strategy
- Relative effectiveness of hatchery reintroduction, hatchery supplementation, and natural recolonization in reestablishing and recovering chum salmon populations
- Significance of ecological interactions between hatchery- and natural-origin fish, such as predation by steelhead and coho on chum salmon (LCFRB 2010a)
- Potential for incidental harvest of chum salmon to increase in terminal fishing areas as chum salmon are reintroduced in Oregon and populations increase

These critical uncertainties represent preliminary priorities identified by Oregon and Washington recovery planners and NMFS Northwest Regional Office and Northwest Fisheries Science Center staff during a November 2010 workshop. They are preliminary priorities only (and are not in ranked order); as described in Chapter 10, additional discussion among local recovery planners and NMFS staff will be needed to finalize future research and monitoring priorities for chum salmon.

The management unit plans identify more comprehensive critical uncertainties and research, monitoring, and evaluation needs that, along with list above, will provide the basis for these future discussions. The White Salmon and Washington management unit plans have discrete sections on critical uncertainties for all of the ESUs in general (see Section 8.3 of NMFS 2013, pp. 8-4 through 8-6, and Section 9.6 of LCFRB 2010a, pp. 9-68 through 9-73), while the Oregon management unit plan embeds relevant critical uncertainties within subsections on the four VSP parameters and five ESA listing factors (see Sections 8.4 and 8.5, respectively, of ODFW 2010). In addition, in June 2010, the Lower Columbia Fish Recovery Board completed the *Research, Monitoring, and Evaluation Program for Lower Columbia Salmon and Steelhead* as a companion to its recovery plan (LCFRB 2010b). This document also describes critical uncertainties—and Section 8.6.4 of ODFW (2010) lists research, monitoring, and evaluation needs to address uncertainties related to Oregon's chum salmon recovery strategy. The list above does not include critical uncertainties that apply to multiple ESUs; these will be discussed and considered as decisions are made in implementation. In addition, the critical uncertainties above are of a technical nature; there are also many critical uncertainties related to social, political, and economic issues.

Critical uncertainties are one element of research, monitoring, and evaluation (RME) and adaptive management, which will be key components of the chum salmon recovery strategy (see Chapter 10 for more discussion of RME and adaptive management for this recovery plan).

8.7 Delisting Criteria Conclusion for Columbia River Chum Salmon

The requirement for determining that a species no longer requires the protection of the ESA is that the species is no longer in danger of extinction or likely to become endangered within the foreseeable future, based on evaluation of the listing factors specified in ESA section 4(a)(1). To remove the Columbia River chum salmon ESU from the Federal List of Endangered and Threatened Wildlife and Plants (that is, to delist the ESU), NMFS must determine that the ESU, as evaluated under the ESA listing factors, is no longer likely to become endangered.

The ESA requires that recovery plans, to the maximum extent practicable, incorporate objective, measurable criteria that, 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). The biological and threats criteria in this plan, taken together, meet this statutory requirement.

As described in Section 8.3, if the scenario in Table 8-2 were achieved, it would slightly exceed the WLC TRT's viability criteria in the Coast and Cascade strata (in the latter case, the scenario would exceed the criterion for number of populations but just meet the scoring criterion) (see Table 8-5). However, the scenario would not meet criteria in the Gorge stratum because only one Gorge population (the Lower Gorge) would be viable, instead of two (see Table 8-5).[42] Exceeding the criteria in the Coast and Cascade strata was intentional on the part of local recovery planners to compensate for uncertainties about the feasibility of meeting the WLC TRT's criteria in the Gorge stratum.

[42] As discussed in Section 2.5.4, the TRT's criteria for high probability of stratum persistence require that two or more populations be viable and that the average score for all populations in the stratum be 2.25 or higher.

Table 8-5
Chum Salmon Recovery Scenario Scores Relative to WLC TRT's Viability Criteria

Species	Number of Primary Populations					Stratum Average Criteria			
Chum		Coast	Cascade	Gorge	Total		Coast	Cascade	Gorge
	n ≥ high	5	3	1	9	Avg. score	2.29	2.25	3
	TRT criterion (n ≥ 2) met?	Yes	Yes	No		TRT criterion (avg. ≥ 2.25) met?	Yes	Yes	Yes

Source: Based on LCFRB (2010a), Table 4-7.

Recovery planners' uncertainty about meeting WLC TRT criteria in the Gorge chum stratum is based on questions about available habitat and anthropogenic impacts that are unlikely to change in the near future (e.g., inundation of habitat by Bonneville Reservoir) and on questions regarding Gorge strata and population delineations and historical role (LCFRB 2010a, ODFW 2010). These questions include whether the Gorge populations were highly persistent historically, whether they functioned as independent populations within their stratum in the same way that the Coast and Cascade populations did, and whether the Gorge stratum itself should be considered a separate stratum from the Cascade stratum.

As discussed in Section 3.2, NMFS has considered the WLC TRT's viability criteria (from McElhany et al. 2003 and 2006 and summarized in Table 2-3), the additional recommendations in McElhany et al. (2007), the recovery scenarios and population-level goals in the management unit plans, and the questions management unit planners raised regarding the historical role of the Gorge stratum.

NMFS has concluded that the WLC TRT's criteria adequately describe the characteristics of an ESU that meet or exceed the requirement for determining that a species no longer needs the protection of the ESA. These criteria provide a framework within which to evaluate specific recovery scenarios. NMFS has evaluated the recovery scenario presented in the management unit plans for Columbia River chum salmon (summarized in Table 3-1 of this recovery plan) and the associated population-level abundance and productivity goals (see Section 8.3).

Regarding the divergence of the scenario from the WLC TRT's criteria, the TRT noted in its revised viability criteria (McElhany et al. 2006) the need for case-by-case evaluations of the continuum of ESU-level risk associated with some strata not meeting their criteria. In commenting on the recovery scenarios presented in the interim Washington management unit plan[43]—and by extension the recovery scenarios presented in Table 3-1 of this plan—the WLC TRT stated that achieving the recovery scenarios would improve the status of the Gorge strata, even if the TRT's criteria for those strata were not

[43] In February 2006, NMFS approved the December 2004 version of the Washington management unit plan as an interim regional recovery plan for Lower Columbia River Chinook salmon and steelhead and Columbia River chum salmon. In May 2010, the LCFRB completed a revision of its 2004 plan (LCFRB 2010a), which is incorporated into this ESU-level recovery plan as Appendix B.

met. The TRT also noted that targeting the Cascade stratum for above the minimum TRT criteria would help lower ESU extinction risk. In addition, the TRT noted that the Gorge and Cascade strata are relatively similar compared to the Cascade and Coast strata. Also significant in the TRT's view was that options for recovery of the Gorge stratum would be preserved, in case future conditions or analyses were to require high stratum persistence for ESU viability (McElhany et al. 2006, p. 9).

Based on the information provided by the WLC TRT and the management unit recovery planners, NMFS concludes that the recovery scenarios in Table 3-1 and the associated population-level abundance and productivity goals in Section 8.3 represent one of multiple possible scenarios that would meet biological criteria for delisting. The similarities between the Gorge and Cascade strata, coupled with compensation in the Cascade stratum for not meeting TRT criteria in the Gorge stratum, would provide an ESU no longer likely to become endangered. NMFS endorses the recovery scenario and population-level goals found in the management unit plans for Columbia River chum salmon (summarized in Table 3-1 and Section 8.3) as one of multiple possible scenarios consistent with delisting. As noted earlier in this chapter (see Section 8.3), Oregon did not identify abundance targets for chum salmon populations because data for use in calculating abundance targets and conservation gaps are not available. In this plan (see Table 8-2), NMFS has included placeholder abundance targets for Oregon chum salmon populations based on the minimum abundance thresholds presented in McElhany et al. (2006 and 2007). NMFS expects that these targets will be refined over time as more information becomes available.

NMFS also agrees with the management unit planners that the historical role of the Gorge populations and stratum merits further examination. The extent to which compensation in the Cascade stratum is ultimately considered necessary to achieve an acceptably low risk at the ESU level will depend on how questions regarding the historical role of the Gorge populations are resolved.

NMFS therefore has developed the following biological criteria for the Columbia River chum salmon ESU (NMFS has amended the WLC TRT's criteria to incorporate the concept that each stratum should have a probability of persistence consistent with its historical condition, thus allowing for resolution of questions regarding the Gorge stratum):

1. All strata that historically existed have a high probability of persistence or have a probability of persistence consistent with their historical condition. High probability of stratum persistence is defined as:

    a. At least two populations in the stratum have at least a 95 percent probability of persistence over a 100-year time frame (i.e., two populations with a score of 3.0 or higher based on the TRT's scoring system).

    b. Other populations in the stratum have persistence probabilities consistent with a high probability of stratum persistence (i.e., the average of all stratum population scores is 2.25 or higher, based on the TRT's scoring system). (See Section 2.6 for a brief discussion of the TRT's scoring system.)

   c. Populations targeted for a high probability of persistence are distributed in a way that minimizes risk from catastrophic events, maintains migratory connections among populations, and protects within-stratum diversity.

   A probability of persistence consistent with historical condition refers to the concept that strata that historically were small or had complex population structures may not have met Criteria A through C, above, but could still be considered sufficiently viable if they provide a contribution to overall ESU viability similar to their historical contribution.

2. The threats criteria described in Section 3.2.2 have been met.

9. Lower Columbia River Steelhead

9.1 Steelhead Biological Background

9.1.1 Steelhead Life History and Habitat

Lower Columbia River steelhead (*Oncorhynchus mykiss*) exhibit perhaps the most complex life history of any Pacific salmonid. These fish can be anadromous or freshwater residents (and under some circumstances, apparently yield offspring of the opposite form). Steelhead, the anadromous form of *O. mykiss*, are under the jurisdiction of NMFS, while the resident freshwater forms, usually called “rainbow” or “redband” trout, are under the jurisdiction of the U.S. Fish and Wildlife Service. Steelhead are iteroparous, meaning they can spawn more than once. Repeat spawners are called “kelts.”

Two distinct life history types of steelhead—summer and winter runs—historically were and currently are found in the lower Columbia River. The two life history types differ in degree of sexual maturity at freshwater entry, spawning time, and frequency of repeat spawning. Most summer-run steelhead from the Lower Columbia River steelhead DPS re-enter freshwater between May and October and require several months to mature before spawning, generally between late February and early April. Most winter-run steelhead re-enter freshwater between December and May as sexually mature fish; peak spawning occurs later than for summer steelhead, in late April and early May. (See Figures 9-1 and 9-2.) Iteroparity (repeat spawning) rates for Columbia Basin steelhead have been reported as high as 2 to 6 percent for summer steelhead and 8 to 17 percent for winter steelhead populations (Leider et al. 1986, Hulett et al. 1993, and Busby et al. 1996).

Within the same watershed, winter and summer steelhead generally spawn in geographically distinct areas (Myers et al. 2006). Summer steelhead can often reach headwater areas above waterfalls that are impassable to winter steelhead during the high-velocity flows common during the winter-run migration. In basins where both winter and summer steelhead are present, the summer life history strategy appears to be able to persist only above the barrier falls that exclude winter steelhead. Although the summer steelhead’s long duration of pre-spawning holding in freshwater enhances their opportunity to take advantage of periodically favorable passage conditions, it may also result in a higher pre-spawning mortality rate that puts summer steelhead at a competitive disadvantage relative to winter steelhead (Myers et al. 2006). Historically, winter steelhead may have been excluded from interior Columbia River subbasins by Celilo Falls.

Steelhead spawn in a wide range of conditions ranging from large streams and rivers to small streams and side channels (Myers et al. 2006). Productive steelhead habitat is characterized by suitable gravel size, depth, and water velocity, and by complexity, primarily in the form of large and small wood (Barnhart 1986). Steelhead may enter streams and arrive at spawning grounds weeks or even months before spawning and therefore are vulnerable to disturbance and predation. They need cover in the form of overhanging vegetation, undercut banks, submerged vegetation, submerged objects such as logs and rocks, floating debris, deep water, turbulence, and turbidity (Geiger 1973). Their spawning timing must optimize avoiding risks from gravel-bed scour during high flow and increasing water temperatures that can become lethal to eggs. Spawning generally occurs earlier in areas of lower elevation, where water temperature is warmer, than in areas of higher elevation, with cooler water temperature.

Depending on water temperature, steelhead eggs may incubate for 35 to 50 days before hatching, after which alevins remain in the gravel 2 to 3 weeks, until the yolk-sac is absorbed. Generally, emergence occurs from March into July, with peak emergence time generally in April and May. Fry emergence is principally determined by the time of egg deposition and the water temperature during the incubation period. In the Lower Columbia subdomain, emergence timing differs slightly between winter and summer life-history types and among subbasins. These differences may be a function of spawning location (and hence water temperature) or of genetic differences between life-history types.

Following emergence, fry usually move into shallow and slow-moving margins of the stream. As they grow, they inhabit areas with deeper water, a wider range of velocities, and larger substrate, and they may move downstream to rear in large tributaries or mainstem rivers. Young steelhead typically rear in streams for some time before migrating to the ocean as smolts. Steelhead smolts generally migrate at ages ranging from 1 to 4 years, but most steelhead smolt after 2 years in freshwater (Busby et al. 1996). In the lower Columbia River, outmigration of steelhead smolts (of both summer and winter life-history types) generally occurs from March to June, with peak migration usually in April or May.

Catch data suggest that juvenile steelhead migrate directly offshore during their first summer, rather than migrating nearer to the coast. Maturing Columbia River steelhead are found off the coast of Northern British Columbia and west into the North Pacific Ocean (Busby et al. 1996). Fin-mark and coded-wire tag data suggest that winter steelhead tend to migrate farther offshore but not as far north into the Gulf of Alaska as summer steelhead (Burgner et al. 1992). Most steelhead spend 2 years in the ocean (range 1 to 4 years) before migrating back to their natal streams (Shapovalov and Taft 1954, Narver 1969, Ward and Slaney 1988). Once in the river, adult steelhead apparently rarely eat and grow little, if at all.

The key freshwater habitat needs of Lower Columbia River steelhead at different life stages are shown in Table 9-1. Steelhead typically rear in a wider range of stream gradients and average velocities than do other salmon species.

Table 9-1
Key Habitat for Steelhead, by Life Stage

Life Stage	Key Habitat Descriptions
Spawning	Riffles, tailouts, and glides containing a mixture of gravel and cobble sizes with flow of sufficient depth for spawning activity
Incubation	As for spawning, but with sufficient flow for egg and alevin development
Fry Colonization	Shallow, slow-velocity areas within the stream channel, often associated with stream margins
Active Rearing	Gravel and cobble substrates with sufficient depth and velocity, and boulder/large cobble/wood obstruction to reduce flow and concentrate food
Inactive Rearing	Stable cobble/boulder substrates with interstitial spaces
Migrant	All habitat types having sufficient flow for free movement of juvenile migrants
Pre-Spawning Migrant	All habitat types having sufficient flow for free movement of sexually mature adult migrants
Pre-Spawning Holding	Relatively slow, deep-water habitat types (with cool temperatures), typically associated with (or immediately adjacent to) the main channel

Source: Adapted from Northwest Power and Conservation Council (2004b).

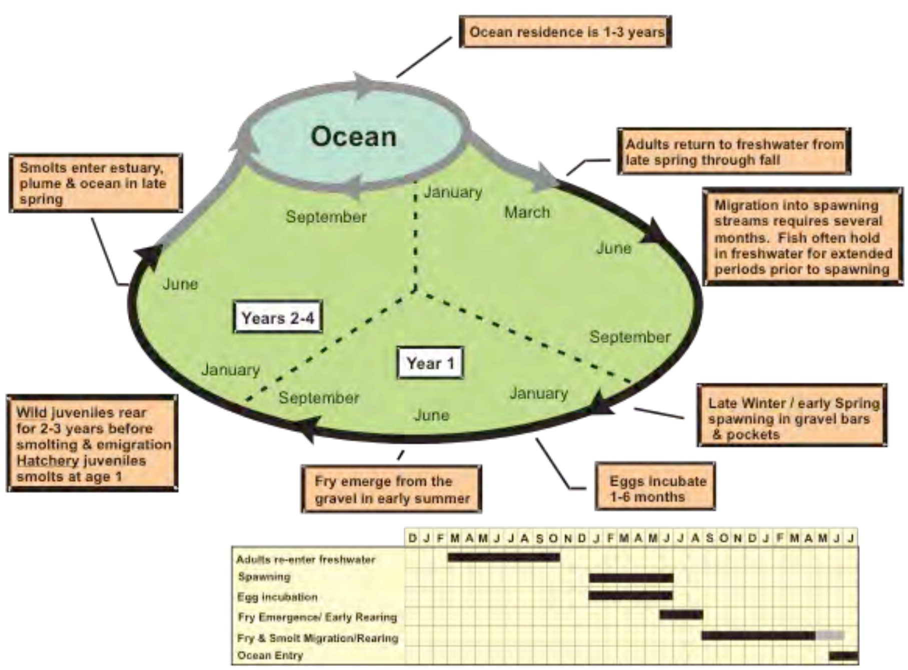

Figure 9-1. *Life Cycle of LCR Summer Steelhead*
(Source: LCFRB 2010a)

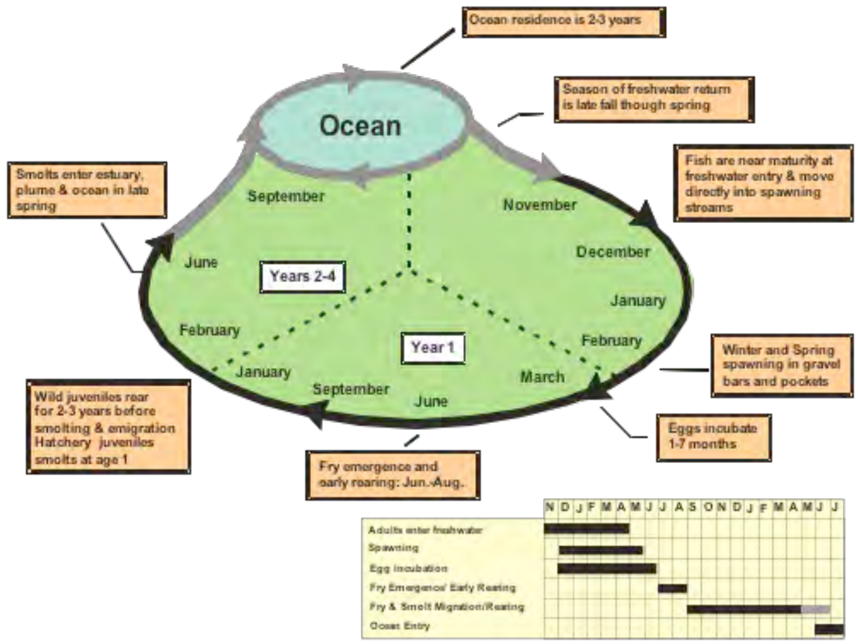

Figure 9-2. *Life Cycle of Winter Steelhead*
(Source: LCFRB 2010a)

9.1.2 Historical Distribution and Population Structure of LCR Steelhead

The WLC TRT identified 23 historical independent populations of Lower Columbia River steelhead: 17 winter-run populations and six summer-run populations, within the Cascade and Gorge ecozones.[1] Table 9-2 lists these populations and indicates core populations (which historically were highly productive) and genetic legacy populations (which represent important historical genetic diversity). Figures 9-3 and 9-4 show the geographical distribution of Lower Columbia River steelhead strata and populations.

[1] Steelhead populations within the Coast ecozone are part of a separate DPS—the unlisted Southwest Washington DPS—and are not addressed in this recovery plan; however, they are addressed in the Oregon and Washington management unit plans to address state planning needs. The White Salmon and Little White Salmon steelhead populations are part of the Middle Columbia steelhead DPS and are addressed in a separate species-level recovery plan, the *Middle Columbia River Steelhead Distinct Population Segment ESA Recovery Plan* (NMFS 2009a). However, recovery actions for the White Salmon population of Mid-Columbia steelhead are included in the White Salmon management unit plan (*ESA Recovery Plan for the White Salmon River Watershed,* NMFS 2013; see Appendix C of this recovery plan) because this population shares geography with Lower Columbia River coho and Chinook salmon and Columbia River chum in the White Salmon subbasin.

Table 9-2
Historical LCR Steelhead Populations

Stratum	Historical Populations	Core or Genetic Legacy Populations
Cascade summer	Kalama (WA)	Core
	NF Lewis (WA)	
	EF Lewis (WA)	Genetic legacy
	Washougal (WA)	Core, genetic legacy
Gorge summer	Wind (WA)	Core
	Hood (OR)	
Cascade winter	Lower Cowlitz (WA)	
	Upper Cowlitz (WA)	Core, genetic legacy
	Cispus (WA)	Core, genetic legacy
	Tilton (WA)	
	SF Toutle (WA)	
	NF Toutle (WA)	Core
	Coweeman (WA)	
	Kalama (WA)	
	NF Lewis (WA)	Core
	EF Lewis (WA)	
	Salmon Creek (WA)	
	Clackamas (OR)	Core
	Sandy (OR)	Core
	Washougal (WA)	
Gorge winter	Lower Gorge (WA and OR)	
	Upper Gorge (WA and OR)	
	Hood (OR)	Core, genetic legacy

Source: Myers et al. (2006), McElhany et al. (2003).

Up through 2006, ten artificial propagation programs produced steelhead considered to be part of this DPS. In 2007, the release of Cowlitz Hatchery winter steelhead into the Tilton River was discontinued; in 2009, the Hood River winter steelhead program was discontinued; and in 2010, the release of hatchery winter steelhead into the Upper Cowlitz and Cispus rivers was discontinued. In 2011, NMFS recommended removing these programs from the DPS. A Lewis River winter steelhead program was initiated in 2009, and in 2011, NMFS proposed that it be included in the DPS (76 *Federal Register* 50448). Table 9-3 shows the eight steelhead hatchery programs that currently are included in the DPS. For a list of steelhead hatchery programs not included in the DPS, see Jones (2011).

Table 9-3
Artificial Propagation Programs Included in the LCR Steelhead DPS

Run Type	Washington Programs	Oregon Programs
Summer steelhead	Kalama River Wild	Hood River*
Winter steelhead	Cowtliz Trout Hatchery - Lower Cowlitz Kalama River Wild Lewis River Wild late-run	Clackamas Hatchery Sandy Hatchery Hood River

* The wild summer broodstock program (ODFW stock #50) has been suspended and the non-local summer steelhead program (Skamania stock) terminated.

Source: 71 *Federal Register* 8844, 76 *Federal Register* 50448, and Jones (2011).

9.2 Baseline Population Status of LCR Steelhead

Out of the 23 populations in this DPS, 16 are considered to have a low or very low probability of persisting over the next 100 years (see Table 9-4), and six populations have a moderate probability of persistence (LCFRB 2010a, ODFW 2010, Ford 2011).[2] Only the summer-run Wind population is considered viable. Although current Lower Columbia River steelhead populations are depressed compared to historical levels and long-term trends show declines, many populations are substantially healthier than their salmon counterparts, typically because of better habitat conditions in core steelhead production areas (LCFRB 2010a). However, all four strata in the DPS fall short of the WLC TRT criteria for viability.

The low to very low baseline persistence probabilities of most Lower Columbia River steelhead populations reflects low abundance and productivity. In addition, it is likely that genetic and life history diversity has been reduced as a result of pervasive hatchery effects and population bottlenecks. Spatial structure remains relatively high for most populations (LCFRB 2010a, ODFW 2010).

9.2.1 Baseline Status of LCR Summer Steelhead

Baseline persistence probabilities were estimated to be low or very low for three out of the six summer steelhead populations that are part of the Lower Columbia River DPS, moderate for two, and high for one—the Wind, which is considered viable (see Figure 9-3) (LCFRB 2010a, ODFW 2010).

[2] As described in Section 2.6, the WLC TRT recommended methods for evaluating the status of Lower Columbia River salmon and steelhead populations. The TRT's approach is based on evaluating the population parameters of abundance, productivity, spatial structure, and diversity and then integrating those assessments into an overall assessment of population persistence probability. As described in Section 5.1, management unit recovery planners evaluated their respective populations' baseline status in a manner generally consistent with the WLC TRT's approach, with the baseline period being either circa 1999 (for Washington populations) or 2006-2018 (for Oregon populations). Unless otherwise noted, NMFS and the management unit planners believe that those assessments accurately reflect the status of the population at that time; the assessments are the basis for the summaries presented here and are consistent with the conclusions of the Northwest Fisheries Science Center in its *Status Review Update for Pacific Salmon and Steelhead Listed under the Endangered Species Act* (Ford 2011). New information on population status will continue to accumulate over time and will be taken into account as needed to reflect the best available science regarding a population's status.

Declines in persistence probability are attributable primarily to low abundance and productivity. Except in the North Fork Lewis subbasin, where dams have impeded access to historical spawning habitat, most summer steelhead populations continue to have access to historical production areas in forested, mid- to-high-elevation subbasins that remain largely intact. It is likely that historical hatchery effects have reduced the genetic diversity of many summer steelhead populations and caused declines in productivity (LCFRB 2010a). The Hood population has the highest proportion of hatchery spawners, at 53 percent (ODFW 2010). The highest pHOS rate among the Washington populations is 35 percent, for the East Fork Lewis (LCFRB 2010a).

9.2.2 Baseline Status of LCR Winter Steelhead

Thirteen of the 17 Lower Columbia River winter steelhead populations have low or very low baseline probabilities of persistence, and the remaining four are at moderate probability of persistence (see Figure 9-4) (LCFRB 2010a, ODFW 2010).

Declines in persistence probability are related primarily to low abundance and productivity. In addition, it is likely that historical hatchery effects have reduced the genetic diversity of most winter steelhead populations and caused declines in productivity. Most populations have maintained their spatial structure, meaning that returning adults can access most areas of significant historical habitat (although many of these habitats no longer support significant production) (LCFRB 2010a, ODFW 2010). For the Upper Cowlitz, Cispus, Tilton, North Fork Lewis, and Sandy populations, passage to upper basin habitat is partially or entirely blocked by dams (LCFRB 2010a; ODFW 2010); the Upper Gorge population is constrained by hatchery weirs, and the Hood population is constrained by the presence and operation of an irrigation dam. Steelhead distribution has been partially restored in the Upper Cowlitz, Cispus, and Tilton subbasin by trapping and transferring adults and juveniles around impassable dams.

For additional discussion of Lower Columbia River steelhead population status, see the management unit plans (LCFRB 2010a, pp. 6-57 through 6-52, and ODFW 2010, pp. 55-56) and Ford (2011).

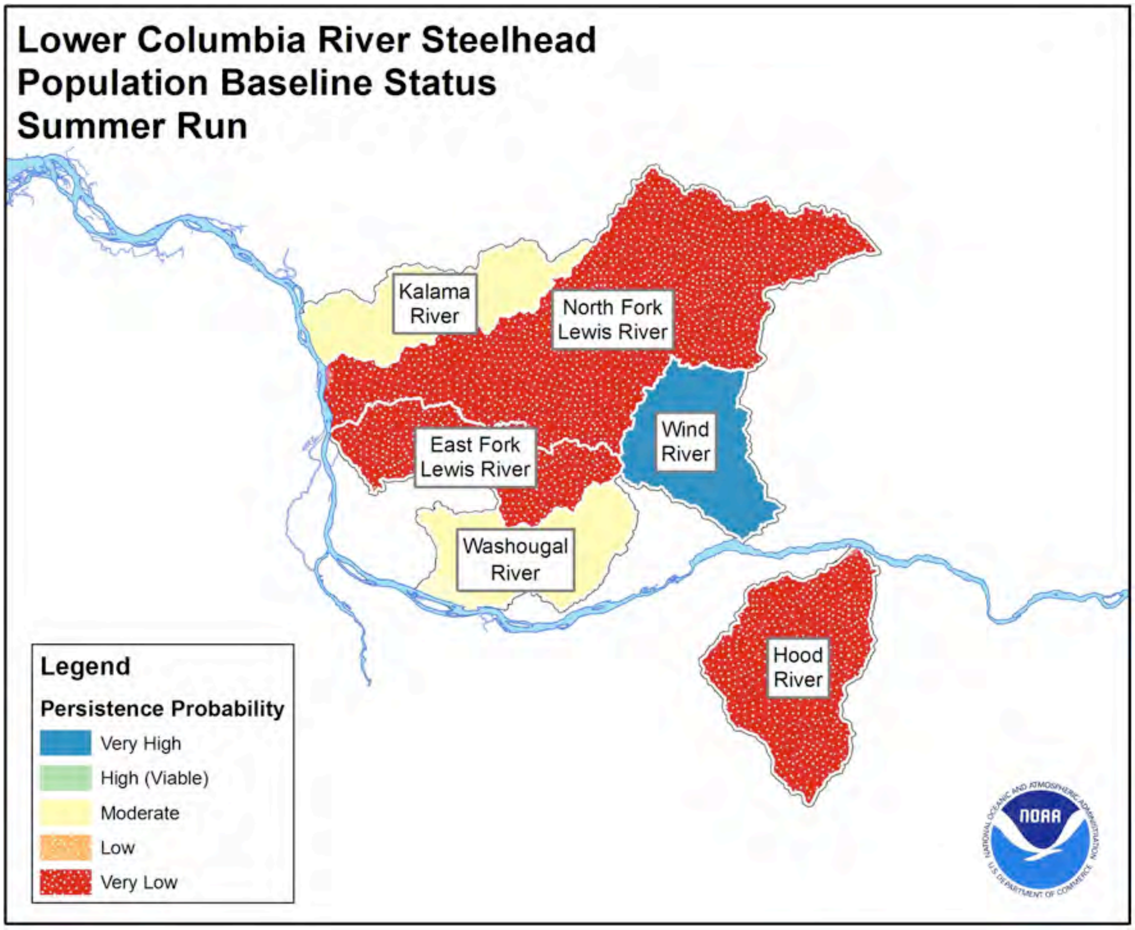

Figure 9-3. *Baseline Status of LCR Summer Steelhead Populations*

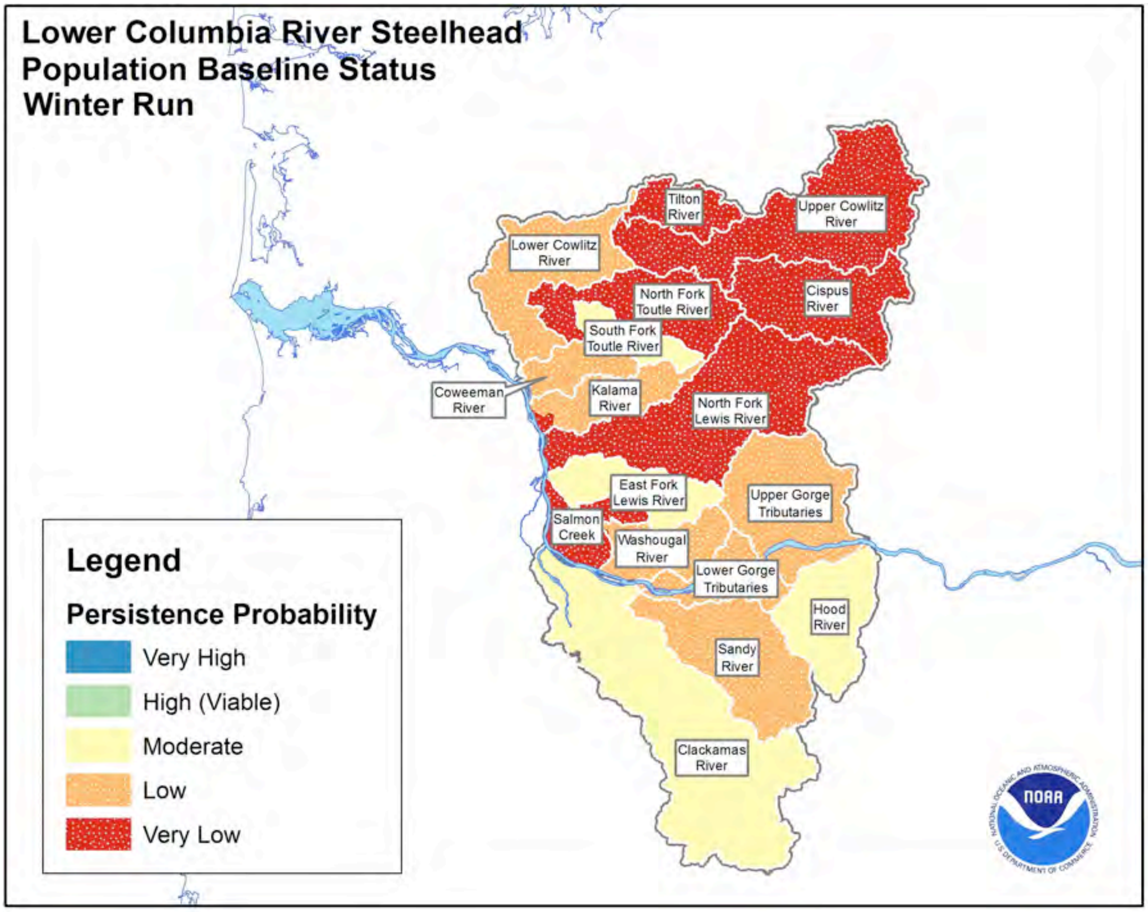

Figure 9-4. *Baseline Status of LCR Winter Steelhead Populations*

9.3 Target Status and Conservation Gaps for Steelhead Populations

Table 9-4 shows the baseline and target status for each Lower Columbia River steelhead population, along with historical abundance and target abundance. Local recovery planners coordinated with NMFS in making decisions about the target status for each population, taking into consideration opportunities for improvement in view of historical production, current habitat conditions and potential, and the desire to accommodate objectives such as maintaining harvest opportunities. (Note: the target statuses in Table 9-4 are the same as the persistence probabilities in the recovery scenario presented in Table 3-1 in Section 3.13.) As described in Section 5.1, although Oregon and Washington recovery planners used somewhat different methodologies to estimate baseline status and target abundance and productivity NMFS and the management unit planners agree that the methodologies led to similar conclusions regarding the baseline status for Lower Columbia River steelhead populations.

Substantial improvements are needed in the persistence probability of most steelhead populations if the DPS is to achieve recovery (see Figures 9-5 and 9-6). For example, 16 (11 winter and five summer) of 23 historical populations are targeted for high persistence probability or better. Of these, seven of the 17 historical winter-run populations and two of the six historical summer-run populations have very low or low baseline persistence probabilities. Some level of recovery effort will be needed for every population—even stabilizing populations that are expected to remain at their baseline status—to arrest or reverse continuing long-term declining trends. For most populations, meeting recovery objectives will require improvement in abundance, productivity, and diversity; several populations will also require improvements in spatial structure.

In the Cascade summer steelhead stratum, three of four populations are targeted for high persistence probability. These include the Kalama and Washougal, both large, productive populations historically. Today abundance and productivity in the Kalama population are high, but improvements are needed in spatial structure and diversity. Only one summer steelhead population—the North Fork Lewis—is expected to remain at its baseline status of very low persistence probability; this is because of loss of habitat access related to Merwin Dam, ongoing hatchery programs that produce summer steelhead for harvest, and the desire not to interfere with winter steelhead recovery efforts in the upper North Fork Lewis.

Both populations in the Gorge summer steelhead stratum are designated primary. The Wind population has a high baseline persistence probability and is targeted for very high persistence. The Hood population is targeted to move from very low to high probability of persistence; however, Oregon notes that achieving this target is unlikely (ODFW 2010). Challenges include the small amount of historical and current habitat (and thus the limited options for restoration), anthropogenic impacts that are unlikely to change in the near future (e.g., inundation of historical habitat by Bonneville Reservoir and roads that restrict access to habitat), and high uncertainty in the data and analyses for small populations.[3] The Oregon management unit plan states that most of these issues are related to the population structure designation and suggests re-evaluating the Gorge stratum population structure for all species (ODFW 2010). As discussed in Chapter 3, NMFS agrees that such an evaluation is needed.

In the Cascade winter steelhead stratum, nine of 14 historical populations are targeted for high or better persistence probability. These include the two genetic legacy populations and five of six core populations (those that were historically the most productive). One of these, the Clackamas population, is targeted to move from medium to high persistence probability, but Oregon notes that achieving this target status is unlikely because the level of tributary habitat improvement needed is considered infeasible (ODFW 2010). The sixth core population in this stratum, the North Fork Lewis, is targeted for medium persistence probability. In this stratum, only Salmon Creek, in a highly urbanized subbasin, is expected to remain at its baseline persistence probability of very low.

Of the three populations in the Gorge winter steelhead stratum, two—the Lower Gorge and the Hood (which is both a core and a genetic legacy population)—are targeted for

---

[3] In the method used by the WLC TRT and management unit planners to establish abundance goals, target abundance is based to some extent on the gap between current and historical abundance. If the historical abundance of Gorge stratum steelhead populations has been significantly overestimated, then the abundance needed to achieve their target status may also be overestimated (ODFW 2010).

high persistence probability. The third, the Upper Gorge, is designated as stabilizing and is expected to remain at its low baseline status because of questions about the historical role of the population and current habitat potential.

If the scenario in Table 9-4 were achieved, it would meet or exceed the WLC TRT's viability criteria, particularly in the Cascade winter stratum but also in the Cascade summer stratum.[4] Exceeding the criteria in the Cascade strata was intentional on the part of local recovery planners to compensate for uncertainties about the feasibility of meeting the WLC TRT's criteria in the Gorge summer stratum.[5] (Delisting criteria for the Lower Columbia River steelhead DPS are described in Sections 3.2 and Section 9.7.)

Figures 9-5 and 9-6 display the population-level conservation gaps for Lower Columbia River steelhead graphically. The conservation gap reflects the magnitude of improvement needed to move a population from its baseline status to the target status. For additional discussion of status targets and conservation gaps for Lower Columbia River steelhead populations, see the management unit plans (LCFRB 2010a, pp. 6-62 through 6-64 and ODFW 2010 pp. 148-150).

[4] As discussed in Section 2.5.4, the TRT's criteria for high probability of stratum persistence require that two or more populations be viable and that the average score for all populations in the stratum be 2.25 or higher. In the Cascade winter stratum, nine populations are targeted for high or very high persistence probability, and, using the WLC TRT's scoring system, the average viability score for all populations in the stratum would be 2.61.

[5] As noted in the discussion above, the Oregon management unit plan stated that achieving the target of high persistence probability for the Clackamas winter population is unlikely because the level of tributary habitat improvement needed is unfeasible. Even if the Clackamas population remained at its baseline status of medium probability of persistence, the Cascade winter steelhead stratum could still meet the WLC TRT's viability criteria for high probability of persistence, assuming adequate improvements in the persistence probability of the other populations in the stratum.

Table 9-4

Baseline and Target Persistence Probability and Abundance of LCR Steelhead Populations

			Baseline Persistence Probability[6]					Abundance		
Stratum	**Population**	**Contribution**	**A&P**	**S**	**D**	**Net**	**Target Persistence Probability**	**Historical**	**Baseline[7]**	**Target**
Cascade summer	Kalama (WA) [C]	Primary	H	VH	M	M	H	1,000	500	500
	NF Lewis (WA)	Stabilizing	VL	VL	VL	VL	VL	--[8]	150	--
	EF Lewis (WA)	Primary	VL	VH	M	VL	H	600	< 50	500
	Washougal (WA) [C]	Primary	M	VH	M	M	H	2,200	400	500
Gorge summer	Wind (WA) [C]	Primary	VH	VH	H	H	VH	--	1,000	1,000
	Hood (OR)	Primary	VL	VH	L	VL	H*	3,822	35	2,008
Cascade winter	Lower Cowlitz (WA)	Contributing	L	M	M	L	M	1,400	350	400
	Upper Cowlitz (WA) [C, GL]	Primary	VL	M	M	VL	H	1,400	< 50	500
	Cispus (WA) [C, GL]	Primary	VL	M	M	VL	H	1,500	< 50	500
	Tilton (WA)	Contributing	VL	M	M	VL	L	1,700	< 50	200
	SF Toutle (WA)	Primary	M	VH	H	M	H+	3,600 (SF and NF Toutle combined)	350	600
	NF Toutle (WA) [C]	Primary	VL	H	H	VL	H		120	600
	Coweeman (WA)	Primary	L	VH	VH	L	H	900	350	500
	Kalama (WA)	Primary	L	VH	H	L	H+	800	300	600
	NF Lewis (WA) [C]	Contributing	VL	M	M	VL	M	8,800	150	400
	EF Lewis (WA)	Primary	M	VH	M	M	H	900	350	500

[6] A&P = Abundance and productivity, S = spatial structure, and D = genetic and life history diversity. Net = overall persistence probability of the population. VL = very low, L = low, M = moderate, H = high, VH = very high.

[7] Baseline abundance was estimated as described in Section 5.1 and does not equal observed natural-origin spawner counts. The baseline is a modeled abundance that represents 100-year forward projections under conditions representative of a recent baseline period using a population viability analysis that is functionally equivalent to the risk analyses in McElhany et al. (2007). Projections generally assume conditions similar to those from 1974 to 2004. Oregon numbers reflect fishery reductions between the 1990s and about 2004, while Washington numbers reflect fishery impacts prevalent in the period immediately prior to listing in 1999.

[8] " — " indicates that no data are available from which to make a quantitative assessment.

Table 9-4

Baseline and Target Persistence Probability and Abundance of LCR Steelhead Populations

			Baseline Persistence Probability[6]					Abundance		
Stratum	**Population**	**Contribution**	**A&P**	**S**	**D**	**Net**	**Target Persistence Probability**	**Historical**	**Baseline[7]**	**Target**
	Salmon Creek (WA)	Stabilizing	VL	H	M	VL	VL	--	< 50	--
	Clackamas (OR) [C]	Primary	M	VH	M	M	H*	21,186	3,897	10,671
	Sandy (OR) [C]	Primary	L	M	M	L	VH	11,687	674	1,519
	Washougal (WA)	Contributing	L	VH	M	L	M	800	300	350
Gorge winter	L. Gorge (OR & WA)	Primary	L	VH	M	L	H	--	200	300
	U. Gorge (OR & WA)	Stabilizing	L	M	M	L	L	--	200	--
	Hood (OR) [C, GL]	Primary	M	VH	M	M	H	3,822	1,127	2,079

C = Core populations, meaning those that historically were the most productive.

G = Genetic legacy populations, which best represent historical genetic diversity.

*Oregon's analysis indicates a low probability of meeting the delisting objective of high persistence probability for this population.

Source: LCFRB (2010a) and ODFW (2010).

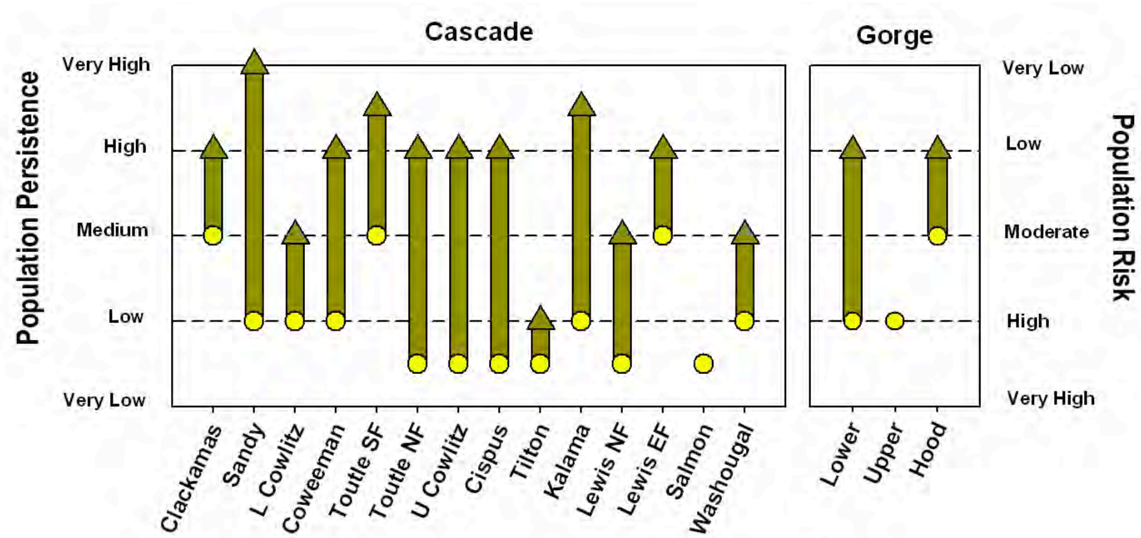

Figure 9-5. *Conservation Gaps for LCR Winter Steelhead Populations: Difference between Baseline and Target Status*

Source: LCFRB 2010a.

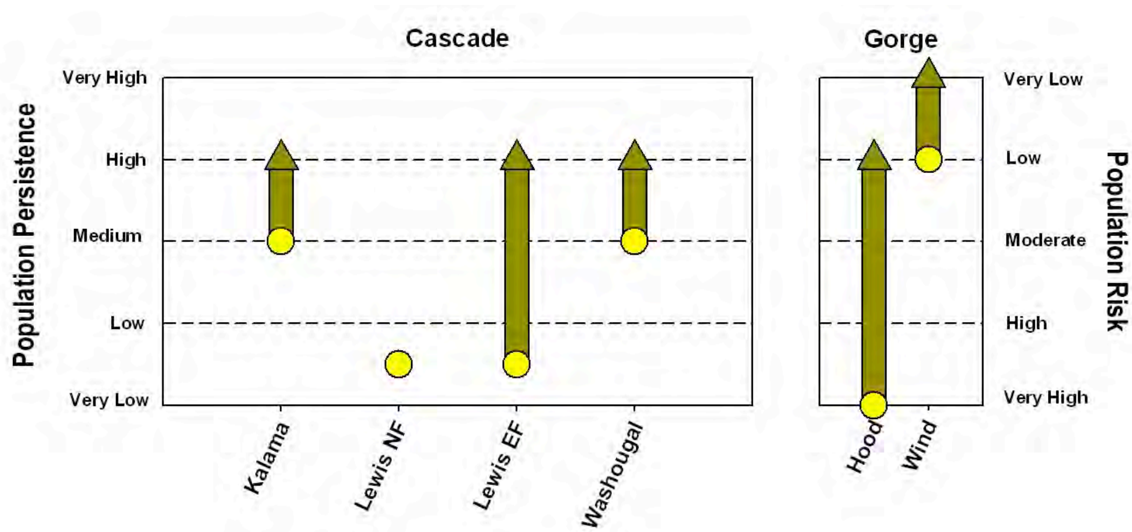

Figure 9-6. *Conservation Gaps for LCR Summer Steelhead Populations: Difference between Baseline and Target Status*

Source: LCFRB 2010a.

9.4 Limiting Factors and Threats for LCR Steelhead

Lower Columbia River steelhead are affected by a legacy of habitat degradation, harvest, hatchery production, and hydropower development that together have reduced the persistence probability of almost every population. Historically, high harvest rates contributed to population depletions, while stock transfers and straying of hatchery-origin fish reduced productivity and genetic and life history diversity. Construction of tributary and mainstem dams has constrained the spatial structure of some steelhead populations by blocking or impairing access to historical spawning areas. Over time, population abundance and productivity have been reduced through habitat alterations. Habitat alterations in the Columbia River estuary also have contributed to increased predation on steelhead juveniles. Today, widespread habitat degradation, predation, and the lingering effects of hatchery-origin fish continue to be significant limiting factors for most steelhead populations.

Tables 9-5 and 9-6 and the text that follows summarize baseline limiting factors and threats for Lower Columbia River steelhead strata based on population-specific limiting factors and threats identified in the management unit plans. In cases where conditions have changed significantly since the management unit plans' analyses of limiting factors and threats (e.g., if harvest rates have dropped or a dam is no longer present), this is noted in the text. Unless otherwise noted, NMFS agrees that the management unit plans' identification of limiting factors provide a credible hypothesis for understanding population performance and identifying management actions.

Because the individual management unit plans used somewhat different terms in identifying limiting factors, NMFS has translated those terms into standardized and more general terminology taken from a NMFS "data dictionary" of possible ecological concerns that could affect salmon and steelhead (Hamm 2012; see Section 5.4). In addition, in Tables 9-5 and 9-6, NMFS has rolled up the population-specific limiting factors (see Appendix H) to the stratum level—a process that has resulted in some loss of specificity.

In addition, each management unit plan used a different approach for identifying limiting factors and threats (see Section 5.3). One difference relevant to the crosswalk is that while the Oregon management unit plan identified primary and secondary limiting factors for each population in each threat category,[9] the Washington management unit plan categorized limiting factors in this way only for habitat-related limiting factors, and the estuary module did not use the primary and secondary terminology. For the crosswalk and this table, NMFS assigned primary and secondary status to non-habitat limiting factors for Washington populations (based on the Washington management unit plan's quantification of threat impacts and the professional judgment of Lower Columbia Fish Recovery Board's staff and consultants). It is likely that some apparent distinctions in results between Washington and Oregon populations are artifacts of differences in limiting factor assessment methodologies and not an actual difference in conditions or their effects on salmon and steelhead populations. In addition, there is not necessarily a bright line between primary and secondary limiting factor designations.

[9] In the Oregon management unit plan, primary limiting factors are those that have the greatest impact and secondary limiting factors have a lesser but still significant impact.

Nevertheless, NMFS believes that the designations are useful, particularly for looking across ESUs and populations and identifying patterns (see Chapter 4).

The management unit plans provide more detail on limiting factors and threats affecting each Lower Columbia River steelhead population, including magnitude, spatial scale, and relative impact (see LCFRB 2010a, Chapter 3 and various sections of Volume II, and ODFW 2010, pp. 129-140). For a regional perspective on limiting factors and threats that affect multiple salmon and steelhead ESUs, see Chapter 4 of this recovery plan. For a description of the data dictionary, the approach NMFS used to correlate management unit terms for limiting factors with the standardized NMFS terminology at the population scale, and the approach for rolling up from the population to the stratum scale, see Section 5.4 and Appendix H.

Management unit recovery planners in Oregon and Washington recognized that six major categories of manageable threats—tributary habitat, estuary habitat, hydropower, harvest, hatcheries, and predation—were useful as an organizing construct for grouping limiting factors, quantifying impacts on population productivity, and determining how much different categories of threats would need to be reduced to close the gap between baseline and target population status. Planners in both Washington and Oregon quantified the impacts of each of these major threat categories on population status, along with a reduction in each impact that would be consistent with achieving population target status. The results of that analysis are presented in Section 9.5 and provide a related but slightly different perspective on limiting factors. The threat reduction targets also allow actions to be scaled to achieve a specific impact reduction, and to be linked to monitoring and performance benchmarks.

Table 9-5

Baseline Limiting Factors and Threats Affecting LCR Winter Steelhead: Stratum-Level Summary

Ecological Concern	Threat(s)	VSP Parameters Affected	Cascade Winter	Gorge Winter
Tributary Habitat Limiting Factors				
Riparian Condition	Past and/or current land use practices	All	Secondary for North Fork Lewis juveniles; primary for juveniles in all other populations	Primary for Upper and Lower Gorge adults and juveniles; secondary for Hood juveniles
Channel Structure and Form	Past and/or current land use practices/ transportation corridor	All	Secondary for North Fork Lewis juveniles; primary for juveniles in all remaining populations	Primary for Upper and Lower Gorge adults and juveniles; secondary for Hood juveniles
Peripheral and Transitional Habitats: Side Channel and Wetland Conditions	Past and/or current land use practices/ transportation corridor	All	Secondary for North Fork Lewis juveniles; primary for juveniles in all other populations	Primary for Upper and Lower Gorge adults and juveniles; secondary for Hood juveniles

Table 9-5

Baseline Limiting Factors and Threats Affecting LCR Winter Steelhead: Stratum-Level Summary

Ecological Concern	Threat(s)	VSP Parameters Affected	Cascade Winter	Gorge Winter
Peripheral and Transitional Habitats: Floodplain Conditions	Past and/or current land use practices/ transportation corridor	All	Secondary for North Fork Lewis juveniles; primary for juveniles in all remaining populations	Primary for Upper and Lower Gorge adults and juveniles; secondary for Hood juveniles
Sediment Conditions	Past and/or current land use practices/ transportation corridor	All	Secondary for Clackamas, Upper Cowlitz and Cispus juveniles; secondary for Sandy adults and juveniles; primary for juveniles in all other WA populations	Secondary for Hood juveniles
Water Quality (Temperature)	Land uses that impair riparian function/decrease streamflow, dams	A,P,D	Secondary for OR, Upper Cowlitz and Cispus juveniles; primary for juveniles in all other WA populations	Secondary for Hood juveniles
Water Quantity (Flow)	Dams, land use, water withdrawals for irrigation, municipal uses, and hatchery operations	All	Secondary for juveniles in all populations	Secondary for juveniles in all populations, primary for Hood juveniles (irrigation withdrawals)
Toxic Contaminants	Agricultural chemicals, urban and industrial practices	A,P,D		Secondary for Hood juveniles
Estuary Habitat Limiting Factors[10]				
Toxic Contaminants	Agricultural chemicals, urban and industrial practices	A,P,D	Secondary for juveniles in all populations	

[10] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the DPS, the estuarine limiting factors in this table and Section 9.4.2 reflect the determinations in the Oregon management unit plan, applied to all Lower Columbia River steelhead populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

Table 9-5

Baseline Limiting Factors and Threats Affecting LCR Winter Steelhead: Stratum-Level Summary

Ecological Concern	Threat(s)	VSP Parameters Affected	Cascade Winter	Gorge Winter
Food[11] (Shift from macrodetrital- to microdetrital-based food web)	Dam reservoirs	All	Secondary for juveniles in all populations	
Peripheral and Transitional Habitats: Estuary Condition	Past and/or current land use practices, transportation corridor, mainstem dams	All	Secondary for juveniles in all populations	
Channel Structure and Form	Past and/or current land use practices/ transportation corridor	All	Primary for juveniles in all populations	
Sediment Conditions	Past and/or current land use practices/transporta tion corridor, dams	All	Primary for juveniles in all populations	
Water Quality (Temperature)	Land uses that impair riparian function/decrease streamflow, dam reservoirs	A,P,D	Secondary for juveniles in all populations	
Water Quantity (Flow)	Columbia River mainstem dams	All	Primary for juveniles in all populations	
Hydropower Limiting Factors				
Habitat Quantity (Access)	Bonneville Dam	All		Secondary for Upper Gorge and Hood adults and juveniles
Habitat Quantity (Inundation)	Bonneville Dam	All		Secondary for Upper Gorge and Hood juveniles[12]
Habitat Quantity (Access)	Tributary Dams	All	Primary for Upper Cowlitz, North Fork Lewis, Cispus, and Tilton adults and juveniles; secondary for Clackamas juveniles; secondary for Sandy adults	Secondary for Hood juveniles
Harvest Limiting Factors				
Direct Mortality	Fisheries	A,D	Secondary for adults in all populations	

[11] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is unclear.

[12] The exact extent to which Bonneville Reservoir inundated habitats for any species is unknown. Some biologists have hypothesized impacts to spring Chinook salmon as a result of inundation. Based on spawning habitat preferences, it is likely that impacts of inundation were greatest on fall Chinook and chum salmon.

Table 9-5

Baseline Limiting Factors and Threats Affecting LCR Winter Steelhead: Stratum-Level Summary

Ecological Concern	Threat(s)	VSP Parameters Affected	Cascade Winter	Gorge Winter
Hatchery Limiting Factors				
Food[13]	Smolts from all Columbia Basin hatcheries competing for food and space in the estuary	All	Secondary for juveniles in all populations	
Population Diversity	Stray hatchery fish interbreeding with wild fish	A,P,D	Primary for Upper and Lower Cowlitz, Cispus, Tilton, Lewis, Salmon Creek, and Sandy adults; secondary for adults in all other populations	Secondary for adults in all populations
Predation Limiting Factors				
Direct Mortality	Land use	A,P,D	Secondary for juveniles in all populations	
Direct Mortality	Dams	A,P,D		Secondary for Upper Gorge and Hood adults and juveniles

Table 9-6

Baseline Limiting Factors and Threats Affecting LCR Summer Steelhead: Stratum-Level Summary

Ecological Concern	Threat(s)	VSP Parameters Affected	Cascade Summer	Gorge Summer
Tributary Habitat Limiting Factors				
Riparian Condition	Past and/or current land use practices	All	Primary for juveniles in all populations	
Channel Structure and Form	Past and/or current land use practices/ transportation corridor	All	Primary for juveniles in all populations	
Peripheral and Transitional Habitats: Side Channel and Wetland Conditions	Past and/or current land use practices/ transportation corridor	All	Primary for juveniles in all populations	

[13] Some scientists suspect that closely spaced releases of hatchery fish from all Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the estuary. NMFS (2013) and LCFRB (2010) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon and steelhead in freshwater, estuarine, and nearshore ocean habitats.

Table 9-6

Baseline Limiting Factors and Threats Affecting LCR Summer Steelhead: Stratum-Level Summary

Ecological Concern	Threat(s)	VSP Parameters Affected	Cascade Summer	Gorge Summer
Peripheral and Transitional Habitats: Floodplain Conditions	Past and/or current land use practices/ transportation corridor	All	Primary for juveniles in all populations	
Sediment Conditions	Past and/or current land use practices/ transportation corridor	All	Primary for Kalama, Washougal, and East Fork Lewis juveniles	Primary for Wind juveniles; secondary for Hood juveniles
Water Quality (Temperature)	Land uses that impair riparian function/decrease streamflow, dams	A,P,D	Primary for Washougal and East Fork Lewis juveniles	Primary for Wind juveniles; secondary for Hood juveniles
Water Quantity (Flow)	Dams, land use, irrigation, municipal, and hatchery withdrawals	All	Secondary for juveniles in all populations except North Fork Lewis	
Toxic Contaminants	Agricultural chemicals, urban and industrial practices	A,P,D		Secondary for Hood juveniles
Estuary Habitat Limiting Factors[14]				
Toxic Contaminants	Agricultural chemicals, urban and industrial practices	A,P,D	Secondary for juveniles in all populations	
Food[15] (Shift from macrodetrital- to microdetrital-based food web)	Dam reservoirs	All	Secondary for juveniles in all populations	
Peripheral and Transitional Habitats: Estuary Condition	Past and/or current land use practices/transportation corridor, mainstem dams	All	Secondary for juveniles in all populations	
Channel Structure and Form	Past and/or current land use practices/ transportation corridor	All	Secondary for juveniles in all populations	

[14] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the DPS, the estuarine limiting factors in this table and Section 9.4.2 reflect the determinations in the Oregon management unit plan, applied to all Lower Columbia River steelhead populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

[15] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is unclear.

Table 9-6

Baseline Limiting Factors and Threats Affecting LCR Summer Steelhead: Stratum-Level Summary

Ecological Concern	Threat(s)	VSP Parameters Affected	Cascade Summer	Gorge Summer
Sediment Conditions	Past and/or current land use practices/transportation corridor, dams	All	Primary for juveniles in all populations	
Water Quality (Temperature)	Land uses that impair riparian function/decrease streamflow, dam reservoirs	A,P,D	Secondary for juveniles in all populations	
Water Quantity (Flow)	Columbia River mainstem dams	All	Primary for juveniles in all populations	
Hydropower Limiting Factors				
Habitat Quantity (Access)	Bonneville Dam	All		Secondary for Wind and Hood adults and juveniles
Habitat Quantity (Inundation)	Bonneville Dam	All		Secondary for Hood and Wind juveniles[16]
Habitat Quantity (Access)	Tributary dams	All	Primary for North Fork Lewis adults and juveniles	Secondary for Hood adults and juveniles
Harvest Limiting Factors				
Direct Mortality	Fisheries	A,D	Secondary for adults in all populations	
Hatchery Limiting Factors				
Food[17]	Smolts from all Columbia Basin hatcheries	All	Secondary for juveniles in all populations	
Population Diversity	Stray hatchery fish interbreeding with wild fish	A,P,D	Primary for North Fork Lewis adults; secondary for East Fork Lewis and Washougal adults	Primary for Hood adults
Predation Limiting Factors				
Direct Mortality	Land use	A,P,D	Secondary for juveniles in all populations	Secondary for Hood juveniles
Direct Mortality	Dams	A,P,D		Secondary for Hood adults and juveniles

[16] The exact extent to which Bonneville Reservoir inundated habitats for any species is unknown. Some biologists have hypothesized impacts to spring Chinook salmon as a result of inundation. Based on spawning habitat preferences, it is likely that impacts of inundation were greatest on fall Chinook and chum salmon.

[17] Some scientists suspect that closely spaced releases of hatchery fish from all Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the estuary. NMFS (2011a) and LCFRB (2010a) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon and steelhead in freshwater, estuarine, and nearshore ocean habitats.

9.4.1 Tributary Habitat Limiting Factors

Because steelhead are stream-type fish that typically rear in tributary reaches for a year or more, they depend heavily on tributary habitat conditions for their early survival (LCFRB 2010a). Loss and degradation of tributary habitat is one of the main limiting factors for Lower Columbia River steelhead (see Tables 9-5 and 9-6).

Impaired side channel and wetland conditions along with degraded floodplain habitat have significant negative impacts on juvenile steelhead throughout the DPS and are identified as primary limiting factors for all summer populations and all winter steelhead populations except the North Fork Lewis and Hood, where they are identified as secondary factors. In most cases, these limiting factors have resulted from extensive channelization, diking, wetland conversion, stream clearing, and gravel extraction, which have barred steelhead from historically productive habitats and simplified remaining habitats, weakening watershed processes that are essential to the maintenance of healthy ecosystems and reducing refugia and resting places. Degraded riparian conditions and channel structure and form issues are also primary limiting factors for juveniles of all summer steelhead populations and all winter populations except the North Fork Lewis and Hood, where these conditions are identified as secondary factors. A lack of large woody debris and appropriately sized gravel in the remaining accessible tributary habitat has significantly reduced the amount of suitable spawning and rearing habitat for winter steelhead.

Sediment conditions are identified as a limiting factor for juveniles in all Cascade winter populations; for Kalama, Washougal, East Fork Lewis, Wind, and Hood summer steelhead juveniles; and for juveniles from the Hood winter population. The high density of unimproved rural roads throughout the area, as well as timber harvest practices and other land use patterns on unstable slopes adjacent to riparian habitat, contributes to an abundance of fine sediment in tributary streams. The resulting excess fine sediment increases turbidity and covers spawning gravel, limiting egg development and incubation. In addition, water quality—specifically, elevated water temperature brought about through land use practices and dam reservoirs—is a primary limiting factor for juveniles in the East Fork Lewis, Washougal, and Wind summer populations and juveniles in all Washington Cascade winter populations except the Upper Cowlitz and Cispus. Water temperature is a secondary factor for juveniles from the Clackamas and Sandy winter steelhead populations and Hood summer steelhead juveniles. The influence of dams, land use, low-head hydro diversions, and irrigation withdrawals has led to water quantity issues being identified as a secondary limiting factor for all populations except the North Fork Lewis. These water quantity issues are related to altered hydrology and flow timing.

In the Cascade ecozone, land uses that have led to the conditions that limit tributary habitat productivity include forest management and timber harvest, agriculture, rural residential and urban development, and gravel extraction. A mix of private, state, and federal forest land predominates in the upper mainstem and headwater tributaries of the Cascade subbasins, while the lower mainstem and tributary reaches of most subbasins are characterized by agricultural and rural residential land use, with some urban development, especially in the Salmon Creek and Clackamas subbasins.

A unique issue in the Cascade stratum is legacy effects in the Toutle subbasin of the 1980 Mount St. Helens eruption. The North Fork Toutle in particular was heavily affected by sedimentation from the eruption. A sediment retention structure was constructed on the North Fork Toutle in an attempt to prevent continued severe sedimentation of stream channels and associated flood conveyance, transportation, and habitat degradation problems. The structure currently blocks access to as many as 50 miles of habitat for anadromous fish. Although fish are transported around the structure via a trap and haul system, it remains a source of chronic fine sediment to the lower river; this reduces habitat quality and has interfered with fish collection at its base.

In the Gorge ecozone, habitat limiting factors are generally the same as those described for the DPS as a whole, with some exceptions. For example, sediment conditions and water quality were not identified as limiting factors for the Upper and Lower Gorge winter steelhead populations. In addition, the primary cause of impaired side channel, wetland, and floodplain conditions for these populations is transportation corridor development. Highway and transportation corridors run parallel to the Columbia River shoreline, traversing all creek drainages in ways that restrict access and disconnect upland and lowland habitat processes. For the Hood winter steelhead population, all tributary habitat limiting factors were secondary with the exception of reduced instream flow caused by irrigation withdrawals, which was identified as a primary limiting factor. For the Hood summer population, riparian conditions and impaired side channel, wetland, and floodplain habitat were identified as primary tributary limiting factors.

Also unique to the Hood populations, both winter and summer, was the identification of organophosphates, insecticides, and other agricultural chemicals as a secondary limiting factor for juveniles. In addition, inundation of historical habitat by Bonneville Reservoir is identified as a secondary limiting factor for Upper Gorge winter steelhead and both winter and summer Hood populations.

9.4.2 Estuary Habitat Limiting Factors[18]

As stream-type fish, steelhead spend less time in the Columbia River estuary and plume than do ocean-type salmon such as fall Chinook, yet estuary habitat conditions nevertheless play an important role in the survival of steelhead juveniles, particularly those displaying less dominant life history strategies. Water quantity issues related to altered hydrology and flow timing are identified as a primary limiting factor for all populations, as is impaired sediment and sand routing; these limiting factors are associated with hydroregulation at large storage reservoirs in the interior of the

[18] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the DPS, the estuarine limiting factors in this section and Tables 9-5 and 9-6 reflect the determinations in the Oregon management unit plan, applied to all Lower Columbia River steelhead populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

Columbia Basin, and, in the case of sediment issues, land uses both past and present. Much of the land surrounding the Columbia River estuary is in agricultural or rural residential use and has been extensively modified via dikes, levees, bank stabilization, and tide gates. Altered hydrology and sediment routing influence habitat-forming processes, the quantity and accessibility of habitats such as side channels and wetlands, the dynamics of the Columbia River plume, and the estuarine food web. Channel structure issues, in the form of reduced habitat complexity and diversity, also are a primary limiting factor for juveniles from all populations. Again, simplification of channel structure is related to conversion of land to other uses—agricultural, rural residential, and as a transportation corridor.

Lack of access to peripheral and transitional habitats, such as side channels and wetlands is a secondary limiting factor for all populations, with access being impaired by the land uses—including the transportation corridor—and by flow alterations caused by mainstem dams. Other secondary limiting factors in the estuary that affect all steelhead populations are exposure to toxic contaminants (from urban, industrial, and agricultural sources) and elevated late summer and fall water temperatures, which are related to (1) land use practices that impair riparian function or decrease streamflow, and (2) large hydropower reservoirs.[19] Altered food web dynamics involving a transition from a macrodetrital-based food web to a microdetrital-based food web also are considered a secondary limiting factor for all populations.[20] These changes in the estuarine food web are caused primarily by increased microdetrital inputs from hydropower reservoirs and the loss of wetland habitats through diking and filling.

9.4.3 Hydropower Limiting Factors

The severity of dam-related impacts on winter steelhead populations varies throughout the DPS. Flow management operations at large storage reservoirs in the interior of the Columbia Basin (Grand Coulee, Dworshak, etc.) affect all juvenile Lower Columbia River steelhead in the lower mainstem and estuary, and potentially in the plume—primarily by altering flow volume and timing. These alterations impair sediment routing, influence habitat-forming processes, reduce access to peripheral habitat, and change the dynamics of the Columbia River plume and estuarine food web (see Section 9.4.2).[21] Moreover, the large reservoirs associated with mainstem dams contribute to elevated water temperatures downstream in late summer and fall. Although the management unit plans identified temperature impacts of the hydropower system as a secondary limiting factor for all juvenile steelhead, migration of juvenile steelhead occurs primarily in April through June (Dawley et al. 1986, McCabe et al. 1986, Roegner et al. 2004, Bottom et al. 2008, cited in Figure 2.2 of Carter et al. 2009), when elevated

---

[19] Although the management unit plans identified temperature impacts as a secondary limiting factor for juveniles in all populations, the timing of juvenile steelhead migration raises questions about the significance of this limiting factor; see Section 9.4.3.

[20] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is unclear.

[21] It is likely that flow impacts of the hydropower system affect the Lower Columbia River steelhead DPS more through changes in habitat-forming processes (including impacts to the plume) and food web impacts than through changes in migratory travel time.

mainstem temperatures are unlikely to be having a significant impact. The impacts of Bonneville Dam on passage and habitat quantity have been identified as a secondary limiting factor for Upper Gorge winter steelhead, Wind summer steelhead, and both populations of Hood steelhead.[22]

The effects of tributary dams vary among steelhead populations. In the Cascade winter steelhead stratum, tributary hydropower development is a primary limiting factor for adults and juveniles in the Upper Cowlitz, Cispus, and North Fork Lewis populations, which historically were among the most productive winter steelhead populations, and for the Tilton population; access to significant amounts of historical habitat in these river systems has been blocked by tributary dams, which also have had adverse impacts on downstream habitat through reduced gravel recruitment and other effects. Tributary hydropower issues related to upstream passage of adult winter steelhead past the Bull Run water system dams in the Sandy subbasin and downstream passage of juvenile winter steelhead through the PGE Clackamas River Project were identified as secondary limiting factors. There are no tributary hydropower facilities in the Coweeman, Toutle, Kalama, Salmon Creek, or Washougal subbasins.[23]

In the Cascade summer steelhead stratum, impaired habitat access and passage has been identified as a primary limiting factor for North Fork Lewis summer steelhead; tributary dams have blocked access to or inundated about 50 percent of the historical habitat for that population (LCFRB 2010a). In addition, tributary dams have adverse effects on downstream habitat through reduced gravel recruitment and other impacts. There are no tributary hydropower facilities in the Kalama and Washougal subbasins.

In the Gorge winter steelhead stratum, impaired adult passage is considered a secondary limiting factor for the Hood River population because of Laurence Lake Dam and Powerdale Dam (removed in 2010). The impacts of Bonneville Dam on adult and juvenile passage are identified as a secondary factor for both the Upper Gorge and Hood winter steelhead populations. Upstream passage to potential spawning grounds is limited by Bonneville Dam, and inundation of historical habitat has reduced habitat quantity for juveniles.

In the Gorge summer steelhead stratum, Powerdale Dam on the Hood River hindered access of adult steelhead to historical spawning areas until its removal in 2010. Inundation from the Bonneville Dam and the concomitant loss of historical riparian ecosystems has also reduced habitat quality for juvenile summer steelhead in the Hood River population.

9.4.4 Harvest Limiting Factors

Harvest-related mortality is identified as a secondary limiting factor for all populations within the DPS. Currently, harvest-related mortality on steelhead is limited to incidental mortality in Columbia River mainstem commercial gillnet fisheries, incidental mortality

---

[22] The exact extent to which Bonneville Dam inundated habitats for any species is unknown. Some biologists have hypothesized impacts to steelhead as a result of inundation. Based on spawning habitat preferences, it is likely that impacts of inundation were greatest on fall Chinook and chum salmon.

[23] However, the North Fork Toutle sediment retention structure currently blocks access to as many as 50 miles of habitat for anadromous fish.

in tributary recreational fisheries, and small levels of directed harvest in tribal fisheries above Bonneville Dam in Zone 6. Before the mid-1970s, harvest levels on natural-origin steelhead regularly exceeded 70 percent. However, implementation of mark-selective fisheries for hatchery steelhead has reduced recent impacts to 10 percent or less for most populations. Summer steelhead populations originating above Bonneville Dam are subject to somewhat higher rates—on the order of 15 percent or less— as a result of the combined effects tribal and non-tribal fisheries. Although the management unit plans identify steelhead harvest as a limiting factor, they also determine that the significant reduction in the harvest of steelhead over the last 20 or 30 years has resulted in harvest levels that appear to be consistent with achieving recovery objectives (ODFW 2010, LCFRB 2010a).

9.4.5 Hatchery-Related Limiting Factors

More than 2 million winter steelhead and 1.4 million summer steelhead were released from Lower Columbia River hatchery programs in 2008 (ODFW 2010). Many Lower Columbia River steelhead populations have large proportions of hatchery-origin spawners. Population-level effects resulting from stray hatchery fish interbreeding with natural-origin fish are identified as a primary limiting factor for the Upper and Lower Cowlitz, Cispus, Tilton, Lewis, Salmon Creek, and Sandy winter populations and the North Fork Lewis and Hood summer populations, and as a secondary limiting factor for the East Fork Lewis and Washougal summer populations and all other winter populations.[24] Hatchery straying, combined with past stock transfers, is believed to have reduced genetic diversity within and among Lower Columbia River steelhead populations. Productivity likewise has declined as a result of the influence of hatchery-origin fish. High proportions of hatchery-origin spawners are sometimes intentional, however, because hatchery fish are being used to reintroduce steelhead where they have been extirpated or nearly so (e.g., in the Cowlitz, and Lewis subbasins). In identifying hatchery-related limiting factors, the management unit plans evaluated only negative impacts of hatchery fish on productivity of natural fish and not the positive demographic benefits that such reintroduction programs can provide in the short term.

Some scientists suspect that closely spaced releases of hatchery fish from all Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the estuary. NMFS (2011a) and LCFRB (2010a) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon and steelhead in freshwater, estuarine, and nearshore ocean habitats.

[24] The nature and extent of risk to natural populations posed by hatchery programs affecting these populations will be the focus of future ESA section 7 consultations.

9.4.6 Predation

Direct mortality from predation is a secondary limiting factor that affects all Lower Columbia River steelhead populations. Anthropogenic changes to habitat structure have led to increased predation by Caspian terns, double-crested cormorants, and various other seabird species in the Columbia River estuary and plume. Steelhead spawning above Bonneville Dam also are subject to predation by non-salmonid fish (primarily pikeminnows above and below the dam but also walleye and smallmouth bass in the reservoir). Winter steelhead spawning above Bonneville Dam are also subject to predation by marine mammals (primarily sea lions) at Bonneville Dam.

9.5 Baseline Threat Impacts and Threat Reduction Targets

Table 9-7 shows the estimated impact on each Lower Columbia River steelhead population of potentially manageable threats, organized into six threat categories: tributary habitat degradation, estuary habitat degradation, hydropower, harvest, hatcheries, and predation. Both baseline and target impacts are shown, with the targets representing levels that would be consistent with long-term recovery goals. Impact values indicate the percentage reduction in abundance and productivity that is attributable to human activities related to a particular threat category. The value associated with any particular threat category can be interpreted as the percent reduction in abundance and productivity from historical conditions if that threat category were the only one affecting the population. The table also shows the overall percentage improvement that is needed to achieve the target impacts and corresponding population status.[25] These cumulative values across all threat categories (both baseline and target) are multiplicative rather than additive. Both the Oregon and Washington management unit plans use cumulative survivals across threat categories to illustrate the overall level of improvement needed. Each plan assumes that there is a direct proportional relationship between the projected changes in cumulative survival and the required changes in natural-origin spawner abundance and productivity. For populations where the survival improvement needed is larger than 500 percent, Table 9-7 does not report the exact value, in part because the value is highly uncertain.[26]

As an example, the baseline status of the Clackamas winter steelhead population has been severely reduced by the combined effects of multiple threats. The cumulative reduction in status was estimated at 81.8 percent from the multiplicative impacts of multiple threats acting across the salmon life cycle. Thus, current status is just 18.2 percent of the historical potential with no human impact. Tributary habitat and hatchery

---

[25] The percentage of survival improvement needed is the percentage change in net impacts, is derived from information in the Washington and Oregon management unit plans, and is calculated as follows: $[(1-\text{Cumulative}_{\text{Target}})-(1-\text{Cumulative}_{\text{Baseline}})]/[1-\text{Cumulative}_{\text{Baseline}}] \times 100$. These values generally correspond to population improvement targets identified for Washington populations in LCFRB (2010a). Comparable numbers are not explicitly reported in ODFW (2010) but are implicit in the modeling approach that Oregon recovery planners used to derive target impacts.

[26] For some populations—many of them small—the survival improvement needed is very large and highly uncertain because various other factors also are uncertain (i.e., the population's baseline persistence probability, the exact degree of impact of human activities on tributary habitat, and whether the population's response to reductions in impacts will be linear). In addition, very small populations do not necessarily follow predictable patterns in their response to changing conditions.

impacts are the largest, accounting independently for reductions of 65 and 23 percent, respectively, in population productivity, with corresponding reductions in abundance, spatial structure, and diversity. The Oregon management unit plan identifies a recovery strategy for this population that involves significant reductions in the impact of habitat and hatcheries and smaller reductions in the impacts of estuarine habitat and predation. For instance, the plan targets tributary habitat impacts to be reduced from the estimated baseline level of 65 percent to 24 percent (i.e., an approximately 117 percent improvement relative to baseline conditions). With the targeted reductions in individual impacts, the cumulative effect of all impacts would drop from 81.8 percent at baseline to 50 percent at the target status. This change would translate into a 170 percent improvement in survival relative to the baseline. Although the population would still be experiencing abundance and productivity that are 74.7 percent lower than historical conditions, the extinction risk at this mortality level would be estimated sufficient to meet the targets for this plan.

Oregon and Washington recovery planners used somewhat different definitions or methods to quantify the estimated impacts of anthropogenic threats. Baseline impacts for Washington populations reflect conditions prevalent at the time of ESA listing (circa 1999), while the baseline impacts for Oregon populations reflect conditions through 2004. Dam impacts for Washington populations reflect passage mortality, habitat loss caused by inundation, and loss of access to historical production areas; for Oregon populations, the estimates in the "Dams" column of Table 9-7 reflect direct upstream and downstream passage mortality only, with other dam impacts accounted for in the habitat and predation threat categories. Hatchery impacts for Washington populations were limited to not more than 50 percent per population, in accordance with Hatchery Scientific Review Group (HSRG) assessments of the potential for genetic effects (Hatchery Scientific Review Group 2009); Oregon recovery planners estimated that hatchery impacts were equivalent to the rates at which hatchery fish were found on natural spawning grounds, based on analyzed relationships and reflecting a concern for both genetic and ecological effects. Washington recovery planners derived estimates of impacts to tributary habitat using the Ecosystem Diagnosis and Treatment (EDT) model. Oregon recovery planners estimated the mortality associated with estuary habitat degradation, hydropower, harvest, hatcheries, and predation and assigned all remaining mortality (relative to the difference between the current modeled abundance and estimated historical abundance) to tributary habitat. In general, the tributary habitat values in Table 9-7 have the highest degree of uncertainty relative to the other threat categories and, for Oregon populations, may include causes of mortality associated with the other threat categories but not directly captured in those mortality estimates. (See Section 5.5 for more on the methodologies used to estimate baseline impacts.)

Estimates of threat impacts are useful in showing the relative magnitude of impacts on each population. Given the differences in methodologies, some values in Table 9-7 for Oregon and Washington populations are not necessarily directly comparable. Thus, values for Oregon populations are most directly comparable to those for other Oregon populations, and values for Washington populations are most directly comparable to those for other Washington populations. Regardless of differences in specific threat impact definitions and methods, the net effect of changes from all threats is useful in understanding the magnitude of population improvement needed to achieve the target population status.

The target impacts represent one of several possible combinations of threat reductions that could conceivably close the conservation gap and lead to a population achieving its target status. The particular threat reductions shown in Table 9-7 reflect policy decisions and the methodologies and assumptions used by the different recovery planning teams. (For a description of how target impacts were developed, see Section 5.6.) In estimating impacts, management unit recovery planners evaluated each threat category independently (i.e., values in the table reflect the mortality of steelhead exposed to that particular category of threats, whether or not they are exposed to threats in other categories). The estimates of baseline threat impacts have high levels of uncertainty and in many cases should be considered working hypotheses that are testable as part of recovery plan implementation. Despite this uncertainty, it is the expert judgment of NMFS and management unit scientists that, based on the best available information at this time, the estimates of baseline threat impacts provide a reasonable estimate of the relative magnitude of different sources of anthropogenic mortality and serve as an adequate basis for designing initial recovery actions.[27] As more and better information is collected, it will be applied to recovery efforts in an adaptive management framework.

As shown in Table 9-7, loss and degradation of tributary habitat, hatchery effects, and predation are pervasive threats that affect most steelhead populations. However, expected threat reductions vary by population.

In the Cascade ecozone, the Upper Cowlitz, Cispus, Tilton, and North Fork Lewis winter populations and the East Fork Lewis summer population are targeted for the largest improvements, with sizeable reductions needed in all or most threat categories, including predation. For the Upper Cowlitz, Cispus, Tilton, and North Fork Lewis winter populations, the greatest gains in persistence probability are expected to be achieved by reestablishing natural populations above tributary dams; however, reductions in hatchery- and tributary habitat-related threats are also targeted to contribute significantly to gains in persistence probability. For the East Fork Lewis summer population, improvements in tributary habitat are projected to provide the greatest benefit. All of these populations are designated primary except the Tilton and North Fork Lewis winter populations, which are designated as contributing.

Other Cascade populations targeted for large threat reductions are the Clackamas and Sandy winter steelhead populations. For Sandy winter steelhead, the most significant threat reductions are targeted to be achieved through reductions in hatchery-related threats.[28] For Clackamas winter steelhead, sizeable reductions in both hatchery- and tributary habitat-related threats are called for.[29] The threat reductions needed to achieve targets for other primary and contributing populations within the Cascade strata are relatively small, with improvements in tributary habitat figuring most prominently. This is the case for the Lower Cowlitz, North and South Fork Toutle, Coweeman, Kalama,

---

[27] As implementation proceeds, research, monitoring, and evaluation and adaptive management will be key in helping to refine scientific understanding of the impact of threats on population persistence and of the extent to which management actions are reducing threats.

[28] The Oregon management unit plan states that, because of fairly recent changes in the management of the hatchery steelhead program, current stray rates in the Sandy winter steelhead population already are lower than the 10 percent called for delisting (ODFW 2010).

[29] However, the Oregon management unit plan describes the targeted level of tributary habitat improvements for the Clackamas winter steelhead population as infeasible (see ODFW 2010).

East Fork Lewis, and Washougal winter populations and the Kalama and Washougal summer populations. For the Kalama summer steelhead population, Table 9-7 does not show threat reductions because the baseline abundance and productivity of the population are high; however, improvements in diversity will be needed in the Kalama summer population to meet recovery objectives.

The Salmon Creek winter and North Fork Lewis summer steelhead populations are not targeted for threat reductions, although they are expected to benefit from actions to reduce threats to other species and populations. These populations are designated as stabilizing because of habitat degradation in the highly urbanized Salmon Creek subbasin and because access to most of the North Fork summer population's historical spawning habitat has been blocked by Merwin Dam.

In the Gorge strata, all populations are designated as primary except the Upper Gorge winter population, which is considered contributing. For the Lower and Upper Gorge winter populations, target status is targeted to be achieved mostly by reducing tributary habitat-related threats, especially in Oregon. For the Hood winter population, no tributary habitat threat reductions are called for. Instead, the greatest gains in persistence probability are targeted from reductions in hatchery- and hydropower-related threats. The Hood summer steelhead population is targeted for significant reductions in multiple threat categories, with particularly large reductions in tributary habitat- and hydropower-related threats and a complete elimination of hatchery threats (summer steelhead will no longer be released in the Hood subbasin).[30] For the Wind summer steelhead population, Table 9-7 does not show threat reductions because the baseline abundance and productivity of the population are very high; however, improvements in diversity will be needed in the Wind summer population to meet recovery objectives.

With harvest impacts on natural-origin winter steelhead having dropped substantially from historical highs, further reductions in harvest impacts do not figure prominently in the threat reduction scenarios for most steelhead populations. The recovery strategy involves continued management of fisheries to limit impacts to baseline levels.

Threat reductions associated with estuary habitat improvements are needed for recovery and will benefit every steelhead population; however, net reductions in this threat category are smaller than those for tributary habitat-related threats, hatcheries, predation, and, in some cases, hydropower and harvest because for most populations the impacts of estuarine habitat-related threats are less.

More information on threat reductions, including methodologies used to determine baseline and target impacts, is available in the management unit plans (ODFW 2010, pp. 151-168 and 195-200; LCFRB 2010a, pp. 4-30 through 4-33 and 6-65 through 6-70).

[30] The targeted level of tributary habitat improvements for the Hood summer steelhead population is described in the Oregon management unit plan as infeasible (see ODFW 2010).

Table 9-7

Impacts of Potentially Manageable Impacts of Threats and Impact Reduction Targets Consistent with Recovery of LCR Steelhead Populations

	Impacts at Baseline[31]							Impacts at Target							% Survival Improvement Needed[32]
Population	T. Hab[33]	Est[34]	Dams[35]	Har[36]	Hat[37]	Pred[38]	Cumulative[39]	T. Hab	Est	Dams	Harv	Hat	Pred	Cumulative	
Cascade Summer															
Kalama (WA)	0.43	0.15	0.00	0.10	0.01	0.24	0.6719	0.43	0.15	0.00	0.10	0.01	0.24	0.6719	0
NF Lewis (WA)	0.40	0.15	0.50	0.10	0.47	0.24	0.9076	0.40	0.15	0.50	0.10	0.47	0.24	0.9076	0
EF Lewis (WA)	0.70	0.15	0.00	0.10	0.26	0.24	0.8709	0.35	0.08	0.00	0.05	0.13	0.12	0.5651	>500

31 Impact figures represent a percentage reduction in abundance and productivity that is attributable to human activities related to a particular threat category. Methods used to estimate impacts differ for Oregon and Washington populations. For example, baseline impacts reflect conditions circa 1999 for Washington populations and through 2004 for Oregon populations. Given the methodological differences, impact figures are not necessarily directly comparable. See Sections 5.5 and 5.6 for more on methodologies.

32 Survival improvements indicate the percentage improvement (rounded to the nearest 10) in population survival needed to achieve target impacts and are derived from the cumulative values (baseline and target). For most populations this was calculated using the following equation: $[(1\text{-Cumulative}_{\text{Target}})\text{-}(1\text{-Cumulative}_{\text{Baseline}})]/[1\text{-Cumulative}_{\text{Baseline}}] \times 100$. For the East Fork Lewis population , this equation yields a different result than that reported in LCFRB (2010a) because, for populations that have a very low probability of persistence and require very large improvements, the Washington management unit plan limited threat-specific reductions to 50 percent of the current impact as interim targets until the population response to improvements can be accurately gauged. For the East Fork Lewis, the numbers reported in this table are consistent with LCFRB (2010a) rather than with the aforementioned equation. In addition, these cumulative impact numbers are not explicitly reported in ODFW (2010) but are implicit in the modeling approach that Oregon recovery planners used to derive target impacts. For populations where the survival improvement needed is larger than 500 percent, this table does not report the exact value, for the reasons explained in Section 9.5.

33 Reduction in tributary habitat production potential relative to historical conditions. Oregon and Washington used different methods to estimate historical abundance. Oregon's approach, which incorporates safety margins and includes causes of mortality that are not captured in the other five threat categories, tends to indicate a higher potential impact from tributary habitat loss and degradation than does Washington's.

34 Reduction in juvenile survival in the Columbia River estuary as a result of habitat changes (relative to historical conditions); excludes predation.

35 Reflects passage mortality, habitat loss caused by inundation, and loss of access to historical production areas for Washington populations; for Oregon populations, dam impacts reflect direct passage mortality only.

36 Includes direct and indirect mortality.

37 Reflects only the negative impacts of hatchery-origin fish, such as high pHOS and low PNI (proportion of natural influence), not the benefits of conservation hatchery programs.

38 Includes the aggregate predation rate in the Columbia River mainstem and estuary by northern pikeminnow, marine mammals, Caspian terns, and cormorants.

39 Cumulative values (both baseline and target) are multiplicative rather than additive and are equal to $(1\text{-}[(1\text{-}M_{thab})(1\text{-}M_{est})(1\text{-}M_{dams})(1\text{-}M_{harv})(1\text{-}M_{hatch})(1\text{-}M_{pred})])$. Minor differences from numbers in ODFW 2010 and LCFRB 2010a are due to rounding.

Table 9-7

Impacts of Potentially Manageable Impacts of Threats and Impact Reduction Targets Consistent with Recovery of LCR Steelhead Populations

Population	Impacts at Baseline[31]							Impacts at Target							% Survival Improvement Needed[32]
	T. Hab[33]	Est[34]	Dams[35]	Har[36]	Hat[37]	Pred[38]	Cumulative[39]	T. Hab	Est	Dams	Harv	Hat	Pred	Cumulative	
Washougal (WA)	0.40	0.15	0.00	0.10	0.30	0.24	0.7558	0.32	0.12	0.00	0.08	0.24	0.19	0.6611	40
Gorge Summer															
Wind (WA)	0.50	0.14	0.11	0.17	0.01	0.27	0.7704	0.50	0.14	0.11	0.17	0.01	0.27	0.7704	0
Hood (OR)[40]	0.95	0.07	0.36	0.15	0.53	0.15	0.9899	0.14	0.07	0.16	0.15	0.00	0.08	0.4746	>500
Cascade Winter															
Lower Cowlitz (WA)	0.70	0.15	0.00	0.10	0.49	0.24	0.9110	0.69	0.15	0.00	0.10	0.48	0.23	0.9053	10
Upper Cowlitz (WA)	0.40	0.15	1.00	0.10	0.49	0.24	1.00	0.20	0.08	0.50	0.05	0.25	0.12	0.7693	>500[41]
Cispus (WA)	0.60	0.15	1.00	0.10	0.49	0.24	1.00	0.30	0.08	0.50	0.05	0.25	0.12	0.7981	>500
Tilton (WA)	0.90	0.15	1.00	0.10	0.49	0.24	1.00	0.45	0.08	0.50	0.05	0.25	0.12	0.8414	>500
SF Toutle (WA)	0.80	0.15	0.00	0.10	0.24	0.24	0.9116	0.74	0.14	0.00	0.09	0.22	0.22	0.8762	40
NF Toutle (WA)	0.80	0.15	0.00	0.10	0.33	0.24	0.9221	0.64	0.12	0.00	0.08	0.26	0.19	0.8253	120
Coweeman (WA)	0.50	0.15	0.00	0.10	0.12	0.24	0.7442	0.43	0.13	0.00	0.09	0.10	0.20	0.6751	30
Kalama (WA)	0.50	0.15	0.00	0.10	0.02	0.24	0.7151	0.37	0.11	0.00	0.07	0.02	0.18	0.5810	50
NF Lewis (WA)	0.10	0.15	0.92	0.10	0.49	0.24	0.9787	0.05	0.08	0.46	0.05	0.25	0.12	0.7041	>500
EF Lewis (WA)	0.50	0.15	0.00	0.10	0.48	0.24	0.8488	0.45	0.14	0.00	0.09	0.44	0.22	0.8120	20
Salmon Creek (WA)	0.80	0.15	0.00	0.10	0.50	0.24	0.9419	0.80	0.15	0.00	0.10	0.50	0.24	0.9419	0

40 Oregon's analysis indicates a low probability of meeting the delisting objective of high viability persistence probability for this population.

41 The Upper Cowlitz, Cispus, and Tilton populations require improvements in every threat category. However, given that hydropower impacts are 100 percent for these populations, they will not benefit from improvements in the other threat categories until some degree of passage is restored. Although passage improvements alone will not lead to recovery, how successful passage improvements are will greatly influence how much improvement is needed in the other threat categories. In addition the formula for percent survival improvement for these populations was modified to account for the 100 percent hydropower impacts (i.e., to avoid having to divide by zero).

Table 9-7

Impacts of Potentially Manageable Impacts of Threats and Impact Reduction Targets Consistent with Recovery of LCR Steelhead Populations

	Impacts at Baseline[31]							Impacts at Target							%
Population	T. Hab[33]	Est[34]	Dams[35]	Har[36]	Hat[37]	Pred[38]	Cumul-ative[39]	T. Hab	Est	Dams	Harv	Hat	Pred	Cumul-ative	Survival Improve-ment Needed[32]
Clackamas (OR)[42]	0.65	0.10	0.05	0.10	0.23	0.12	0.8175	0.24	0.08	0.05	0.10	0.10	0.07	0.4996	170
Sandy (OR)	0.82	0.10	0.04	0.10	0.52	0.12	0.9409	0.81	0.08	0.00	0.10	0.10	0.07	0.8683	120
Washougal (WA)	0.50	0.15	0.00	0.10	0.08	0.24	0.7326	0.46	0.14	0.00	0.09	0.08	0.22	0.6967	10
Gorge Winter															
L. Gorge —WA portion	0.60	0.15	0.00	0.10	0.01	0.22	0.7637	0.48	0.12	0.00	0.08	0.00	0.18	0.6548	50
L. Gorge—OR portion	0.60	0.10	0.00	0.10	0.10	0.12	0.7434	0.40	0.08	0.00	0.10	0.10	0.07	0.5842	60
U. Gorge—WA portion	0.60	0.14	0.11	0.10	0.01	0.30	0.8090	0.60	0.14	0.11	0.10	0.01	0.30	0.8090	0
U. Gorge—OR portion	0.51	0.07	0.16	0.15	0.10	0.16	0.7540	0.30	0.07	0.16	0.15	0.10	0.10	0.6235	50
Hood (OR)	-0.01	0.07	0.36	0.15	0.30	0.16	0.6995	-0.01	0.07	0.16	0.15	0.10	0.10	0.4675	80

42 Oregon's analysis indicates a low probability of meeting the delisting objective of high viability persistence probability for this population.

9.6 DPS Recovery Strategy for LCR Steelhead

This section describes the recovery strategy for Lower Columbia River steelhead. A general summary of the DPS-level strategy is presented first. This is followed by subsections on each of the threat categories and critical uncertainties that pertain to the strategy. Where appropriate, stratum-specific strategies are described for each threat category.

9.6.1 Strategy Summary

The recovery strategy for the Lower Columbia River steelhead DPS is aimed at restoring the Cascade and Gorge winter and summer strata to a high probability of persistence.[43] Although the strategy involves threat reductions in all categories, the most crucial elements are as follows:

1. Protect favorable tributary habitat and restore degraded but potentially productive habitat, especially in subbasins where large improvements in population abundance and productivity are needed to achieve recovery goals. This is the case in the Upper Cowlitz, Cispus, North Fork Toutle, Kalama, and Sandy subbasins for winter steelhead and in the East Fork Lewis and Hood subbasins for summer steelhead.

2. Protect and improve the South Fork Toutle, East Fork Lewis, Clackamas, and Hood winter steelhead populations, which currently are the best-performing winter populations, to a high probability of persistence. This will be accomplished through population-specific combinations of threat reductions, to include protection and restoration of tributary habitat (crucial for all except the Hood population), reductions in pHOS, and—for the Hood population—removal of Powerdale Dam (this was completed in 2010).

3. Significantly reduce hatchery impacts on the Hood summer steelhead population[44] and, to a lesser degree, on many other populations, especially the Upper Cowlitz, Cispus, Tilton, North Fork Lewis, and Clackamas winter populations and the East Fork summer population. Continue to limit hatchery impacts on the Kalama and Wind summer steelhead populations to improve population diversity. (The baseline abundance and productivity of these two populations are high and very high, respectively.)

4. Reestablish naturally spawning winter steelhead populations above tributary dams in the Cowlitz system (Upper Cowlitz and Cispus populations) and improve the status of the Tilton winter steelhead population through hatchery

---

[43] Steelhead populations in the Coast ecozone are part of the Southwest Washington steelhead DPS and are not listed under the federal ESA; thus, they are not addressed in this recovery plan.

[44] The Sandy winter steelhead population was also targeted for a significant reduction in hatchery impacts (i.e., 80 percent). However, the Oregon management unit plan states that, because of fairly recent changes in the management of the hatchery steelhead program, current stray rates in the Sandy winter steelhead population already are lower than the 10 percent called for in the threat reduction targets (ODFW 2010 p. 196).

reintroductions and comprehensive threat reductions; reintroduce winter steelhead above dams on the North Fork Lewis River.

5. Reduce predation by birds, non-salmonid fish, and marine mammals.

If the DPS is to achieve recovery, improvements are needed in the persistence probability of most populations, and very large improvements are needed in the status of some populations (the Upper Cowlitz, Cispus, North Fork Toutle, Kalama, and Sandy winter populations and the East Fork Lewis and Hood summer populations). (See Table 9-4 for the target status for each steelhead population and Figures 9-5 and 9-6 for the gaps between baseline and target status.)

The recovery strategy for Lower Columbia River steelhead is a long-term, "all-H" approach in which plan implementers begin work on all of the elements described above immediately and implement actions associated with each of the six threat categories simultaneously.[45] As part of a series of 3- to 5-year implementation schedules, management unit planners will work with NMFS staff to prioritize individual actions within each threat category, rather than across threat categories (see Chapter 11 for more on implementation). Recovery will require improvements in every threat category, even those improvements in Table 9-7 that are relatively small. Substantial actions are needed to improve tributary habitat, reduce the effects of hatcheries on natural populations, manage predation, and, for some populations, address hydropower passage issues. Without improvements in all of these threat categories, the full benefits of actions in any individual sector, such as improved passage at tributary dams, are unlikely to be realized and the expected threat reductions will not be achieved. Recovery also will require contributions from estuary habitat actions; however, for stream-type fish such as steelhead, these gains are expected to be less than those from coordinated efforts to address tributary habitat, hatchery, and predation impacts.

Immediate implementation of certain actions is expected to reduce short-term population risk relatively quickly; examples include site-specific projects to (1) protect and restore habitat complexity and diversity, (2) provide access to side channels and off-channel habitats, and (3) protect or restore floodplain connectivity and function. The benefits of other actions, such as restoring riparian conditions to improve watershed function, will not be felt for years or decades after implementation. For many populations, actions are needed soon to start reducing the impact of hatchery-origin fish so that populations can become self-sustaining as habitat conditions improve. A first step in this process is to develop population-specific transition strategies that specify how and when hatchery strategies described in the management unit plans will be implemented.

Key uncertainties that need to be addressed to support implementation of near-term actions for Lower Columbia River steelhead relate to techniques for reducing pHOS and increasing passage efficiencies past tributary dams, and the pace at which reintroduced populations become functional and self-sustaining (see Section 9.6.7).

---

[45] Implementation of recovery actions to reduce threats in each category is already under way, although the scale of effort is less than that called for in this recovery plan.

The subsections below describe recovery strategies and near-term and long-term priorities for each threat category. For specific management actions in each threat category, linked to population and location, see the management unit plans (LCFRB 2010a and ODFW 2010).

9.6.2 Tributary Habitat Strategy

Lower Columbia River steelhead will benefit from the regional tributary strategy described in Section 4.1.2. The regional strategy is directed toward protecting and restoring high-quality, well-functioning salmon and steelhead habitat through a combination of (1) site-specific management actions that will protect habitat and provide benefits relatively quickly, (2) watershed-based actions designed to protect or restore habitat-forming processes and provide benefits over the long term, and (3) landscape-scale programmatic actions that affect a class of activities (such as stormwater management or forest practices) over multiple watersheds. Actions of particular benefit to steelhead focus on protecting and restoring habitat complexity and diversity, access to side channels and off-channel habitats, and floodplain connectivity and function in high-priority stream reaches. Improving riparian cover and recruitment of large wood to streams also will be a priority. The subsections below summarize additional, stratum-specific tributary habitat strategies for steelhead.

9.6.2.1 Cascade Winter and Summer Steelhead Tributary Habitat Strategies

In implementing the tributary habitat strategy for the Cascade strata, considerations include the following:

- Generally, habitat conditions are favorable in the upper portions of the Cowlitz, Cispus, and North Fork Lewis subbasins, where winter steelhead populations are targeted for viability but where access has been blocked by dams. In these areas, protecting high-quality habitat and restoring upslope processes that improve and maintain habitat quality will be priorities. Large portions of these areas are in federal forest land; this highlights the importance of implementing the Northwest Forest Plan to protect habitats in those areas.

- Habitat conditions are also generally favorable in the Sandy subbasin (the Sandy winter steelhead population is targeted for very high persistence probability). Again, large portions of this subbasin are in federal forest land. Implementation of the City of Portland's Bull Run water supply habitat conservation plan also will improve habitat quality and increase the amount of habitat available to Sandy winter steelhead.

- Substantial restoration effort will be needed in areas currently accessible to Lower Columbia River steelhead. Because steelhead use mid- to upper-basin habitats for spawning and rearing, restoration efforts will focus on such areas, both in historically highly productive watersheds and in areas where production potential is more limited. Specific actions will include those described above for Lower Columbia River steelhead generally.

- State or private forest land predominates in the upper portions of the Toutle, Kalama, and North Fork Lewis subbasins, and the upper portions of the East Fork Lewis and Washougal subbasins also are forested, with state/federal and private/federal ownership, respectively. These forest lands must be managed to protect and restore watershed processes (such as by implementing the Northwest Forest Plan and Washington's habitat conservation plan for state-owned forest land and Forest Practices Rules for private forest land).

- Managing the impacts of growth and development will be important in all subbasin but particularly in the Washougal, where human population growth is expected to be large.

- In all subbasins, but particularly in the East Fork Lewis, restoring lowland floodplain function, riparian function, and stream habitat diversity will be important. The historically active floodplain and channel migration zone in the lower mainstem East Fork Lewis has been drastically altered by modifications to protect rural residential development, agricultural land, and gravel mining operations.

In addition to the actions described as part of the regional strategy for tributary habitat, addressing passage barriers such as culverts will benefit steelhead by restoring access to habitat in a number of locations; in some cases, additional assessment is needed to inventory passage barriers and prioritize them for removal or improvement. For the North Fork Toutle winter steelhead population, addressing sedimentation and passage issues at the North Fork Toutle sediment retention structure will be key. In the Sandy subbasin, municipal water withdrawals by the City of Portland have adverse effects on instream flows and are being addressed by implementation of the city of Portland's Bull Run Water Supply habitat conservation plan.

Assuming that the impacts of other threats are reduced to the levels shown in Table 9-7, the scale of habitat improvements that will be needed for Cascade winter steelhead populations ranges from minimal in the case of the Salmon Creek and Sandy populations (the Salmon Creek population is targeted to be maintained at its baseline status, and habitat conditions in the Sandy subbasin are generally good) to reductions of 50 percent (Upper Cowlitz, Cispus, Tilton) or more (Clackamas) in baseline habitat impacts to tributary habitat productivity.[46]

The scale of habitat improvements needed for Cascade summer steelhead populations ranges from minimal in the case of the Kalama and North Fork Lewis populations (which are targeted for high and very low persistence probabilities, respectively) to a 20 percent reduction in baseline tributary habitat impacts in the Washougal and a 50 percent reduction in the East Fork Lewis.

---

[46] The Oregon management unit plan notes that achieving the level of habitat improvement identified to meet the target status of high persistence probability for the Clackamas winter steelhead population is not feasible (ODFW 2010, p. 195). It is possible that the Cascade winter steelhead stratum would meet the WLC TRT's viability criteria for high probability of stratum persistence even if the Clackamas population were maintained at its baseline status, depending on the outcome of recovery efforts for other populations in the stratum.

9.6.2.2 Gorge Winter and Summer Steelhead Tributary Habitat Strategies

In implementing the tributary habitat strategy for the Gorge strata, considerations include the following:

- Gorge populations occur in watersheds that are largely federal, state, and private forest land. These lands must be managed to protect and restore watershed processes.
- In the lower reaches of most Gorge tributary streams, floodplains have been drastically altered or disconnected as a result of channel modification to facilitate and protect development and agricultural land.
- Water quality and flow in the Hood subbasin are adversely affected by water withdrawals for irrigation, low-head hydropower, and the use of agricultural chemicals.
- For the Lower and Upper Gorge winter steelhead populations, site-specific actions will include addressing or mitigating the impacts of the highway and railroad transportation corridors that run parallel to the Columbia River shoreline, traversing all creek drainages in ways that restrict access and disconnect upland and lowland habitat processes.

In addition to the actions described as part of the regional strategy for tributary habitat, for the Hood summer population, reduced instream flow from irrigation withdrawals is a primary threat, so actions to identify and implement flow improvements will be important.

Assuming that the impacts of other threats are reduced to the levels shown in Table 9-7, reductions in baseline tributary habitat impacts needed to meet target statuses for Gorge winter steelhead populations are on the order of 20 to 40 percent for the Upper and Lower Gorge winter steelhead populations. For the Hood population, although existing habitat appears to be adequate, the Oregon management unit plan expects that habitat actions benefitting other species will also benefit winter steelhead.

Assuming that the impacts of other threats are reduced to the levels shown in Table 9-7, the scale of habitat improvements needed to meet targets for Gorge summer steelhead populations ranges from minimal, for the currently viable Wind summer population,[47] to an 85 percent reduction in baseline tributary habitat impacts for the Hood population. The Oregon management unit plan notes that tributary habitat improvements of this magnitude are not feasible in the Hood subbasin and that the Hood population is unlikely to achieve a high persistence probability (ODFW 2010).

[47] Although the Wind summer steelhead population currently is viable and is not targeted for improvements in abundance and productivity, increases in the diversity of this population are needed for it to achieve recovery goals.

9.6.3 Estuary Habitat Strategy

Improving Columbia River estuary habitat as described in the regional estuary habitat strategy will benefit all Columbia Basin ESUs, including Lower Columbia River steelhead. (For a summary of the regional estuarine habitat strategy, see Section 4.2.2.) The regional strategy reflects actions presented in the Oregon and Washington management unit plans to reduce estuarine habitat-related threats and is consistent with actions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a).

The *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) assumes that feasible estuarine habitat improvements and predation management measures could result in a maximum increase of 20 percent in the number of outmigrating juveniles leaving the Columbia River estuary. Oregon and Washington recovery planners set targets of reducing anthropogenically enhanced mortality in the estuary for winter steelhead populations based on the estuary module and their own approaches to threat reductions (ODFW 2010 195-199, Tables 6-30 through 6-35; LCFRB 2010a p. 6-66, Table 6-13).

9.6.4 Hydropower Strategy

The hydropower recovery strategy for Lower Columbia River steelhead is to address impacts of tributary hydropower dams through implementation of FERC relicensing agreements and thereby reestablish viable winter-run populations in the Upper Cowlitz and Cispus subbasins and achieve survival gains in other populations affected by tributary hydropower facilities.

The strategy also includes measures to improve passage survival at Bonneville Dam for the populations that spawn above Bonneville Dam and implementation of mainstem flow management operations designed to benefit spring migrants from the interior of the Columbia Basin; NMFS expects that these flow management operations will also improve survival in the estuary and, potentially, the plume for all Lower Columbia River salmon and steelhead populations. NMFS estimates that survival of Lower Columbia River steelhead passing Bonneville Dam was 90.6 percent for juveniles from 2002 to 2009 and 98.5 percent for adults from 2002 to 2007 (NMFS 2008a). NMFS expects that implementation of actions in the 2008 FCRPS Biological Opinion and its 2010 Supplement will improve juvenile steelhead salmon survival at Bonneville Dam by less than ½ percent, and that adult survival will be maintained at recent high levels (NMFS 2008a). Consequently, Oregon has not incorporated survival benefits from passage improvements at Bonneville into the hydropower threat reduction targets for Oregon populations above Bonneville.[48] The Washington management unit plan assumes that actions identified in the 2008 FCRPS Biological Opinion and its 2010 Supplement will aid adults and juveniles from all steelhead populations originating above Bonneville Dam. For more on actions to improve mainstem dam passage, see the regional hydropower strategy in Section 4.3.2.

[48] Hydropower-related threat reduction targets for Oregon populations above Bonneville Dam are associated with removal of Powerdale Dam on the Hood River.

In its management unit plan, Oregon incorporated several actions addressing impacts of the Columbia River hydropower system that are not included in the FCRPS Biological Opinion and its 2010 Supplement but that Oregon maintains are needed to benefit Lower Columbia River salmon and steelhead populations that spawn above Bonneville Dam. The state of Oregon's position is that the FCRPS action agencies should conduct operations in addition to those incorporated in the FCRPS Biological Opinion to address the needs of ESA-listed salmon and steelhead. Oregon is a plaintiff in litigation against various federal agencies, including NMFS, challenging the adequacy of measures in the FCRPS Biological Opinion and its 2010 Supplement. NMFS does not agree with Oregon regarding the need for or likely efficacy of the additional actions Oregon proposed in that litigation, including the actions in the Oregon management unit plan that are not part of the FCRPS Biological Opinion and its 2010 Supplement. For more detail on these actions and NMFS' view of them, see the regional hydropower strategy in Section 4.3.2.

The subsections below summarize stratum-level hydropower strategies for Lower Columbia River steelhead.

9.6.4.1 Cascade Winter Steelhead Hydropower Strategy

Passage improvements and hatchery reintroduction programs are the main elements of the hydropower strategy for Cascade winter steelhead. Passage will be created or improved at projects on the Cowlitz (Upper Cowlitz, Cispus, and Tilton populations) and Lewis (North Fork Lewis population) rivers, while hatchery reintroduction programs will be used to reestablish viable winter steelhead populations in the Upper Cowlitz and Cispus subbasins and to improve the persistence probability of the Tilton population (from very low to low) and North Fork Lewis (from very low to medium) population. These changes will be implemented under the terms of FERC relicensing agreements completed with (1) Tacoma Power for the Cowlitz River Project in 2000, and (2) PacifiCorp and the Cowlitz PUD for the Lewis River Hydroelectric Projects in 2004. Habitat above the dams in these systems is relatively intact, with well-functioning watershed processes and a high percentage of federal land ownership.

In the Cowlitz subbasin, Mayfield Dam blocks winter steelhead access to the upper watershed; approximately 40 percent of the spawning and rearing habitat in the Cowlitz subbasin is not accessible. Under a trap and haul program begun in 1994, adult winter steelhead are collected at the Cowlitz hatcheries and released into the Upper Cowlitz, Cispus, and Tilton subbasins. The resulting naturally produced smolts are collected at the Cowlitz Falls Fish Collection Facility, acclimated at the Cowlitz Salmon Hatchery, and released in the mainstem Cowlitz (LCFRB 2010a). Passage at these dams is expected to be improved at some point as part of the 2000 FERC relicensing agreement.[49] Tacoma Power will evaluate fish returns and survival through the reservoirs and assess passage options. Adult passage will be by trap and haul unless certain settlement agreement criteria (fish sorting, productivity, etc.) are met. If they are met, passage at Mayfield Dam is likely to be provided via a new fish ladder, whereas passage at the much larger Mossyrock Dam likely will be provided by either trap and haul or a tramway.

---

[49] As of fall 2010, Tacoma Power had improved downstream passage survival at Mayfield Dam for juvenile steelhead from the Tilton winter-run population.

In the North Fork Lewis subbasin, three dams (Merwin, Yale, and Swift) block passage to the upper North Fork Lewis, beginning with Merwin Dam at RM 20. As part of the 2004 FERC relicensing agreement for these dams, reintroduction of winter steelhead into habitat upstream of the three dams is being evaluated and is likely to begin in 2012-2013. The keys to successful reintroduction will be adequate passage of juveniles and adults to and from the upper watershed, hatchery supplementation, and habitat improvements. In addition, hydroregulation on the Lewis River has altered the natural flow regime below Merwin Dam, and the flow regime will be need to be adjusted to provide adequate flows for habitat formation, fish migration, water quality, floodplain connectivity, habitat capacity, and sediment transport. However, floodplain and channel alterations in the lower river will limit the ability to restore the natural flow regime, and flow modifications will need to take place in concert with restoration of lower river floodplain function. (LCFRB 2010a)

Maintaining access to headwater spawning areas in the Cowlitz and Lewis systems may become increasingly important because the effects of climate change on stream temperatures may not be as pronounced there (LCFRB 2010a).

In the Clackamas subbasin, PGE's River Mill-Faraday-North Fork Dam complex, which has both upstream and downstream passage facilities, impairs downstream steelhead passage and may also delay adult upstream passage and reduce spawner distribution and success. As part of the 2006 FERC relicensing agreement, PGE agreed to improve downstream juvenile mortality through the dam complex to 3 percent or less and has already rebuilt the ladder and trap at North Fork Dam.

9.6.4.2 Cascade Summer Steelhead Hydropower Strategy

There are no tributary hydropower dams in the Kalama, East Fork Lewis, or Washougal subbasins. In the North Fork Lewis subbasin, summer steelhead recovery efforts will be focused below Merwin Dam.

9.6.4.3 Gorge Winter and Summer Steelhead Hydropower Strategy

Tributary hydropower impacts for the Hood winter and summer steelhead populations will be addressed by the removal of Powerdale Dam. The dam, which was operated by PacifiCorp, was removed in 2010 under the terms of a settlement agreement reached in 2003. The dam had passage systems in place; nevertheless, removal is expected to improve upstream and downstream survival, increase access to historical spawning and rearing habitat, and reduce hydropower impacts on Hood winter and summer populations by 55 percent. There are no tributary dams in the Wind subbasin.

Actions in the 2008 FCRPS Biological Opinion and its 2010 Supplement will also provide slight improvements in juvenile survival at Bonneville Dam for the Upper Gorge winter and Hood winter and summer populations (see the regional hydropower strategy in Section 4.3.2).

9.6.5 Harvest Strategy

Before the mid-1970s, steelhead harvest impacts were on the order of 70 percent or more. Harvest impacts were reduced in 1975 when the commercial harvest of steelhead in non-treaty fisheries was prohibited, and reduced further in the late 1980s and early 1990s through the implementation of mass marking and hatchery-fish-only retention requirements. For most populations harvest impacts are now 10 percent or less. Harvest impacts to populations above Bonneville Dam are somewhat higher, on the order of 15 percent or less, as a result of the additional impacts that occur in tribal fisheries.

As discussed in Section 9.4.4, although harvest-related mortality is identified as a secondary limiting factor for all populations within the DPS, substantial actions already have been implemented to reduce harvest impacts on natural-origin steelhead. Analysis in the Oregon and Washington management unit plans determined that maintaining steelhead harvest at current levels is consistent with achieving recovery objectives (ODFW 2010, LCFRB 2010a). The harvest strategy is to ensure continued regulation of fisheries to limit impacts to current levels, using ancillary and precautionary actions as described in Section 4.5.2 (the regional harvest strategy).

The Washington plan recommends maintaining harvest impacts on Cascade winter and summer steelhead of between 5 and 10 percent for the 50-year implementation period; this will be accomplished through improved monitoring and application of regulations in mainstem and tributary fisheries. Oregon did not incorporate any reduction to the 10 percent baseline harvest impact rate into its threat reductions for winter steelhead populations. In addition to maintaining current harvest regulations and impacts, the Washington management unit plan recommends (1) continuing to improve gear and regulations to minimize incidental impacts to naturally spawning steelhead, (2) establishing specific triggers for in-season Columbia River fishery adjustments as needed to support lower Columbia River winter steelhead recovery goals and strategies, (3) managing Columbia River commercial fisheries by time, area, and gear to target hatchery fish and minimize impacts to naturally spawning steelhead, and (4) monitoring naturally spawning steelhead encounter rates in tributary recreational fisheries, particularly in populations targeted for viability or high persistence probability.

9.6.5.1 Cascade Winter and Summer Steelhead Harvest Strategy

The DPS-level harvest strategies will benefit populations in the Cascade winter and summer strata.

9.6.5.2 Gorge Winter and Summer Steelhead Harvest Strategy

The DPS-level harvest strategies will benefit populations in this stratum. In addition, for the Upper Gorge, Wind, and Hood populations, Oregon proposes discussing Zone 6 fishery impacts with tribes to reduce potential additional impacts. Potential actions include extending harvest sanctuaries from tributary mouths and modifying season length or timing (ODFW 2010).

9.6.6 Hatchery Strategy

The regional hatchery strategy described in Section 4.4.2 summarizes goals and approaches relevant to Lower Columbia River steelhead. Details of how the hatchery strategy will be implemented in each steelhead stratum will be developed as part of the transition schedules, but the subsections below provide some information.

9.6.6.1 Cascade Winter Steelhead Hatchery Strategy

Hatcheries will be used in reintroducing winter steelhead in the Upper Cowlitz (Upper Cowlitz, Cispus, and Tilton populations) and North Fork Lewis subbasins. Hatchery-origin adult winter steelhead already are being released upstream of dams to spawn naturally in the Upper Cowlitz, Cispus, and Tilton rivers; these fish come from hatchery programs that were founded with local stock and have not been augmented with non-local stocks. Local stocks will also be used to develop hatchery programs that will be used to reintroduce winter steelhead to the upper Lewis subbasin. WDFW may also consider supplementation programs in some other Cascade populations to bolster natural fish numbers above critical levels in selected areas until habitat is restored to levels where a population can be self-sustaining.

The hatchery strategy involves continued hatchery production as mitigation and for fishery enhancement of winter steelhead in the Lower Cowlitz, Kalama, East Fork Lewis, Salmon Creek, Washougal, Clackamas, and Sandy[50] subbasins. Effective control of reproductive and competitive interactions between hatchery-origin fish and natural populations will be particularly important in these cases, with details varying depending on the population's target status. In addition, although there are no hatchery programs located in the Coweeman, hatchery-produced winter steelhead are released there for fishery enhancement.

For the Clackamas population, a pHOS target of 10 percent will be met by reducing Eagle Creek winter steelhead hatchery releases (from 150,000 to 100,000 beginning in 2009). The Clackamas will be managed initially as an integrated program, with a sliding scale developed for take of wild winter steelhead broodstock.[51] The Sandy subbasin winter steelhead program will also be managed as an integrated program, with a sliding scale developed for take of wild winter steelhead broodstock.

The Clackamas subbasin above North Fork Dam will be maintained as a wild fish sanctuary. No hatchery winter steelhead are currently released, nor are the expected to be released, into the North and South Fork Toutle subbasins.

---

[50] The Sandy winter steelhead population was targeted for an 80 percent reduction in hatchery impacts. The Oregon management unit plan states that, because of fairly recent changes in the management of the hatchery steelhead program, that target has been met, and current stray rates are lower than the 10 percent objective for this population (ODFW 2010).

[51] ODFW will also explore the feasibility of shifting the Clackamas hatchery winter steelhead program to one that holds and rears fish for an extra year to better mimic their natural life cycle (ODFW 2010).

9.6.6.2 Gorge Winter Steelhead Hatchery Strategy

In the Hood subbasin, Oregon proposes to install a floating weir to remove stray hatchery winter steelhead and to implement a sliding scale for take of wild winter steelhead broodstock for an integrated hatchery program. There are no hatcheries and no releases of hatchery-origin steelhead at present in the Upper Gorge tributaries, and the Washington plan proposes that this area be maintained as a refuge area for winter steelhead (LCFRB Vol. II). In the Lower Gorge, Oregon proposes to investigate placing a new weir and trap to sort hatchery-origin winter steelhead from natural-origin winter steelhead migrating upstream on Eagle Creek, Tanner Creek, or both. There are no hatcheries or winter steelhead releases in the Washington lower Gorge tributaries currently, and no future releases of hatchery-origin winter steelhead are planned for these tributaries.

9.6.6.3 Cascade Summer Hatchery Strategy

Fishery enhancement programs are expected to continue in the North Fork Lewis, Kalama, East Fork Lewis, and Washougal subbasins. Washington will develop either integrated or segregated programs in each of these subbasins to meet criteria appropriate to the target status of these populations.

9.6.6.4 Gorge Summer Hatchery Strategy

The Wind subbasin is expected to be maintained as a refuge area for natural-origin fish. The summer steelhead hatchery program in the Hood subbasin was discontinued in 2009. No future releases of hatchery-origin summer steelhead are planned for the lower Gorge tributaries in Washington.

9.6.7 Predation Strategy

The regional predation strategy (see Section 4.6.2) involves reducing predation by birds, fish, and marine mammals and will benefit all Lower Columbia River ESUs, including summer and winter steelhead.

9.6.8 Critical Uncertainties

Each aspect of the steelhead recovery strategy has a number of critical uncertainties. For all ESUs, there are uncertainties regarding how habitat actions will translate into changes in productivity and capacity (Roni et al. 2011). Prioritizing and identifying next steps in resolving uncertainties is a near-term priority. Critical uncertainties specific to the Lower Columbia River steelhead recovery strategy include the following:

- Effectiveness of weirs, shifts in production, and other techniques in achieving pHOS targets
- Effectiveness of various approaches to developing integrated hatchery/natural populations, especially for populations with very low natural-origin abundance
- Effective methods of providing adequate downstream passage efficiency for juveniles migrating past tributary dams

- Effectiveness of hatchery reintroduction programs and the pace of local adaptation of reintroduced stocks above tributary dams

- Most appropriate boundary between Mid-Columbia and Lower Columbia River steelhead DPSs[52]

These critical uncertainties represent preliminary priorities identified by Oregon and Washington recovery planners and NMFS Northwest Regional Office and Northwest Fisheries Science Center staff during a November 2010 workshop. They are preliminary priorities only (and are not in ranked order); as described in Chapter 10, additional discussion among local recovery planners and NMFS staff will be needed to finalize future research priorities for Lower Columbia River steelhead.

The management unit plans identify more comprehensive critical uncertainties and research, monitoring, and evaluation needs that, along with the list above, will provide the basis for these future discussions. The Washington management unit plan has a discrete section on critical uncertainties for all of the ESUs in general (see Section 9.6 of LCFRB 2010a, pp. 9-68 through 9-73), while the Oregon management unit plan embeds relevant critical uncertainties within subsections on monitoring and evaluation needs related to the four VSP parameters and five ESA listing factors (see Sections 8.4 and 8.5, respectively, of ODFW 2010). In addition, in June 2010, the *Lower Columbia Fish Recovery Board completed the Research, Monitoring, and Evaluation Program for Lower Columbia Salmon and Steelhead* as a companion to its recovery plan (LCFRB 2010b). This document also describes critical uncertainties. The list above does not include critical uncertainties that apply to multiple ESUs; these will be discussed and considered as decisions are made in implementation. In addition, the critical uncertainties above are of a technical nature; there are also many critical uncertainties related to social, political, and economic issues.

Critical uncertainties are one element of research, monitoring, and evaluation (RME) and adaptive management, which will be key components of the steelhead recovery strategy (see Chapter 10 for more discussion of RME and adaptive management for this recovery plan).

9.7 Delisting Criteria Conclusion for LCR Steelhead

The requirement for determining that a species no longer requires the protection of the ESA is that the species is no longer in danger of extinction or likely to become endangered within the foreseeable future, based on evaluation of the listing factors specified in ESA section 4(a)(1). To remove the Lower Columbia River steelhead DPS from the Federal List of Endangered and Threatened Wildlife and Plants (that is, to

[52] In its 2011 5-year review (76 *Federal Register* 50448), NMFS discussed uncertainties regarding the most appropriate boundary between the Mid-Columbia and Lower Columbia River steelhead DPSs. New information, primarily DNA microsatellite variation, underscores the transitional nature of populations in this area and the uncertainty associated with the ESU and DPS boundaries there. Given all this information, it might be reasonable either to reassign the White Salmon and Klickitat River steelhead from the Middle Columbia River DPS to the Lower Columbia River DPS or to maintain the existing DPS boundary. NMFS recommended maintaining the existing boundary but will reexamine the issue in future 5-year reviews as new information becomes available.

delist the DPS), NMFS must determine that the DPS, as evaluated under the ESA listing factors, is no longer likely to become endangered.

The ESA requires that recovery plans, to the maximum extent practicable, incorporate objective, measurable criteria that, 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). The recovery criteria in this plan (both biological and threats criteria) meet this statutory requirement.

As described in Section 9.3, if the scenario in Table 9-4 were achieved, it would meet or exceed the WLC TRT's viability criteria, particularly in the Cascade winter stratum but also in the Cascade summer stratum (see Table 9-8).[53] Exceeding the criteria in the Cascade stratum was intentional on the part of local recovery planners to compensate for uncertainties about the feasibility of meeting the WLC TRT's criteria in the Gorge stratum, in particular the questions raised by Oregon about the feasibility of meeting the target status for the Hood summer population.

Table 9-8
Steelhead Recovery Scenario Scores Relative to WLC TRT Viability Criteria

Species	Number of Primary Populations				Stratum Average Criteria		
		Cascade	Gorge	Total		Cascade	Gorge
Winter Steelhead	n ≥ high	9	2	11	Avg. score	2.61	2.33
	TRT criterion (n ≥ 2) met?	Yes	Yes		TRT criterion (avg. ≥ 2.25) met?	Yes	Yes
Summer Steelhead	n ≥ high	3	2	5	Avg. score	2.38	3.50
	TRT criterion (n ≥ 2) met?	Yes	Yes		TRT criterion (avg. ≥ 2.25) met?	Yes	Yes

Source: Based on LCFRB (2010a), Table 4-7.

Oregon recovery planners raised questions about the feasibility of meeting the recovery target of high persistence probability for both the Clackamas winter and Hood summer steelhead populations (ODFW 2010, Table 6-36). The Oregon management unit plan states that achieving a high probability of persistence for the Clackamas population would require more tributary habitat improvements than are believe feasible (ODFW 2010, Table 3-30). Because the recovery scenario targets nine steelhead populations for high persistence probability in the Cascade stratum, the WLC TRT criteria would likely

[53] As discussed in Section 2.5.4, the TRT's criteria for high probability of stratum persistence require that two or more populations be viable and that the average score for all populations in the stratum be 2.25 or higher. In the Cascade winter stratum, nine populations are targeted for high or very high persistence probability, and, using the WLC TRT's scoring system, the average viability score for all populations in the stratum would be 2.61.

be met even without achieving high persistence probability for the Cascade winter population.

Oregon recovery planners' uncertainty regarding the Hood summer steelhead population is based in part on questions about the feasibility of meeting the habitat and hatchery threat reduction targets for this population (ODFW 2010) and in part on questions raised by both Oregon and Washington management unit planners regarding Gorge stratum and population delineations and the historical role of the Gorge populations (LCFRB 2010a, ODFW 2010). These questions include whether the Gorge populations were highly persistent historically, whether they functioned as independent populations within their stratum in the same way that the Coast and Cascade populations did, and whether the Gorge stratum itself should be considered a separate stratum from the Cascade stratum.

As discussed in Section 3.2, NMFS has considered the WLC TRT's viability criteria (from McElhany et al. 2003 and 2006 and summarized in Table 2-3), the additional recommendations in McElhany et al. (2007), the recovery scenarios and population-level goals in the management unit plans, and the questions raised regarding the historical role of the Gorge strata.

NMFS has concluded that the WLC TRT's criteria adequately describe the characteristics of a DPS that meet or exceed the requirement for determining that a species no longer needs the protection of the ESA. These criteria provide a framework within which to evaluate specific recovery scenarios. NMFS has evaluated the recovery scenario presented in the management unit plans for Lower Columbia River steelhead (summarized in Table 3-1 of this recovery plan) and the associated population-level abundance and productivity goals (see Section 9.3) and has concluded that they also adequately describe the characteristics of a DPS that no longer needs the protections of the ESA. NMFS endorses the Lower Columbia River steelhead recovery scenario and the associated population-level goals in the management unit plans (summarized in Table 3-1 and Section 9.3) as one of multiple possible scenarios consistent with delisting.

NMFS also agrees with the management unit planners that the historical role of the Gorge populations and strata merits further examination. The extent to which compensation in the Cascade stratum is ultimately considered necessary to achieve an acceptably low risk at the DPS level will depend on how questions regarding the historical role of the Gorge populations are resolved.

NMFS therefore has developed the following delisting criteria for the Lower Columbia River steelhead DPS. (NMFS has amended the WLC TRT's criteria to incorporate the concept that each stratum should have a probability of persistence consistent with its historical condition, thus allowing for resolution of questions regarding the Gorge strata):

1. All strata that historically existed have a high probability of persistence or have a probability of persistence consistent with their historical condition. High probability of stratum persistence is defined as:

a. At least two populations in the stratum have at least a 95 percent probability of persistence over a 100-year time frame (i.e., two populations with a score of 3.0 or higher based on the TRT's scoring system).

b. Other populations in the stratum have persistence probabilities consistent with a high probability of stratum persistence (i.e., the average of all stratum population scores is 2.25 or higher, based on the TRT's scoring system). (See Section 2.6 for a brief discussion of the TRT's scoring system.)

c. Populations targeted for a high probability of persistence are distributed in a way that minimizes risk from catastrophic events, maintains migratory connections among populations, and protects within-stratum diversity.

A probability of persistence consistent with historical condition refers to the concept that strata that historically were small or had complex population structures may not have met Criteria A through C, above, but could still be considered sufficiently viable if they provide a contribution to overall ESU viability similar to their historical contribution.

2. The threats criteria described in Section 3.2.2 have been met.

10. Adaptive Management and Research, Monitoring, and Evaluation

The long-term success of recovery efforts for Lower Columbia River salmon and steelhead will depend on the strategic use of research, monitoring, and evaluation (RME) to provide useful information to decision makers within an adaptive management framework. Research, monitoring, and evaluation programs associated with recovery plans need to gather the information that will be most useful in tracking and evaluating implementation and action effectiveness and assessing the status of listed species. Planners and managers then need to use the information collected to guide and refine recovery strategies and actions. These elements of recovery plans are crucial for salmon and steelhead because of the complexity of the species' life cycles, the range of factors affecting survival, and the limits on our understanding of how specific actions affect species' characteristics and survival.

Research, monitoring, and evaluation for salmon and steelhead are complicated by the existence of multiple entities in the region conducting relevant monitoring. Within the Columbia Basin and the Lower Columbia recovery subdomain, many organizations, including federal, state, tribal, local, and private entities, conduct various kinds of monitoring. Developing regional coordination for these efforts is essential if we are to design and implement sound monitoring programs that provide relevant, valid, and accessible data and use limited resources most effectively.

The management unit recovery plans contain or will contain specific RME plans for their areas. These RME plans are based on regional guidance for adaptive management and RME and will guide recovery planning RME efforts and funding in their respective areas, within a context of ongoing regional guidance and coordination.

This chapter provides the following information:

- A brief description of the concept of adaptive management and a brief overview of salmon and steelhead recovery plan RME needs
- A summary of regional guidance for adaptive management and RME
- An overview of the RME components of each management unit plan and the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a)
- An overview of RME regional coordination efforts and needs[1]

10.1 Overview of Adaptive Management and RME Needs

Adaptive management is the process of adjusting management actions and/or overall approach based on new information. Adaptive management works by coupling decision

[1] For a list of preliminary critical uncertainties for each ESU, see Sections 6.6.8, 7.4.3.8, 7.5.3.8, 7.6.3.6, 8.6.8, and 9.6.7.

making with data collection and evaluation. Most importantly, it works by offering an explicit process through which alternative approaches and actions can be proposed, prioritized, implemented, and evaluated (NMFS 2007). Successful adaptive management requires that monitoring and evaluation plans be incorporated into overall implementation plans for recovery actions. These plans should link monitoring and evaluation results explicitly to feedback on the design and implementation of actions. In adaptive management, recovery strategies are treated like working hypotheses that can be acted upon, tested, and revised (Lee 1999). Figure 10-1 illustrates the adaptive management process.

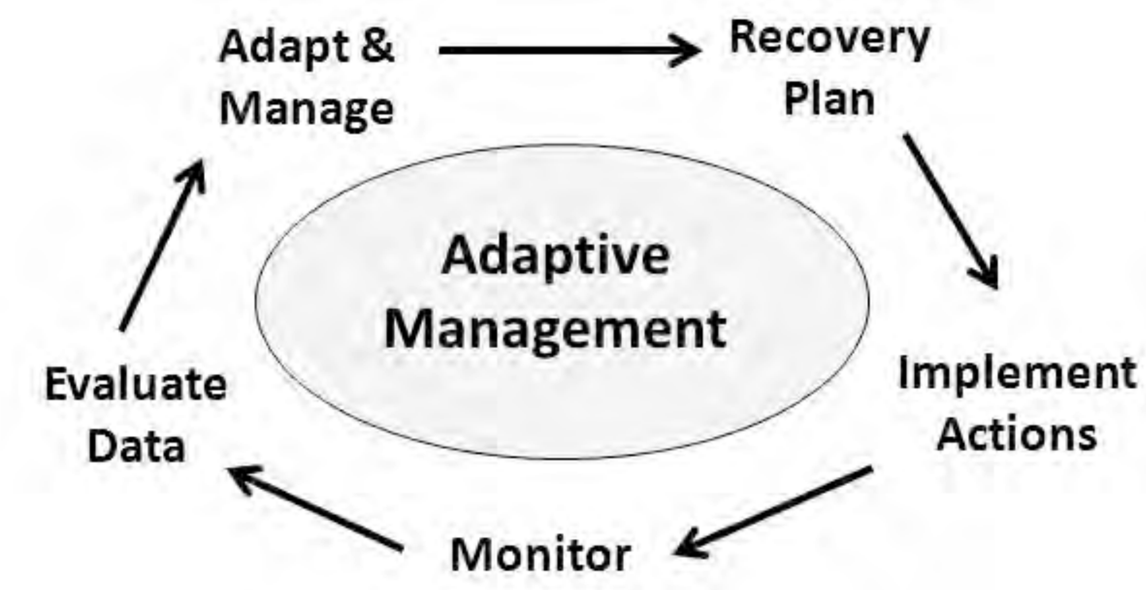

Figure 10-1. *The Adaptive Management Cycle*

Several types of monitoring are needed to support adaptive management (NMFS 2007):

- Implementation monitoring and compliance monitoring, which are used to evaluate whether recovery plan actions are being implemented as directed.
- Status and trend monitoring, which assesses changes in the status of an ESU and its component populations, and changes in the status or significance of the threats to an ESU.
- Effectiveness monitoring, which tests hypotheses about cause-and-effect relationships and determines via research whether an action is effective and should be continued.

It is also important to explicitly address the many unknowns in salmon recovery—the "critical uncertainties" that make management decisions much harder. Doing so will involve prioritizing critical uncertainties and ensuring that appropriate research is conducted that can inform managers on the questions (NMFS 2007).

Finally, given the wide array of organizations involved in salmon recovery in the Columbia Basin, including groups from federal agencies, states, and tribes, the task of coordinating all the information being gathered and making it available to decision makers throughout the region is daunting. During the last decade, substantial progress has been made in standardizing fisheries data collection and storage methods.

10.2 Guidance for Adaptive Management and RME

NMFS and other entities have developed documents to guide and coordinate salmon and steelhead RME efforts throughout the Columbia Basin and the Pacific Northwest. Overall, the goal of these guidance documents is to ensure that monitoring programs are designed to provide the information NMFS and others need to understand the effects of recovery actions and evaluate the status of salmon and steelhead populations and the threats they face. Another objective of the guidance documents has been to ensure that data is managed, shared, and integrated in a cost-effective manner. The primary guidance documents are described briefly below.

10.2.1 Adaptive Management for ESA-Listed Salmon and Steelhead Recovery: Decision Framework and Monitoring Guidance

In 2007, the NMFS Northwest Region released *Adaptive Management for ESA-Listed Salmon and Steelhead Recovery: Decision Framework and Monitoring Guidance* (NMFS 2007). This document describes the questions NMFS asks in evaluating species status and making listing and delisting decisions. It offers conceptual-level guidance, not specific instructions, on gathering the information that will be most useful in tracking progress and assessing the status of listed species.

As outlined in the document, a delisting decision is based on evaluation of both the ESU's biological status and the extent to which the threats facing the ESU have been addressed. The document spells out the questions that need to be answered through RME to satisfy the requirements for each component of such a decision. These components are displayed graphically in the form of a "listing status decision framework" (Figure 10-2).

The document emphasizes that adaptive management is an experimental approach in which the assumptions underlying recovery strategies and actions are clearly stated and subject to evaluation (NMFS 2007). It further states that a monitoring and evaluation plan to support adaptive management should provide (1) a clear statement of the metrics and indicators by which progress toward achieving goals can be tracked, (2) a plan for tracking such metrics and indicators, and (3) a decision framework through which new information from monitoring and evaluation can be used to adjust strategies or actions aimed at achieving the plan's goals.

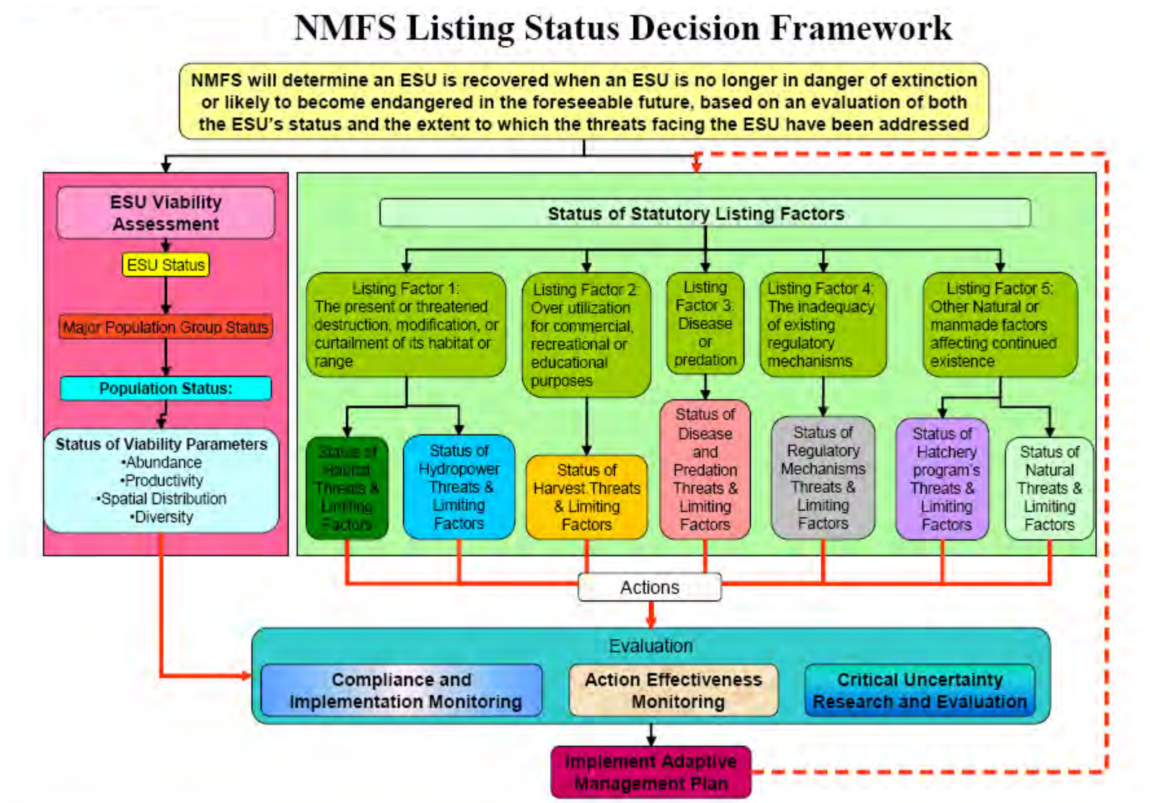

Figure 10-2. *NMFS Listing Status Decision Framework*

The document also discusses the various types of monitoring needed for salmon recovery, categorized as status and trend monitoring, effectiveness monitoring, validation monitoring, implementation monitoring, and research on critical uncertainties.

- **Status and trend monitoring**. Status monitoring is used to characterize existing conditions and establish a baseline for future comparisons. For monitoring of salmon and steelhead population status, the parameters of interest are abundance, productivity, diversity, and spatial structure. Parameters also need to be established to monitor the status of threats to salmon and steelhead (e.g., habitat, hydropower, hatcheries, and harvest). Trend monitoring involves measurements taken at regular time or space intervals to assess the long-term or large-scale trend in a particular parameter (NMFS 2007).

- **Effectiveness monitoring.** Effectiveness monitoring evaluates the direct effect of management actions. Success can be measured against reference areas, baseline conditions, or desired future conditions. Effectiveness monitoring can be implemented at the scale of individual actions, suites of actions across space, or for an entire strategy consisting of multiple actions at a single location.

- **Validation monitoring.** Validation monitoring answers the question: Did the management actions create the intended outcome? This question often involves evaluating the effects of numerous projects on a watershed or species. An example would be evaluating whether the cumulative effects of habitat restoration actions in a specific river basin resulted in increased production of juvenile salmon.

- **Implementation monitoring.** Implementation monitoring determines whether activities were carried out as planned and is generally conducted as an administrative review or site visit. This type of monitoring cannot directly link restoration actions to physical, chemical, or biological responses because none of these parameters are measured (NMFS 2007).

- **Research on critical uncertainties.** The adaptive management guidance notes that research on critical uncertainties may seem expensive or unnecessary but in the long run will reduce monitoring and implementation costs (NMFS 2007).

Finally, the adaptive management guidance (NMFS 2007) discusses considerations for prioritizing monitoring and examines the consequences of different sorts of incomplete data. Management and delisting decisions often must be made with incomplete information. Different types of incomplete information pose correspondingly different types of risks for delisting decisions. This discussion is intended to help planners consider how their own implementation and monitoring decisions may affect NMFS' assessment of ESU status.

10.2.2 Guidance for Monitoring Recovery of Pacific Northwest Salmon and Steelhead

Another document from the NMFS Northwest Region, *Guidance for Monitoring Recovery of Pacific Northwest Salmon and Steelhead* (Crawford and Rumsey 2011), builds on the 2007 adaptive management guidance document with specific recommendations for monitoring, data collection, and reporting ESA information (Crawford and Rumsey 2011). NMFS intends this document to assist those involved with salmon recovery in understanding the desired level of monitoring and the associated level of certainty needed at the regional, local, and project levels to support ESA status evaluations and listing and delisting decisions. NMFS also intends the guidance to assist in the development and implementation of a regional monitoring strategy that will provide the necessary monitoring information in the most cost-effective way for the region. The document does not establish new requirements or modify any existing requirements.

The recommendations included are for federal and state agencies, tribes, local governments, and watershed organizations. Recommendations include monitoring that addresses all of the viable salmonid population (VSP) criteria and the threats to salmon and steelhead (organized under the five ESA listing factors). The guidance also makes recommendations for setting up regional databases and coordinating regional data collection so that the various agencies and tribes involved in salmon recovery can share data as well as report it efficiently to NMFS.

Recommendations for VSP monitoring address adult spawner abundance, productivity, spatial distribution, and diversity. Abundance considerations include use of a sampling design that has known precision and accuracy, monitoring of hatchery contributions, and a goal of a coefficient of variation of 15 percent or less for all populations. Productivity considerations include (1) developing at least 12 brood years of spawner information to allow use of the geometric mean of recruits per spawner to develop productivity estimates, and (2) obtaining estimates of juvenile migrants for at least one significant population within each stratum. The guidance recommends certainty levels for detecting changes in spatial distribution and, for diversity, suggests short-term strategies (use of spawn timing, age distribution, and other observations) and long-term strategies (genetic baseline information for each population).

Habitat-related recommendations include use of a generalized random tessellation stratified (GRTS) sampling program coupled with remote sensing of land use and land cover and coordinated with fish-in/fish-out monitoring where possible. Implementation of habitat restoration efforts should be capable of being reported (e.g., using the data fields in the Pacific Coastal Salmon Recovery Fund [PCSRF] project tracking database) and correlated with limiting factors as defined in the NMFS data dictionary (Hamm 2012). Reach-scale effectiveness monitoring should be conducted for various habitat improvement categories using a Before and After Control Impact (BACI) design wherever possible. There should also be at least one intensively monitored watershed (IMW) in each recovery subdomain. The U.S. Environmental Protection Agency, state agencies, and local governments should monitor stormwater and cropland runoff for concentrations of toxic contaminants and to identify their sources. For monitoring of hydropower-related threats, the guidance largely refers to specific requirements that have been written into FERC licenses.

For monitoring of harvest status and trends, the NMFS monitoring guidance notes the need for improved estimates of population-level harvest impacts, improved models for predicting harvest impacts to populations, and improved monitoring of incidental take and exploitation rate management.

For disease and predation, the guidance suggests that the status of existing invasive species should be compiled for each ESU/DPS and that watershed-level assessments should be conducted for species known to affect salmon and steelhead.

For threats related to hatchery production, the guidance recommends that states and tribes be able to determine annually and with known precision the proportion of hatchery origin spawners (pHOS) for each population. The proportion of natural influence (PNI) for primary populations with supplementation programs should be calculated periodically. Hatchery operators should complete Hatchery and Genetics Management Plans (HGMPs), submit them to NMFS for approval, and track and report on their implementation. Hatchery action effectiveness monitoring should include development of large-scale treatment/reference design to evaluate long-term trends in abundance and productivity of supplemented populations.

To evaluate the adequacy of regulatory actions, the guidance notes the need for a recovery action tracking system capable of recording whether entities have implemented regulatory actions in the recovery plans. It also suggests development of a randomized sampling program to test whether permits issued under regulatory programs designed to protect riparian and instream habitat are in compliance and adequately enforced.

Noting the regional needs to coordinate data collection, evaluation, and reporting, the guidance also makes the following recommendations: (1) regional environmental databases should be coordinated such that information can be readily reported to NMFS and shared among participants, (2) methods and calculations used to assess and evaluate data should be transparent and repeatable, (3) all project tracking should be consistent with the PCSRF project tracking database and the NMFS data dictionary, (4) regional salmon recovery partners should build a distributed data system that can communicate among agencies and report to the public, (5) sampling programs for habitat, water quality, and fish VSP criteria should be coordinated to fit within an integrated master sample program.

10.2.3 Other RME Guidance

A number of other regional efforts provide guidance relevant to developing RME and adaptive management programs for Lower Columbia River salmon and steelhead. These include Columbia River Basin Fish and Wildlife Program 2009 amendments and recommendations for implementing RME for the 2008 NOAA Fisheries FCRPS Biological Opinion and its 2010 Supplement (NMFS 2008f and 2010a).

10.2.3.1 Columbia River Basin Fish and Wildlife Program 2009 Amendments

The Northwest Power and Conservation Council's Fish and Wildlife Program emphasizes implementation of fish and wildlife projects based on needs identified in subbasin plans, federal biological opinions, ESA recovery plans, and the 2008 Fish Accords signed by federal agencies, Indian tribes, and the states of Idaho and Montana. The program amendments also establish reporting guidelines and the use of adaptive management to guide decision making and emphasize a more focused monitoring and evaluation framework coupled with a commitment to use the information obtained to make better decisions. The program includes general guidelines for monitoring and adaptive management in the Columbia Basin as well as a discussion of the need to develop a monitoring, evaluation, research, and reporting plan. A description of the program is available at http://www.nwCouncil.org/library/2009/2009-09/Default.asp.

10.2.3.2 Recommendations for Implementing Research, Monitoring and Evaluation for the 2008 NOAA Fisheries FCRPS Biological Opinion (AA/NOAA/NPCC RM&E Workgroups, June 2009 and May 2010)

Completion of the 2008 Biological Opinion on the operation of the Federal Columbia River Power System (FCRPS) stimulated collaboration related to RME in the mainstem lower Columbia River and estuary. The 2008 FCRPS Biological Opinion and its 2010 Supplement recommended a complex suite of actions to improve survival of salmonids through the migratory corridor of the Columbia River and to improve habitat below Bonneville Dam used for resting, feeding, the physiological transition for fresh to salt water, and migration. Subsequently, federal, state, and tribal entities organized technical work groups to determine how best to implement the recommendations in the Biological Opinion and its Supplement and how to conduct RME to support them. Various guidance documents have been produced through this process and are available at http://www.salmonrecovery.gov/ResearchReportsPublications.aspx.

10.2.3.3 Salmon Monitoring Advisor

The Salmon Monitoring Advisor is a website developed by the Pacific Northwest monitoring community to provide a comprehensive, technically rigorous framework to help practitioners, decision makers, and funders design monitoring programs. The monitoring advisor is a web-based system that synthesizes a wide array of information into a systematic framework that offers an organized, structured procedure to help users efficiently design and implement reliable, informative, and cost-effective salmon monitoring programs. It provides advice and guidelines to help users systematically work through the numerous steps involved in designing, implementing, and analyzing results from monitoring programs to meet particular monitoring objectives. The address for this site is https://salmonmonitoringadvisor.org/.

10.3 RME Plans for the Washington, Oregon, and White Salmon Management Unit Plans

Within the framework of the guidance described above, local recovery planners have or will develop RME programs for their management unit recovery plans. These plans will provide conceptual-level guidance to RME implementation efforts at the local and regional scale. Implementation of these RME plans will also be influenced by the regional coordination efforts described below. Management unit RME plans are briefly summarized below; readers should consult the management unit plans themselves for detail.

10.3.1 Washington Management Unit

The Washington management unit plan (LCFRB 2010a) contains a monitoring and research chapter (see LCFRB 2010a, Chapter 9), which is supplemented by the *Research, Monitoring, & Evaluation Program for Lower Columbia Salmon & Steelhead* (LCFRB 2010b). Together these documents provide the framework for a systematic approach to RME in the LCFRB planning area.

Both documents describe general RME strategies for (1) biological status and trend monitoring, (2) habitat status and trend monitoring, (3) implementation/compliance monitoring, (4) action effectiveness monitoring, and (5) uncertainty and validation research. For each of these monitoring elements, the documents identify objectives, strategies, indicators, sampling and analytical design, and implementation actions needed for the RME program. In addition, the RME program document (LCFRB 2010b) contains inventories of available information and data and identifies critical information needs and priorities.[2] Both documents also address information reporting strategies. Because there is significant overlap between the two documents, they are referred to collectively here as the LCFRB RME program. In general, the LCFRB RME program identifies what needs to be done and how to do it but does not address specific implementation details such as desired confidence levels, statistical power, data collection protocols, and sample sizes. (For biological status and trends and habitat status and trends, such implementation details are being developed through the Pacific

[2] In particular, see Appendix B, "Detailed Inventory of Ongoing Monitoring Activities," and Appendix D, "Gap Analysis of Biological Monitoring Programs."

Northwest Aquatic Monitoring Partnership's Integrated Status and Trend Monitoring process, described below in Section 10.6.2).

The LCFRB RME program is intended to integrate with and complement other state and regional RME efforts for salmon and steelhead. Its goal is to provide a template for action and overall guidance to the extensive group of participants involved in implementation of the LCFRB plan. Specific elements are described briefly below.

10.3.1.1 Biological Status Monitoring

The LCFRB RME program's strategic approach for biological status monitoring is that while the status of every population needs to be assessed, all populations do not need to be monitored. The program advocates assigning the highest priorities for monitoring to populations targeted for high persistence probability and large improvements, and ensuring that populations selected for intensive monitoring represent all strata. For sampling and analytical design, the program recommends a stratified, representative, multi-level sampling framework. Such a sampling design would provide information on every population but sample different populations at different intensities and be designed to ensure representative coverage of all ESUs.

The program also identifies specific needs for a comprehensive natural coho sampling program, expanded adult and juvenile chum sampling efforts, and augmented sampling for adult and juvenile fall Chinook and winter steelhead.

10.3.1.2 Habitat Status Monitoring

The LCFRB RME program recommends monitoring stream corridor and landscape-scale habitat status as well as water quantity and quality. For stream habitat the strategic approach is to use a rotating panel of habitat samples to produce evaluations relative to baseline conditions every 12 years. The program also calls for assessing landscape condition at 12-year intervals, with landscape-scale information to be compiled uniformly across the entire study area. The primary focus of the LCFRB water quantity and water quality RME program is to characterize conditions for salmon and watershed health relative to a baseline at listing. The plan calls for comprehensive assessments of water quality and quantity status and trends at 12-year intervals.

10.3.1.3 Implementation and Compliance Monitoring

The LCFRB RME program identifies the need for implementation and compliance monitoring to determine whether recovery actions have been implemented as planned. The program proposes that this be accomplished by having implementing partners evaluate and report on progress in implementation through a centralized database system, called SalmonPORT, to be developed and maintained by LCFRB.

10.3.1.4 Action Effectiveness Monitoring

The LCFRB RME program addresses action effectiveness monitoring for actions in the categories of stream habitat, hydropower, fisheries, hatcheries, ecological interactions, and mainstem/estuary habitat.

- **Stream Habitat.** For stream habitat, the overall approach is to complete comprehensive assessments of habitat action effectiveness every 6 years. The strategy includes monitoring the effectiveness of specific types of habitat actions, developing and maintaining an inventory of habitat-related actions, and intensively monitoring a subset of habitat actions using formal statistical research design methods. For sampling and analytical design, the plan generally adopts monitoring designs and protocols developed by the Washington Salmon Recovery Funding Board.

- **Hydropower.** For hydropower actions, effectiveness monitoring is intended to determine whether hydropower actions for fish protection, restoration, and mitigation reduce or limit effects on natural-origin fish to levels consistent with conservation and recovery. The strategy calls for evaluating action effectiveness for passage, habitat protection and restoration, reintroduction, and other mitigation actions at all significant tributary and mainstem facilities every 6 years, using criteria as established in FERC licenses, biological opinions, and settlement agreements.

- **Harvest.** The overall objectives for fisheries action effectiveness monitoring include determining whether impacts are limited to prescribed levels and consistent with long-term recovery goals. The strategic approach is to monitor annual impacts and complete comprehensive assessments at 6-year intervals.

- **Hatcheries.** Overall objectives for hatchery action effectiveness monitoring include monitoring to determine whether hatchery impacts on each population are limited to prescribed levels and whether hatchery performance is consistent with goals for each hatchery program. The overall strategy is to monitor each hatchery program as well as the annual incidence of natural spawning by hatchery-origin fish and to complete comprehensive assessments of hatchery action effectiveness at 6-year intervals. Specific criteria for each program are to be developed in Hatchery and Genetic Management Plans.

- **Ecological Interactions**. The strategy for ecological interactions includes monitoring the effectiveness of actions addressing non-native species and predation by northern pikeminnow, marine mammals, and birds and developing 6-year summary evaluations.

- **Mainstem/Estuary.** The LCFRB RME program cites the estuary RME program developed by Johnson et al. to provide status monitoring, action effectiveness monitoring, and uncertainties research.

10.3.1.5 Research Needs

The LCFRB RME program identifies specific research needs for salmon population status, stream habitat and watershed health, hydropower, fisheries, hatcheries, ecological interactions, and the mainstem/estuary.

10.3.1.6 Data Management

The LCFRB RME program identifies a need for a data management needs assessment. It also notes the need to develop and maintain regionally standardized datasets and a data storage and management system, along with a need to produce and distribute regular progress reports and coordinate with other Columbia Basin efforts.

10.3.1.7 Programmatic Evaluation

The LCFRB RME program makes recommendations for programmatic evaluation, or adaptive management.

10.3.2 Oregon Management Unit

The Oregon management unit plan also contains a chapter devoted to research, monitoring, and evaluation (see ODFW 2010, Chapter 8). This chapter outlines the research, monitoring, and evaluation needs of the plan as they pertain to biological criteria (i.e., population VSP parameters) and threats (as organized under the ESA listing factors). It also describes how Oregon will incorporate RME into an adaptive management framework. The ODFW monitoring plan is based closely on the NMFS (2007) guidance document. It is organized around the key questions, as identified in the NMFS document, that must be answered for delisting decisions. It also includes the analytical framework Oregon intends to use to answer those key questions, along with measurable criteria against which the state intends to measure progress toward those goals. Like the LCFRB plan, the ODFW plan addresses status and trend monitoring, implementation monitoring, effectiveness monitoring, and critical uncertainty research.

10.3.2.1 Biological Status Monitoring

The Oregon management unit plan describes biological status monitoring needs for population abundance, productivity, spatial structure, and diversity. Included are decisions and key questions for evaluating population status as it pertains to each of the four VSP parameters, as well as analytical guidelines and measurable criteria. In general, decisions and key questions are derived from TRT documents and the Oregon management unit plan. The plan identifies a need for annual benchmarks of abundance and productivity based on annual, scaled estimates of spawner abundance, harvest of natural-origin fish, age at return, and an index of climate impact. The plan proposes to develop these annual estimates through spatially balanced, random surveys based on the generalized random tessellation stratified (GRTS) technique and using field protocols developed by ODFW.

For spatial structure, the plan identifies a need for annual estimates of the distribution and density of natural-origin spawning adults for each population (and for annual monitoring of juveniles at the stratum scale), as well as for 5-year assessments of habitat conditions throughout the accessible distribution of each population. The plan proposes spatially balanced, random surveys based on the GRTS technique and using ODFW protocols to obtain these estimates. In addition, the plan identifies a need for annual monitoring of streamflow.

For diversity, the plan identifies a need for periodic monitoring of key life history characteristics of each population; annual monitoring of spatial distribution, abundance, and origin of adult spawners in each population; hatchery monitoring; genetic marker monitoring; and periodic assessment of habitat diversity, occupancy, and anthropogenic changes to habitat and the environment.

The plan also calls for fish-in/fish-out (i.e., life-cycle) monitoring in at least one subwatershed in each stratum to provide marine survival estimates and another view of freshwater survival and productivity.

The plan describes a strategic approach to biological status monitoring that includes: (1) documenting the precision and bias associated with various monitoring protocols, (2) implementing GRTS or census-based spawning surveys where possible and using adult trapping facilities where necessary to provide population-level information on VSP parameters, and (3) using GRTS surveys to provide stratum-level information on juvenile abundance and, in at least one subwatershed, monitoring (via traps) adults in/juveniles out to provide an estimate of freshwater productivity. The chapter also describes how ODFW will prioritize resources under limited or fluctuating funding scenarios, including populations that will be cut from RME when resources are inadequate.

10.3.2.2 Monitoring Related to Listing Factors

The Oregon management unit plan discusses monitoring needs related to threats as organized under the five ESA listing factors. For each listing factor, the plan identifies the decision and key questions for delisting and status assessment (based on the NMFS 2007 guidance document) and discusses monitoring needs for status and trends, action effectiveness, and implementation. Discussion of status and trend monitoring includes identification of measurable criteria (metrics and evaluation thresholds), analytical procedures, and specific RME needs.

- **Habitat.** For habitat status and trend monitoring, the plan identifies a need for 5-year estimates of the spatial pattern and status of specific habitat attributes for each population as well as annual assessments of the status and spatial pattern of water quality for each population. The plan calls for these to be determined using spatially balanced, random surveys based on the GRTS technique and using ODFW or Oregon Department of Environmental Quality protocols. The plan also identifies the need for annual assessments of the status and spatial pattern of streamflow for each population.

  In addition to this 5-year monitoring, the plan calls for annual assessments at the stratum scale. Annual assessments are conducted during the summer; after 5 years, they provide a dense enough sample to characterize summer habitat conditions by population. This information complements the 5-year surveys, which are conducted in winter to characterize conditions during that season.

  For habitat implementation and compliance monitoring, the plan notes the needs for annual assessments of (1) compliance with existing habitat protection rules and regulations, (2) implementation of habitat best management practices, and

(3) implementation of habitat recovery actions. For habitat action effectiveness monitoring, the plan advocates use of intensively monitored watersheds (IMWs) as well as site-specific monitoring of habitat protection and BMPs and habitat restoration actions.

- **Hydropower.** For hydropower-related monitoring, the plan generally defers to the Clackamas River Hydroelectric Project Fish Passage and Protection Plan (Portland General Electric Company, 2006). Analytical procedures and RME needs for Laurance Lake Dam are to be determined.[3]

- **Harvest.** For monitoring related to the impacts of harvest, the plan identifies the need for annual estimates of mortality that is due to harvest for each population and annual estimates of the marine survival rates of natural-origin coho salmon (by monitoring adults in and smolts out of one intensively monitored watershed per stratum). For harvest implementation and compliance monitoring, the plan identifies a need for annual estimates of mortality, and for evaluation of whether managers meet targets for implementing mark-selective Chinook salmon fisheries and for shifting spring Chinook salmon commercial and tribal harvest to terminal areas during low-return years. For effectiveness monitoring related to harvest, the plan identifies a need to conduct studies to assess the effectiveness of harvest management actions needed to achieve harvest impact goals.

- **Hatcheries.** For status and trend monitoring related to hatcheries, the plan identifies the need for annual assessments of the abundance, distribution, and origin of hatchery fish spawning in each population, annual monitoring of the spatial and temporal distribution of juvenile fish released by hatchery programs, and all of the status and trend monitoring described for fish abundance and productivity. The plan also describes the need for monitoring and documentation that demonstrate that HGMPs have been implemented and effective.

- **Disease/predation**. For status and trends related to predation (by Caspian terns, double-crested cormorants, marine mammals, and northern pikeminnow), the plan identifies a need for monitoring of predation associated with anthropogenic alterations in the Columbia River estuary, at Bonneville Dam, and in Bonneville Reservoir. For issues related to disease, the plan calls for sampling of natural populations in and near hatcheries to determine occurrence of pathogens that may cause disease. The plan also calls for watershed-scale sampling for the occurrence of invasive aquatic species known to affect salmon and steelhead. Implementation and compliance monitoring and effectiveness monitoring needs for predation and disease are to be determined.

- **Regulatory mechanisms.** For monitoring related to regulatory mechanisms, the plan describes the need for a system that tracks whether regulatory actions called for in the plan are being implemented. It also identifies a need for a randomized sampling program to test whether permits issued under regulatory programs

---

[3] Monitoring of hydropower-related facilities in the Sandy and Hood subbasins was not addressed because the dams have been removed.

designed to protect riparian and instream habitat are being issued as designed and being enforced.

The plan also identifies specific critical uncertainties for each of the VSP parameters and for each of the listing factors and includes an appendix describing existing monitoring programs (see ODFW 2010, Appendix J).

Like the LCFRB plan, the Oregon management unit plan discusses the need for and benefits of integrating monitoring plans throughout the region. As a step toward such integration, the plan advocates development of a survey design process that promotes data sharing, agreement on a core set of monitoring questions, coordination of monitoring activities, and development either of common protocols and methods or of ways to "crosswalk" data derived from different protocols. The plan also notes the need for improved data management and access through development of distributed data systems and data management infrastructure.

10.3.3 White Salmon Management Unit

The White Salmon management unit plan (NMFS 2013) contains a brief discussion of monitoring, intended to provide a framework for the development of a detailed RME plan for the White Salmon, and identifies several critical uncertainties and actions needed to address them.[4] The management unit plan also notes that various monitoring efforts are under way and that there is a need for a coordinated monitoring program, and it includes some notes on initial steps in designing such a program. It also discusses adaptive management in general, identifies in-basin and out-of-subbasin research needs, discusses the various types of monitoring needed (implementation, status/trend, effectiveness), and the need for consistency/coordination with other monitoring programs. The plan also notes that the reintroduction plan for White Salmon River salmon will rely heavily on results of research and be guided by ongoing monitoring and evaluation.

10.4 Estuary Module RME

The *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) also includes a chapter that describes RME needed to assess juvenile salmonid performance in the estuary and to evaluate the effectiveness of the 23 management actions described in the module. Like the management unit RME plans, this chapter notes the need for various types of monitoring (status and trends, action effectiveness research, critical uncertainties research, implementation and compliance monitoring) and for an adaptive management approach. It also discusses the need for coordination of monitoring efforts and for data and information management, synthesis, reporting, and evaluation. The estuary module RME chapter identifies RME needs associated with each management action in the module; describes existing monitoring plans, programs, and projects that relate to those needs; and identifies gaps and potential projects to fill those gaps.

[4] PacifiCorp breached Condit Dam in October 2011 and completely removed the dam in September 2012. Specific actions to improve habitat and monitor results will be determined once post-removal habitat conditions have been evaluated.

Monitoring for the estuary module will build on ongoing efforts, particularly efforts established under the *Research, Monitoring, and Evaluation for the Federal Columbia River Estuary Program* (ERME) (Johnson et al. 2008). The ERME monitoring plan forms the basis for estuary RME in the 2008 Federal Columbia River Power System Biological Opinion (NMFS 2008f) and the 2010 FCRPS Supplemental Biological Opinion (NMFS 2010a).

In addition to the ERME plan, other monitoring plans and guidance documents applicable to estuary RME are listed in the module. To implement these existing monitoring plans, a number of monitoring programs and projects are already under way in the estuary. The module identifies these programs and projects and relates them to the RME needs for each of the 23 management actions in the module, identifies a number of gaps, and suggests projects to fill those gaps. For each monitoring need, the module also recommends sampling design, spatial and temporal scale, variables to be measured, measurement protocols, variables to be derived, analyses needed, and possible implementing and funding entities.

As implementation of monitoring programs proceeds in the estuary and tributaries, there will be a need to ensure appropriate integration. For example, are monitoring designs compatible and/or comparable, are methods compatible or comparable, and are RME efforts addressing recovery plan questions?

10.5 RME in Biological Opinions and Records of Decision

Several federal agencies have natural resource responsibilities related to the ESA and rely on biological opinions and issue records of decision that include RME that may be relevant to salmon recovery. Efforts to develop and coordinate recovery plan monitoring in the Lower Columbia subdomain should consider how RME needs and recommendations outlined in such documents could help fulfill recovery plan monitoring needs. Similarly, in proposing RME activities in biological assessments and records of decision, federal agencies should consider the context of recovery plan monitoring needs.

Examples of relevant biological opinions include those for Federal Energy Regulatory Commission relicensing settlement agreements, harvest management decisions, and habitat actions, particularly large-scale actions. The 2008 Federal Columbia River Power System Biological Opinion and its 2010 Supplement, including the FCRPS Adaptive Management Implementation Plan (AMIP) (NMFS 2009c), along with associated RME work groups, are also relevant in the Lower Columbia, although less so than in the interior of the Columbia Basin.

10.6 Regional Coordination Efforts

Described briefly below are some of the regional entities that serve as a catalyst or provide forums for regional coordination of monitoring efforts. Such coordination efforts take place within the context of the RME guidance documents described above, in Section 10.2, and the management unit RME plans described above, in Section 10.3:

- **The Bonneville Power Administration and Northwest Power and Conservation Council**. The Bonneville Power Administration (BPA) is a major funding source for salmon recovery projects in the Columbia Basin as part of its obligation to mitigate the effects of the operation of the FCRPS on fish and wildlife. The Northwest Power and Conservation Council (NPCC) plays an important role in deciding which projects BPA should fund. As such, these two organizations function as coordinators of RME, both in terms of the RME actions they fund and the information-sharing processes they initiate or approve. For more information, see http://efw.bpa.gov/IntegratedFWP/anadfishresearch.aspx and http://www.nwcouncil.org/fw/.

- **The Columbia Basin Fish and Wildlife Authority**. The Columbia Basin Fish and Wildlife Authority (CBFWA) provides a venue for representatives of the states and tribes to work toward comprehensive and effective planning and implementation of fish and wildlife programs in the Columbia Basin. CBFWA's role includes evaluating monitoring needs and making recommendations to the NPCC and BPA on project funding. CBFWA is also a central source for information and news on status and trends of fish and wildlife in the Columbia Basin. For more information, see http://www.cbfwa.org/index.cfm.

- **The Pacific Northwest Aquatic Monitoring Partnership**. The Pacific Northwest Aquatic Monitoring Partnership (PNAMP) is a coordinating forum whose primary mission is to encourage standardization of monitoring methods among state, federal, and tribal aquatic habitat and salmonid monitoring programs. PNAMP partners strive to improve communication and sharing of resources and data, and they work toward compatible monitoring efforts that will ultimately provide increased scientific credibility, cost-effective use of limited funds, and greater accountability to stakeholders. They develop and advance recommendations for consideration and potential adoption by participating agencies. The PNAMP effort is funded by in-kind services and modest funding from various agencies. A PNAMP demonstration project on Integrated Status and Trends Monitoring is under way in the Lower Columbia subdomain. For more information, see http://www.pnamp.org/.

- **Integrated Status and Effectiveness Monitoring Program**. The Integrated Status and Effectiveness Monitoring Program (ISEMP) is a scientific group working on four intensively monitored watersheds to test and evaluate methods for status and trends monitoring and effectiveness monitoring. It is hoped that the group's results will help others choose and design monitoring programs more effectively. For more information, see http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/index.cfm.

- **FCRPS Biological Opinion Work Groups**. As noted above (in Section 10.2.3.2), completion of the 2008 Biological Opinion on the operation of the Federal Columbia River Power System (FCRPS) stimulated collaboration related to RME in the Columbia Basin, including the mainstem lower Columbia River and estuary. FCRPS Biological Opinion work groups were formed and tasked with determining how best to implement the recommendations in the Biological Opinion and how to conduct related RME. These groups provide wide-reaching catalysts for RME coordination. Because these work groups are ongoing and are evaluating agency proposals for funding, they may create the impetus for future coordination of activities for the Lower Columbia subdomain.

One effort that grew out of this coordination was the Anadromous Salmonid Monitoring Strategy (ASMS). The ASMS was a collaborative process in which Columbia Basin fish management agencies and tribes had an opportunity to react to work group recommendations from the Bonneville Power Administration, U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, and other state and federal agencies that monitor anadromous salmonids and/or their habitat. This interaction led to consensus on monitoring approaches.

Of the above coordination efforts, the Anadromous Salmonid Monitoring Strategy and PNAMP Integrated Status and Trends Monitoring Demonstration Project are particularly relevant in the Lower Columbia recovery subdomain. They are described in more detail below.

10.6.1 Anadromous Salmonid Monitoring Strategy (ASMS)

The Anadromous Salmonid Monitoring Strategy (ASMS) grew out of the Columbia Basin Coordinated Anadromous Monitoring Workshop, which BPA, CBFWA, NMFS, and the NPCC convened in Skamania, Washington, in October and November 2009. The purposes of the workshop were to develop a coordinated anadromous fish monitoring strategy for the Columbia Basin, to reach agreement among participants on an efficient and effective framework for monitoring, and to outline a specific implementation strategy.

The focus of the workshop was the monitoring of population status and trends using VSP criteria, of habitat action effectiveness, and of salmon hatchery effectiveness. Attendees used general guidelines for monitoring study design and for quality standards in each of these topics (primarily these guidelines were drawn from the Crawford and Rumsey [2011] RME guidance document) and collaborated to develop a monitoring strategy for each of four regions within the Columbia Basin, including the Lower Columbia region. In developing the strategies, participants evaluated inventories of all current monitoring work and identified overlaps and gaps for VSP, habitat effectiveness, and hatchery effectiveness data. From these inventories and evaluations, they developed a final, prioritized strategy. The framework and strategy are intended to address the needs of the NPCC's Fish and Wildlife Program and the 2008 FCRPS Biological Opinion and its 2010 Supplement and to contribute to ESA recovery plan and other regional fisheries management monitoring needs.

The ASMS (available at http://www.cbfwa.org/AMS/FinalDocs.cfm) contains the following elements relevant to the Lower Columbia subdomain:

- Lower Columbia subregion monitoring strategy
- Populations targeted for habitat status and trend and fish-in/fish-out monitoring, which will be used to assess habitat action effectiveness

- Critical monitoring projects, monitoring strategy, prioritized monitoring gaps, recommendations for addressing monitoring gaps under the FCRPS Reasonable and Prudent Alternative (RPA), prioritized projects (as of 2009) to be continued as-is or with modifications, and new funding proposals and estimated costs to address monitoring gaps

Co-managers subscribing to this strategy include the Oregon Department of Fish and Wildlife and the Washington Department of Fish and Wildlife. The Lower Columbia Fish Recovery Board also participated in the discussions and subscribes to the strategy. The ASMS products helped to identify gaps in population-scale adult abundance and smolt monitoring in the Lower Columbia subdomain and to obtain funding to fill those gaps. Additional effort, coordination, and funding will be needed to complete a comprehensive monitoring program for the Lower Columbia subdomain that includes the full range of monitoring needed for this recovery plan (e.g., monitoring of population-level spatial structure and diversity, monitoring of habitat status and trends at various scales, and action effectiveness monitoring).

The general ASMS approach for the Lower Columbia subdomain is as follows:

- **Viable salmonid population criteria:** Conduct annual surveys of natural- and hatchery-origin spawner abundance at the population scale to facilitate assessment of productivity, diversity, and distribution. Conduct annual surveys of juvenile density and distribution at the stratum scale; conduct life cycle (fish-in/fish-out) monitoring in at least one subwatershed per stratum.

- **Habitat:** Conduct annual generalized random tessellation stratified (GRTS)-based habitat surveys at the stratum scale; do pre- and post monitoring at habitat restoration sites, and use intensively monitored watersheds. (An intensively monitored watershed was initiated in the Mill/Abernathy/Germany subbasin of the Lower Columbia subdomain in 2003 with funds from NMFS and the Washington Salmon Recovery Funding Board. For the IMW to be effective in meeting its goals, funding should be maintained for monitoring and for implementation of restoration treatments of sufficient scope and intensity to provide detectable fish and habitat responses.

- **Hatchery effectiveness:** Monitor the effects of segregated and integrated hatchery programs, the coded-wire tag program, relative reproductive success, natural- and hatchery-origin spawner abundance, and residualism/ecological interactions.

WDFW and ODFW currently use slightly different approaches to monitor VSP criteria, particularly adult abundance. WDFW estimates of adult abundance have been based on expansions from fish surveys or redd counts combined with mark-recapture studies or from monitoring at weirs. In most cases ODFW's current redd surveys are GRTS-based, which facilitates evaluation of the precision and certainty of the adult abundance estimates. Both agencies are working through the PNAMP Integrated Status and Trends Monitoring program (see below) to improve integration of existing and new monitoring efforts for status and trends.

10.6.2 PNAMP Integrated Status and Trend Monitoring Demonstration Project

The Pacific Northwest Aquatic Monitoring Partnership's (PNAMP) Integrated Status and Trend Monitoring (ISTM) project is intended to demonstrate approaches for and the utility of integrating the collection of information to address multi-scale questions about the status and trends of fish (ESA-listed salmon, steelhead, and, potentially, bull trout), and physical, chemical, and biological attributes in stream networks. The overall intent is to assist PNAMP's participating members in developing strategic action plans for monitoring in the bi-state lower Columbia River demonstration area, as well as to demonstrate the general approach to developing such plans for other areas in the Pacific Northwest. The ISTM effort will provide entities tasked with monitoring fish populations and aquatic habitat in the Pacific Northwest with a roadmap for integration of scientifically sound monitoring programs intended to meet the needs of decision makers and managers. Specifically, the ISTM project will apply this approach and develop recommendations for integrated monitoring plans for ESA-listed salmon and steelhead and their habitats in the Lower Columbia subdomain.

A major objective of the ISTM project is to apply a "master sample" concept to the selection of sampling locations in the Lower Columbia subdomain. The project is being accomplished using a collaborative approach that involves PNAMP members and other local partners, including LCFRB, WDFW, and ODFW, who plan to use the resulting monitoring designs in the implementation of their RME plans. The master sample concept, along with other monitoring and monitoring design tools, has broad applicability to address status and trends questions in the estuarine and near-shore marine areas (area-based master sample), in addition to the status and trends of attributes along linear stream networks.

Other goals of the program include the following:

- Develop a coordinated VSP monitoring program that addresses key regional monitoring questions in a study design of sufficient quality and quantity to determine the status of Lower Columbia River salmon and steelhead.
- Develop a habitat status and trends monitoring design for the Lower Columbia subdomain.
- Identify and prioritize decisions, questions, and objectives.
- Evaluate the extent to which existing programs align with these decisions, questions, and objectives.
- Identify the most appropriate monitoring design to inform priority decisions.
- Use trade-off analysis to develop specific recommendations for monitoring.
- Recommend implementation and reporting mechanisms.

10.7 Additional Needs for RME in the Lower Columbia

Continued challenges in the Lower Columbia subdomain relate to efforts to develop an integrated, comprehensive RME system for the subdomain that is consistent with recovery plan needs and efforts to design data management and integration systems. There is also a need for funding to adequately implement the RME recommendations of the management unit recovery plans.

10.7.1 Integrated RME Program

The overall challenge in the Lower Columbia subdomain is to continue the process begun by CBFWA and NMFS in 2009 to integrate and coordinate the many RME efforts under way and to develop a systematically designed regional RME program. Such a program will help ensure that we have the information needed to assess salmon and steelhead status and the status of habitat and other threats and to ensure that we are using resources appropriately and efficiently. Such integration and coordination efforts should occur within the context of the full range of monitoring needs identified in recovery plans.

10.7.2 Data Management and Integration

Data management and integration also continue to pose challenges in the Lower Columbia subdomain and entire Columbia Basin. Through CBFWA, a collaborative effort is under way to develop assessment and data sharing strategies for meeting regional reporting requirements within each subregion of the ASMS. This effort will also identify gaps in data management and sharing capacities and establish strategies to close those gaps. This effort will address key questions such as how data will be shared, which data dictionary will be used, and what mechanisms will be developed to ensure that consistent evaluations, calculations, and metadata are used and documented (Columbia Basin Fish and Wildlife Authority 2010).

Such a strategy is needed to ensure effective evaluation of the FCRPS Biological Opinion, effective evaluation of recovery plan implementation and progress toward the recovery of ESA-listed salmon and steelhead, and effective implementation of the anadromous salmonid elements of the Columbia River Basin Fish and Wildlife Program. If successful, this data sharing strategy will provide the framework and technical tools to allow data sharing across disparate systems from the local level to the regional level; it also will ensure that comparable data from different sources can be combined to facilitate assessment at the regional scale.

10.8 Research on Critical Uncertainties

As noted in Section 10.3, the management unit recovery plans have identified comprehensive lists of critical uncertainties and research, monitoring, and evaluation needs. The White Salmon and Washington management unit plans have discrete sections on critical uncertainties for all of the ESUs in general (see Section 8.3 of NMFS 2013, pp. 8-4 through 8-6, and Section 9.6 of LCFRB 2010a, pp. 9-68 through 9-73), while the Oregon management unit plan embeds relevant critical uncertainties within subsections on monitoring and evaluation needs related to the four VSP parameters and five ESA listing factors (see Sections 8.4 and 8.5, respectively, of ODFW 2010). In addition, in June 2010, the Lower Columbia Fish Recovery Board completed the *Research, Monitoring, and Evaluation Program for Lower Columbia Salmon and Steelhead* as a companion to its recovery plan (LCFRB 2010b). This document also describes critical uncertainties.

The species chapters of this recovery plan contain preliminary lists of priority critical uncertainties for each species (see Sections 6.6.8, 7.4.3.8, 7.5.3.8, 7.6.3.6, 8.6.8, and 9.6.7). These preliminary priorities were identified by Oregon and Washington recovery planners and NMFS Northwest Regional Office and Northwest Fisheries Science Center staff during a November 2010 workshop. They are preliminary priorities only (and are not in ranked order); additional discussion among local recovery planners and NMFS staff will be needed to finalize future research and monitoring priorities for Lower Columbia River salmon and steelhead. NMFS expects to work with management unit recovery planners to finalize research and monitoring priorities and to ensure that results are incorporated into future 5-year reviews (see Section 10.9).

The work in the management unit plans and the preliminary priorities identified in this recovery plan will provide the basis for continuing discussion of how to prioritize funds and activities for monitoring and research in the lower Columbia Basin.

10.9 RME and ESA 5-Year Reviews

The ESA requires NMFS to assess the status of listed species every 5 years. NMFS completed the most recent 5-year review in 2011 (76 *Federal Register* 50448, NMFS 2011b). NMFS will work with recovery plan implementers and other entities to link prioritization of RME efforts to products that will inform these 5-year reviews in the future.

The Oregon, Washington, and White Salmon management unit plans identify initial monitoring and evaluation actions intended to produce information needed to further refine particular strategies or to validate key assumptions behind recovery objectives. For example, the Oregon management unit plan (ODFW 2010) highlights key uncertainties regarding historical and current population structure in the Gorge strata and calls for additional analysis to refine the identification of historical population structure by the WLC TRT. The White Salmon management unit plan (NMFS 2013) highlights the need for an immediate monitoring effort to evaluate fish recolonization above the former Condit Dam site. Both the Oregon and Washington management unit plans call for a review of methods for assessing population status with the intent of improving the methods to ensure that progress toward recovery objectives can be effectively evaluated. The Oregon and Washington management unit plans also both call for developing—and periodically reviewing and updating—implementation plans for recovery actions (including RME). NMFS anticipates working with the parties involved in these efforts to prioritize and set timelines for these RME tasks to ensure that information is developed and made available for consideration during future 5-year reviews.

11. Implementation and Coordination

Recovery plan implementation involves many entities and stakeholders, and the needs for coordination are complex and occur at multiple levels. For instance, implementation and coordination needs exist at the management unit and subdomain levels and involve government entities at the federal, state, tribal, and local levels and also non-governmental entities. Coordination at the subdomain level is further complicated by the bi-state nature of the Lower Columbia subdomain, the need for coordination on issues of regional scope, and the need for close coordination with implementers of estuary recovery actions.

Coordination needs may differ depending on the type and scale of action in question. For instance, habitat actions require extensive local coordination but also coordination at the ESU or DPS level to ensure that overall recovery needs are being met. Similarly, although many funding decisions are made locally, there is a need for coordination of funding sources at the subdomain scale to ensure the most effective use of limited funds. Recovery strategies and actions related to harvest and hatcheries are another example of actions that require coordination at both state and subdomain scales and with NMFS and other entities.

In general, the management unit plans are the primary documents guiding implementation in the Lower Columbia subdomain. Coordination at the subdomain scale will occur as needed and will be achieved primarily through the Lower Columbia Recovery Plan Implementation Steering Committee, which will be the successor to the Lower Columbia Recovery Planning Steering Committee, which NMFS convened to guide development of this recovery plan and which will continue on to coordinate implementation.

This chapter presents NMFS' vision for recovery plan implementation, defines implementation responsibilities for NMFS and the management units, and describes how implementation of this recovery plan will be structured and coordinated.

11.1 NMFS' Vision for Recovery Implementation

In general, NMFS' vision for recovery implementation is that recovery plan actions are carried out in a cooperative and collaborative manner so that recovery and delisting occur (NMFS 2008d). NMFS' strategic goals to achieve that vision are as follows:

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

NMFS' approach to achieving these goals is as follows:

- Support local efforts by using domain teams to coordinate internally and externally and encourage recovery plan implementation.[1]
- Use recovery plans to guide regulatory decision making.
- Provide leadership in regional forums to develop research, monitoring, and evaluation processes that track recovery action effectiveness and status and trends at the population and ESU levels.
- Provide periodic reports on species status and trends, limiting factors, threats, and plan implementation status.
- Staff and support the Lower Columbia Recovery Plan Implementation Steering Committee

NMFS will carry out its vision, goals, and strategic approach to recovery for the Lower Columbia River ESUs and DPS by working in partnership with the Lower Columbia Recovery Plan Implementation Steering Committee and the management units.

11.2 Prioritizing Recovery Actions

Prioritizing recovery actions is an important part of implementation of this recovery plan. Although the management unit plans establish population priorities and in some cases identify specific sites or reaches for implementation of tributary habitat actions, additional prioritization work is needed at both the management unit and subdomain levels, both within and among threat categories. The sections below describe how the management unit plans approached questions of prioritization and offer perspectives for potential consideration during implementation of the recovery plan.

11.2.1 Prioritizing Populations

As described in Section 3.1.3, management unit recovery planners developed a recovery scenario for each ESU that designates individual population goals at three levels of contribution to recovery: primary, contributing, and stabilizing. Populations designated as primary need to be restored to viability and are in many ways the foundation for ESU recovery. It is likely that primary populations will be prioritized for implementation of recovery actions, and actions benefitting multiple primary populations may be given highest priority. However, the management unit plans are clear that no population is unimportant to recovery. Regardless of whether a population is designated as primary, contributing, or stabilizing, it must achieve the status designated in the recovery scenario if the ESU as a whole is to recover. Recovery actions will be needed even for those populations designated as stabilizing, to maintain them at their baseline persistence probability.

---

[1] Domain teams are an organizational structure internal to NMFS whose purpose is to coordinate recovery plan completion and implementation. The teams promote consistency in internal decision making and work with federal, state, tribal, and local recovery parties to achieve recovery plan objectives.

11.2.2 Geographic Priorities

Establishing priorities at the stream reach scale is useful in identifying and sequencing habitat protection and restoration measures. All of the management unit plans identify site-specific tributary habitat actions for recovery. The Washington management unit plan prioritized tributary habitat actions by stream reach based on the needs of all salmon and steelhead populations, collectively, within a particular subbasin. The Oregon management unit plan did some population-specific prioritization based on where an action will have the greatest beneficial effect and where implementation is most feasible, but for many Oregon subbasin additional assessment is needed to determine protection and restoration priorities at a meaningful spatial scale (ODFW 2010). The White Salmon also identifies areas as a high priority for habitat actions but points to the need for additional information to identify and prioritize specific habitat actions (NMFS 2013). In each case, the priority sites or reaches within each subbasin are not ranked against each other; rather, the management unit plans considered them to together be the highest priority areas for implementation of tributary habitat actions within each subbasin.

Oregon recovery planners determined locations for tributary habitat actions based on reach-scale habitat assessments or, when assessments were unavailable, professional judgment (ODFW 2010). For salmon and steelhead populations in subbasins that lack a reach-scale habitat assessment, the Oregon management unit plan recommends that an assessment be conducted to better define the highest priority areas for implementation of recovery actions (ODFW 2010).

Washington recovery planners used habitat assessment and modeling tools to assess the significance of each stream reach to net production of an individual species within a subbasin.[2] From this assessment, recovery planners identified high-, medium-, and low-priority reaches for each species and then placed reaches into one of four tiers, taking into consideration both the relative importance of a reach within a population and each fish population's importance relative to regional recovery objectives (LCFRB 2010a). This process yielded a four-tier, multi-species prioritization of stream reaches within each subbasin.

The White Salmon management unit plan identifies specific areas as high-priority reaches for habitat protection and restoration based on the expected distribution of salmon and steelhead species within the subbasin. Priority reaches were determined using information from current literature (NMFS 2013).

The *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) identifies priority reaches for each management action it analyzes (see Table 5-6 of NMFS 2011a). However, the estuary module refrains from explicitly prioritizing actions because it considers all of the management actions it identifies as important in improving the survival of juvenile salmonids in the Columbia River estuary and plume. The module does identify actions likely to be most beneficial to stream-type and ocean-type salmonids and actions that are most cost-effective (see Tables 7-2, 7-3, and 7-5 of NMFS 2011a); these analyses take into account the probable implementation constraints

---

[2] For more detail, see p. 3-30 of LCFRB (2010a).

for each action. The module also notes that a logical first step in implementation would be a conversation among all relevant entities and stakeholders to discuss near-term implementation priorities, with a goal of developing a 5-year implementation plan that provides specificity and certainty regarding near-term actions and that identifies lead entities for implementation of specific actions or projects.

11.2.3 Prioritizing Actions

Because the Oregon and Washington management unit plans consider all of the actions they identify as significant for recovery and thus a high priority,[3] they defer detailed prioritization of actions to the implementation phase of recovery. Many decisions about prioritization will be made in the process of developing implementation schedules (see Section 11.3.2). For Oregon populations, an implementation team is expected to develop 3-year implementation schedules that outline priorities for the upcoming years; implementing entities then will use the action priorities outlined in the implementation schedules to identify projects for implementation and seek funding for those projects (ODFW 2010). Similarly, high-priority actions for Washington populations will be identified in a series of 6-year implementation work schedules that will include schedules, costs, and constraints and identify responsibilities. The Lower Columbia Fish Recovery Board, working with a steering committee, will facilitate and coordinate efforts among oversight and implementing partners; this will include setting priorities (LCFRB 2010a). The Washington management unit plan notes that priorities are expected to evolve over time based on new information, progress in implementation, and the adaptive management process.

Both the Oregon and White Salmon management unit plans offer some guidance on how actions might be prioritized, either during the implementation phase or as an aid in identifying actions that need to be implemented immediately to reduce near-term risks. The White Salmon management unit plan recommends that projects be prioritized for funding based on a balance of biological benefit, cost, and feasibility of implementation, with the highest funding priority given to projects that address primary limiting factors, have high biological benefit, are relatively inexpensive, and are feasible (NMFS 2013). The Oregon management unit plan suggests that the following be considered high priorities as actions are identified for implementation and funding:

- Actions for populations that must achieve viability status (i.e., primary populations, which are targeted for high or very high persistence priority)
- Actions that address a threat reduction need
- Actions that address a primary limiting factor
- Actions that address a relatively large gap between baseline and target status, or that address a relatively large threat reduction need
- Actions in locations that will result in or protect accessible and connected high-quality habitat

---

[3] See p. 388 of ODFW (2010) and p. 69 of the overview to LCFRB (2010).

- Restoration actions in high intrinsic potential (IP) locations[4]
- Actions intended to protect threatened high-quality or highly productive habitat
- Actions that provide resiliency against climate change
- Actions in areas that are believed to result in a significant improvement in survival
- Actions that address those threat categories that require the most improvement[5]

For more discussion of prioritization of actions, see p. 387 of ODFW (2010).

The Washington management unit plan does not explicitly address prioritization of actions across threat categories.

11.3 Organizational Structure and Implementation Roles and Responsibilities

Effectively implementing recovery actions for Lower Columbia River Chinook and coho salmon, Lower Columbia River steelhead, and Columbia River chum salmon will require coordinating the actions of diverse private, local, state, tribal, and federal parties across two states. Coordination needs within the Lower Columbia subdomain exist at multiple levels. At the subdomain level, the Lower Columbia Recovery Plan Implementation Steering Committee (LC Steering Committee) will lead efforts to coordinate the actions of these many players, working with subcommittees and other regional forums as needed. At the management unit level, Washington's Lower Columbia Fish Recovery Board will lead implementation in the Washington management unit and the Oregon Department of Fish and Wildlife implementation coordinator and stakeholder team will lead recovery plan implementation in Oregon, supported by the governance structure of the Oregon Plan for Salmon and Watersheds. In the White Salmon subbasin, the Washington Gorge Implementation Team, coordinated by NMFS, currently is tracking progress on implementation of the White Salmon management unit plan (NMFS 2013) and will also coordinate among the multiple entities involved in implementation there. Members of the Washington Gorge Implementation Team include the Yakama Nation, state and local agencies, local conservation districts, and other entities.

Because the planning areas of the Washington and Oregon management units overlap in tidal portions of tributaries with the planning area of the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a), there is also a need for coordination between the management units and entities implementing estuary recovery actions. Finally, NMFS has a unique role in recovery plan implementation. These various coordinating forums and roles are described below.

[4] See ODFW (2010) p. 205, Table 6-39, for a description of high intrinsic potential areas.
[5] This is the only specific guidance in the management unit plans regarding prioritization of actions across the threat categories.

11.3.1 Subdomain Level: Lower Columbia Recovery Plan Implementation Steering Committee

The Lower Columbia Recovery Plan Implementation Steering Committee (LC Steering Committee) will serve as a forum for communication and coordination on a bi-state level, among management units, with entities implementing estuary recovery actions, and with other regional forums. Figure 11-1 shows the makeup of the steering committee and its relationship to other regional entities.

LC RP Implementation Framework

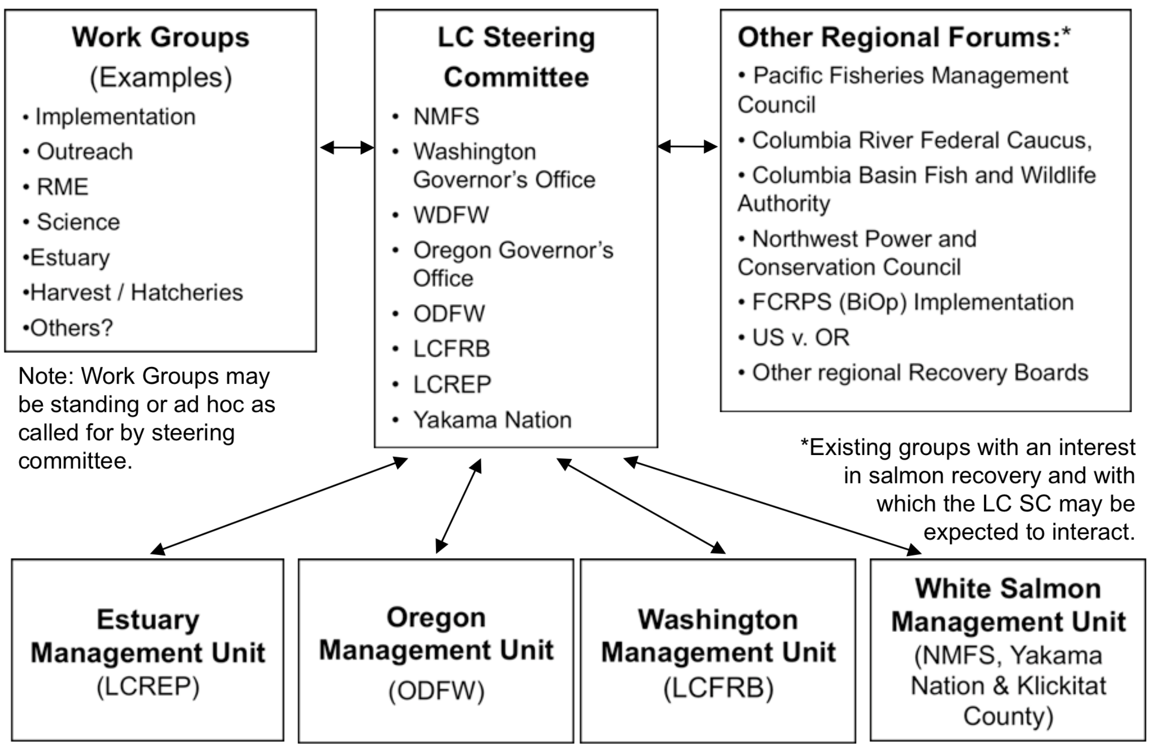

Figure 11-1. *Lower Columbia Recovery Plan Implementation Organizational Structure*

Functions of the steering committee include the following:

- Facilitating communication and coordination between states and among management units on issues related to implementation of recovery actions
- Facilitating communication and coordination with other regional entities and forums on issues related to implementation of recovery actions
- Increasing awareness of the recovery plan and advocating for implementation of recovery actions
- Providing recommendations for prioritization of recovery efforts and the use of resources
- Advancing the application of adaptive management to recovery efforts and the coordination of RME efforts

- Identifying and coordinating funding opportunities for recovery actions and RME
- Convening and overseeing issue-specific work groups as needed
- Providing an interface with the Recovery Implementation Science Team convened by NMFS

The committee will also serve as a link to other regional forums that have an interest in salmon recovery, such as the Northwest Power and Conservation Council, Columbia Basin Federal Caucus, Pacific Fisheries Management Council, and Columbia Basin Fish and Wildlife Authority.

A key related program is implementation of the Northwest Power and Conservation Council's Fish and Wildlife Program subbasin management plans. NMFS, in full coordination with management unit leads, fishery management agencies, and tribes, should ensure that the project selection process for the NPCC's subbasin plans within the management unit is consistent with the ESA priority actions in this recovery plan and the implementation schedules. The steering committee may serve as a coordinating forum for this effort.

11.3.1.1 Organization/Membership

Members of the LC Steering Committee will include, but not be limited to, NMFS, the Lower Columbia Fish Recovery Board, the Washington Governor's Salmon Recovery Office, the Washington Department of Fish and Wildlife, the Oregon Department of Fish and Wildlife, the Oregon Governor's Office, the Lower Columbia Estuary Partnership, and the Yakama Nation. Representatives of these entities constituted the steering committee during recovery plan development. As appropriate, these members may decide to include additional entities.

11.3.1.2 Operations

The LC Steering Committee will meet semi-annually or as needed. Policy issues will be resolved at the appropriate level, be it within the steering committee or within respective local, state, federal, and tribal authorities and agencies.

NMFS will serve as the convening partner and provide facilitation, venues, and other needs associated with convening meetings. Participating agencies and parties will fund their staff's involvement.

11.3.1.3 Areas of Focus

The LC Steering Committee will focus on four functional areas: (1) policy, (2) implementation, (3) research, monitoring, and evaluation, and (4) outreach. For these topic areas, the committee may establish work groups either as standing subcommittees or on an ad hoc basis. The decision to establish such subgroups will be determined based on the anticipated scope of work for each topic, LC Steering Committee members' available staffing and funding, and other considerations, as the LC Steering Committee considers appropriate. The intent of these efforts is to support coordinated and effective implementation of this recovery plan. More detail on each functional area is provided below.

Policy

The LC Steering Committee will serve as a forum for coordinating and discussing policy issues at the subdomain level. The committee may elect to organize subgroups for specific issues. Focus areas could include identifying issues where joint advocacy would support implementation or effectiveness of Lower Columbia recovery actions; providing recovery-plan perspective and input on regulatory and management decisions that affect the Lower Columbia River ESUs and DPS; tracking the status of Lower Columbia-related activities in the NPCC, Federal Caucus, FCRPS litigation, Pacific Fisheries Management Council, and other regional forums; and, as appropriate, developing policy recommendations on specific issues. Subgroups on specific issues will be convened as appropriate.

Implementation

Implementation focus areas for the LC Steering Committee will include discussing the progress of implementation progress and coordinating and resolving issues related to implementation of actions that are regional in scope. Specific implementation-related activities could include tracking the status of implementation schedules for each management unit, helping to resolve issues related to Lower Columbia River harvest and hatchery actions, sharing significant accomplishments, promoting information and technology transfer, communicating priorities for future action, and identifying opportunities where shared advocacy and coordination would help implement key recovery actions. Subgroups may be convened and will consist of staff from management unit recovery planning entities and representatives from partners in funding programs and recovery efforts.

Research, Monitoring, and Evaluation

The LC Steering Committee will ensure that RME activities are appropriately coordinated throughout the subdomain. RME activities in which the committee engages could include ensuring that new information on VSP parameters is adequately reviewed and compiled and that population status summaries are updated accordingly, identifying high-priority knowledge gaps across ESUs and coordinating efforts to address them, identifying how to track threats criteria and providing annual summaries of applicable data, and seeking efficiencies across the subdomain. The LC Steering Committee will convene subgroups on these matters as needed and appropriate.

Outreach

Activities in this focus area will include developing and/or supporting outreach related to recovery of the Lower Columbia River ESUs and DP, such as drafting or reviewing NMFS' biennial reports to Congress and updates to key decision makers (elected officials, agency heads, etc). Subgroups consisting of representatives from state governors' staffs, co-manager policy leads, management unit representatives, and/or partner agency policy staff may be convened.

11.3.2 Management Unit Level

Each management unit planning lead has proposed an organizational structure for plan implementation at the management unit level. In Oregon and Washington, this structure is based on the structure used for development of the respective management unit recovery plans. These approaches differed somewhat and will continue to differ slightly. In Oregon, the Oregon Department of Fish and Wildlife led recovery plan development with assistance from the Oregon Governor's Natural Resources Office and the Lower Columbia River Recovery Planning Stakeholder Team. During implementation, an ODFW implementation coordinator will be the lead staff person for facilitating implementation of the recovery plan. In Washington, the Lower Columbia Fish Recovery Board developed the management unit plan and will coordinate implementation with guidance and support from the Washington Governor's Salmon Recovery Office. In the White Salmon management unit, NMFS, in coordination with the Washington Gorge Implementation Team (WAGIT), has taken the lead in coordinating implementation. NMFS encourages the formation of a Washington Gorge Area Regional Board to coordinate implementation in the White Salmon management unit, if local stakeholders determine that this is appropriate.[6]

For the purposes of implementation, the term "management unit leads" (MU leads) refers to the LCFRB, ODFW (through its Lower Columbia implementation coordinator, who will work in conjunction with Oregon's recovery implementation team) and, for the White Salmon, NMFS (through the Washington Gorge Implementation Team). The MU leads have three primary responsibilities with respect to implementation:

1. Developing implementation schedules. Each MU lead is responsible for developing an implementation schedule for that MU plan and updating the schedule as needed. Implementation schedules identify the following:

    - Recovery projects specific to plan actions for populations within the management units
    - Limiting factor(s) addressed by each project
    - Priority for completing the projects
    - Duration of and schedule for projects
    - Benefits of each project
    - Lead agency/entity to implement each population-specific project
    - Estimated cost for each project over a period of time

2. Coordinating implementation. Management unit leads are responsible for coordinating implementation of recovery actions identified in the management unit plan and implementation schedule. In this capacity, they serve to facilitate communication vertically (i.e., at different spatial scales related to recovery plan governance) and horizontally (i.e., among related programs and interests and outside of the recovery plan governance structure) within their respective inter-

[6] The Washington Gorge Area Regional Board could consist of representatives from Klickitat, Skamania, Yakima, and Benton counties, local landowners, the Yakama Nation, and possibly others. Such a board could also coordinate with the LCFRB.

and intra-agency organizational structures. Specific responsibilities include the following:

- Coordinating with federal and state agencies, tribes, local governments, and other stakeholders
- Developing implementation strategies for and facilitating implementation of actions that require coordination among various entities. Potential activities include local outreach; provision of incentives, technical assistance, and project funding; project management; and monitoring/reporting.

3. Tracking and reporting. Management unit leads are responsible for tracking and reporting on the progress of implementation of their plan actions. Specific responsibilities include:
    - Coordinating plan monitoring within the management unit and ensuring appropriate tracking and reporting of recovery actions
    - Coordinating plan research within the management unit, reporting results, and incorporating them into adaptive management.
    - Reporting on plan progress in relation to goals, strategies, and actions, using mechanisms and processes established for tracking progress, and highlighting plan successes and needs
    - Reviewing and revising the management unit plan implementation schedule as necessary, using monitoring and research to guide actions and incorporating adaptive management as needed
    - Representing the management unit in the LC Steering Committee and relevant subgroups as necessary

Performance of these responsibilities will be influenced by the capacity, authority, and priorities of the management unit leads. Full accomplishment will likely require other support structures or processes. Not all of these duties can be accomplished initially with the resources currently available. Prioritization of initial duties will be guided by the statutory requirements of the ESA and relevant state guidance.

11.3.2.1 Oregon

Oregon's recovery plan implementation framework is intended to provide a collaborative approach to implementation, along with scientific guidance, policy direction, information exchange and coordination, and linkage to state, ESU, and regional forums. Existing forums, groups, and partnerships will serve as the basis of Oregon's implementation framework, but additional resources and funding will be needed to make it work effectively and successfully. The basic components of Oregon's implementation structure include a recovery team, an implementation coordinator, an implementation team, a technical team, and stratum teams. The implementation framework will adapt and change as necessary to adjust to funding, available resources, and implementation needs (ODFW 2010). Oregon's implementation structure is illustrated in Figure 11-2 and described below.

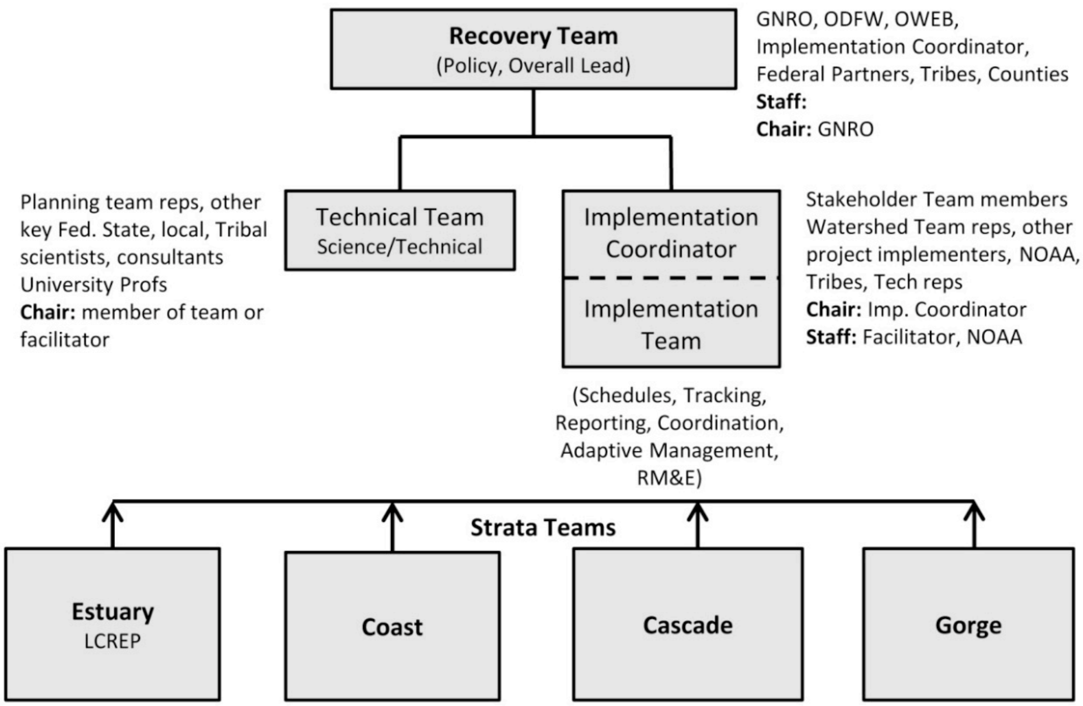

Figure 11-2. *Oregon's Organizational Implementation Structure*

Recovery Team

The recovery team provides oversight and vision for recovery plan implementation. This team is responsible for reporting to NMFS and shares accountability for species recovery in the Oregon management unit. The recovery team provides overall coordination and guidance to the technical and implementation teams, coordinates with other domain teams and the Oregon Plan core team, and serves as the state's representative to the LC Steering Committee. Members of the recovery team include the ODFW implementation coordinator and representatives from the Oregon Governor's Natural Resources Office, ODFW, the Oregon Watershed Enhancement Board, federal agencies, and local and tribal governments. Additional membership will include interested parties from counties, federal agencies, and non-governmental organizations. Although the recovery team serves a unique purpose and function, its members will also be on the implementation team (ODFW 2010).

Implementation Coordinator

An ODFW implementation coordinator will serve as Oregon's management unit lead for recovery plan implementation, acting under the advice and guidance of the recovery team. The implementation coordinator will work in conjunction with the implementation and stratum teams to plan, schedule, track, and report on action implementation, and—in coordination with technical teams—to develop, track, and report on RME activities. The implementation coordinator will also be a member of the recovery team. The implementation coordinator will lead the implementation team in its deliberations and actions, coordinate and lead development of 3-year implementation schedules and adaptive management processes, coordinate and communicate with watershed teams (or individual implementation entities) and the Oregon Plan regional management teams (interagency regional manager forum), and coordinate implementation of actions for which ODFW is responsible. The coordinator will also ensure that ODFW staff engaged in regional forums for hydropower, harvest, and hatchery issues (including the FCRPS Biological Opinion, *U.S. v. Oregon*, Northwest Planning and Conservation Council, and Columbia Basin Fish and Wildlife Authority) understand the content and priorities of the recovery plan so they can advocate for and use it in those forums. Actions and decisions within these forums are important in successfully implementing the recovery plan and achieving recovery of Lower Columbia River salmon and steelhead (ODFW 2010).

Implementation Team

The implementation team provides advice, recommendations, and support to the implementation coordinator, who chairs the team. The team assists in communicating and coordinating with the stratum teams or local implementation groups; developing, tracking, and reporting on 3-year implementation plans; and tracking and reporting on research and monitoring. The implementation team also facilitates the collection and exchange of information, identifies and pursues funding sources, and provides for public participation, education, and outreach.

Implementation team members include members of the LCR Stakeholder Team (i.e., cities, utilities, private forest and agriculture representatives, conservation groups, federal representatives, watershed councils, and soil and water conservation districts), other local stakeholders, interest groups, and tribes and other governments. This diverse group represents differing perspectives, missions, and geographic areas, with the overall objective of collectively and synergistically working to achieve and advance recovery plan goals. NMFS will also participate on the implementation team (ODFW 2010).

Technical Team

The Oregon Technical Team will provide advice and guidance on technical and scientific issues related to RME, data analysis, and adaptive management that support and strengthen effective implementation of recovery plan actions. The technical team will be ad hoc and provide advice and guidance supplemental to that provided by the Oregon Plan Monitoring Team, which is an interagency monitoring forum. The technical team may include members of Oregon's recovery planning team and expert panel, as well as other key state, federal, tribal, utility, and private scientists and biologists, consultants, and university staff as appropriate for the particular issue needing their advice and guidance. A voluntary chair will facilitate team operations (ODFW 2010).

Stratum Teams

Stratum teams will be composed of the various local entities that implement local restoration and conservation actions via their respective authorities, mandates, missions, and work plans and will include watershed councils, soil and water conservation districts, federal and state agencies, local governments, tribes, conservation groups, and utilities. Stratum teams will be encouraged to form on a voluntary basis for a specific stratum or may already exist. In many cases, watershed councils currently serve this function, with representation from a diversity of interest and action groups. Team chairs will be voluntary, and teams will be self-directed. Collaborative teams will facilitate coordination and prioritization of actions and the exchange of information within the stratum. They will provide project information to the implementation coordinator (or members of the implementation team) to support development of 3-year implementation schedules, plans, and reports. Collectively or individually, stratum teams will promote public involvement through outreach, education, and volunteer opportunities (ODFW 2010).

11.3.2.2 Washington

The Lower Columbia Fish Recovery Board will be the lead for implementation of the Washington management unit plan, which notes that achieving recovery will require the combined and coordinated actions of other federal and state agencies, tribal governments, and local governments, along with participation of nonprofit organizations, the business sector, and citizens. Collectively, these parties are referred to as implementing partners (LCFRB 2010a). The LCFRB organizational structure for implementation focuses on fulfilling three main functions: oversight, facilitation/coordination, and implementation. This structure is described below and illustrated in Figure 11-3.

Oversight Authorities and Functions

Key oversight bodies are entities with specific authority or responsibilities for managing the region's fish and wildlife resources. These include NMFS, the U.S. Fish and Wildlife Service, the state of Washington, the Cowlitz Tribe, the Yakama Nation, and the Northwest Power and Conservation Council.[7]

- NMFS has the primary federal authority for the Endangered Species Act, Sustainable Fisheries Act, and Mitchell Act as they apply to salmon and steelhead.
- The Washington Governor's Office has the authority to direct and coordinate state agency actions in support of recovery. The Washington Department of Fish and Wildlife has management authority for the state's fish and wildlife resources.
- The Yakama Nation is a co-manager of fish resources with the state and federal agencies.
- The Northwest Power and Conservation Council oversees implementation of the program to address the effects of the Federal Columbia River Power System on fish and wildlife.

[7] Because the scope of the Washington management unit plan is broader than just salmon and steelhead and includes bull trout, among other species for which the U.S. Fish and Wildlife Service has jurisdiction, that agency is included among the implementing and oversight entities for the Washington management unit plan.

Other federal, state, and local agencies have oversight responsibilities for water, natural resources, land management, and land use. These agencies are considered implementation partners because their responsibilities are not specific to fish management.

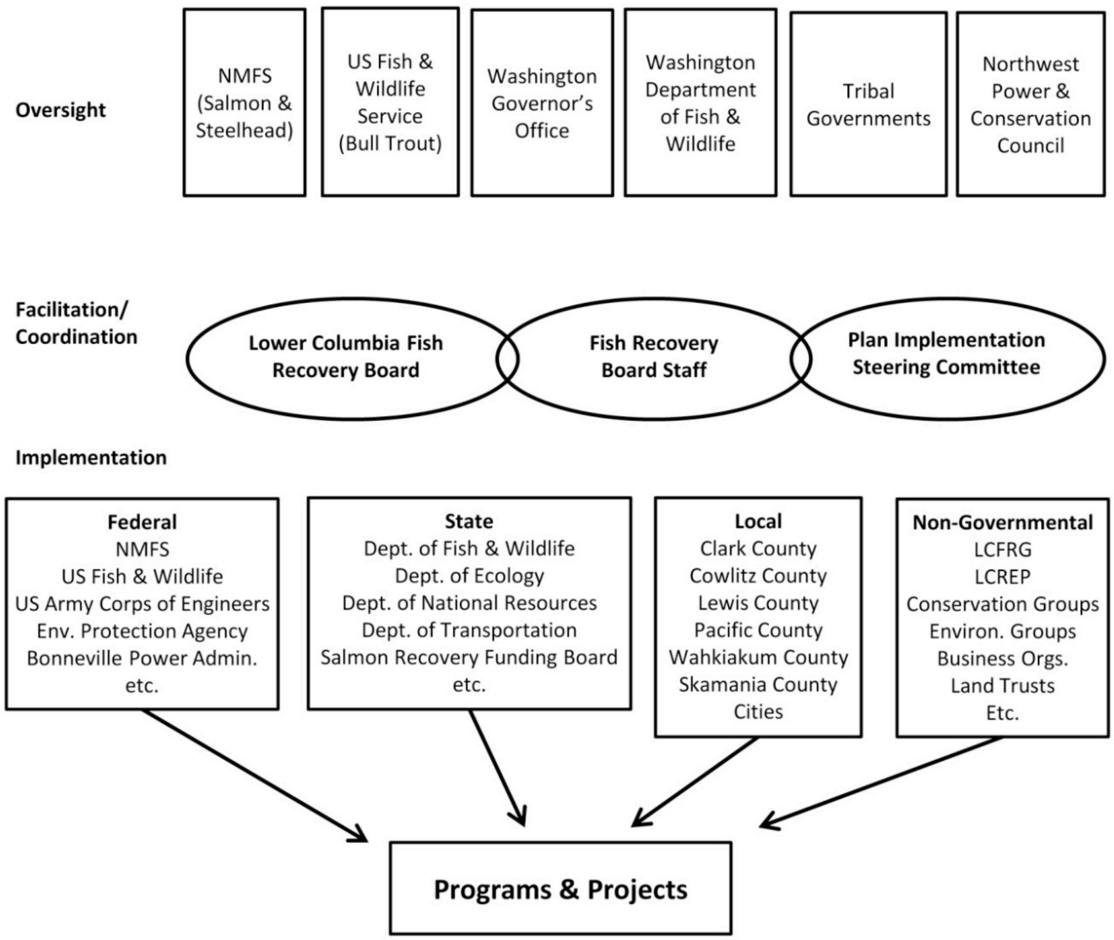

Figure 11-3. *Institutional Structure for Implementing Salmon Recovery in Washington Lower Columbia River Subbasins*

Implementation Steering Committee and Functions

The Lower Columbia Fish Recovery Board, working with a plan implementation steering committee, will facilitate and coordinate efforts of the oversight bodies and implementing partners. NMFS and the U.S. Fish and Wildlife Service, Northwest Power and Conservation Council, Lower Columbia Estuary Partnership, Washington Department of Fish and Wildlife, Governor's Salmon Recovery Office, Washington Department of Ecology, U.S. Forest Service, counties, Cowlitz Indian Tribe, Yakama Nation, Chinook Tribe, and others will be invited to participate on the committee. The steering committee will assist the LCFRB in guiding implementation of the plan.

The steering committee will include representatives of the oversight bodies and a cross-section of implementing partners. Working groups consisting of steering committee members and other implementing partners will be established as needed to address policy or technical issues or to coordinate implementation efforts.

Key functions of the LCFRB and steering committee are as follows:

- Develop and revise a 6-year regional implementation plan.
- Assist implementation partners in developing and implementing their individual 6-year implementation plans.
- Prepare and issue clarifications or interpretations of recovery plan provisions when needed.
- Prepare and issue revisions or updates to the Washington management unit plan.[8]
- Develop and implement the regional public education and outreach program.
- Conduct implementation and biological evaluations in accordance with the adaptive management provisions and benchmarks set forth in this plan.
- Track implementation of measures, actions, programs, and projects and issue annual progress reports.
- Facilitate and assist partners in resolving technical and policy issues that arise during implementation.
- Facilitate communications and the exchange of information and data among implementation and oversight partners.
- Coordinate the collection, management, synthesis, and evaluation of fish and habitat monitoring results collected by the partners.
- Develop implementation partnerships and agreements.

Implementing Partners

Recovery actions will be implemented through the programs and projects of numerous implementing parties, some of which are shown in Figure 11-3. The functions of the implementing partners are as follows:

- Develop and implement a 6-year plan for their recovery actions.
- Monitor and report on their implementation progress to the LCFRB/steering committee.
- Advise the LCFRB/steering committee of issues or developments that affect progress.

Each partner will set forth the tasks and schedule addressing assigned recovery actions and will document the partner's commitment to fulfilling its implementation

---

[8] NMFS would need to formally incorporate any substantial revisions to a management unit plan into this ESU-level recovery plan.

responsibilities in 6-year implementation work schedules (see Section 11.4, "Implementation Time Frames").

The actions identified for each partner are based on the partner's mission, capabilities, responsibilities, authority, and jurisdiction. Each partner is responsible for developing and fully implementing programs to address its assigned actions. Programs are expected to be technically sound and adequately funded and staffed. In the case of regulatory programs, agencies must be committed to taking enforcement actions when necessary to achieve the desired outcome.

In some instances an implementing partner may not have the full or exclusive authority to implement a recovery action. A case in point is the setting of harvest quotas pursuant to international treaty provisions. In such instances, implementing partners will share an implementation responsibility to cooperate in working to achieve the desired outcome.

If needed for coordination, the implementation steering committee may designate a lead agency in carrying out an implementation action shared by two or more partners. Even where a single implementing partner possesses the authority to fully implement a recovery action, the action is likely to be more effectively implemented with the involvement, agreement, and support of other partners.

To achieve this level of cooperation and coordination, implementing partners are requested to identify in their 6-year implementation work schedules interrelationships with other partners that will facilitate, affect, or complement implementation of their recovery actions.

11.3.2.3 White Salmon

NMFS, in conjunction with the Washington Gorge Implementation Team (WAGIT), is coordinating recovery plan implementation in the White Salmon subbasin. Implementation is being facilitated through the various existing programs, including harvest management programs, the Yakama Nation Fish Habitat Program, Washington's Lead Entity Process, watershed planning and implementation processes initiated under state regulations and coordinated through Klickitat County, various state and local habitat and watershed programs, and the various programs administered by the conservation districts. The WAGIT draws upon and works within the many existing programs rather than developing a parallel and potentially conflicting recovery implementation process.

11.3.3 NMFS' Role

NMFS' role in the recovery of Lower Columbia River ESUs is twofold. The first is to ensure that the agency's statutory responsibilities for recovery under the ESA are met. The second is to serve as the convening partner for the LC Steering Committee, provide leadership in coordinating among management units, provide NMFS' perspective regarding recovery plan implementation, and update steering committee members on issues relevant to recovery strategies.

11.3.3.1 ESA Responsibilities

NMFS is required to see that the agency's statutory responsibilities for recovery under the ESA are met. In this capacity, NMFS is responsible for the following:

- Ensuring that the recovery plan meets ESA statutory requirements, tribal trust and treaty obligations, and agency policy guidelines
- Developing ESU-wide performance measures consistent with the recovery strategies outlined in Chapters 6 through 9
- Conducting 5-year reviews
- Making delisting determinations
- Coordinating with other federal agencies to ensure compliance under the ESA
- Implementing recovery plans

11.3.3.2 LC Steering Committee Convening Partner

As the convener of the LC Steering Committee, the NMFS Northwest Regional Office, working through its Lower Columbia Recovery Coordinator and Domain Team, will do the following:

- Convene steering committee meetings on a regular basis (at least twice a year) and convene additional meetings as needed.
- Provide meeting facilitation services and manage the meeting process.
- Provide meeting venues.
- Prepare and distribute meeting notes and follow up on tasks agreed to by the steering committee.
- Serve as a central clearinghouse for information, to include ESU- or DPS-wide stock status, relevant federal scientific research, and gaps in recovery efforts for each ESU or DPS.
- As requested by the LC Steering Committee, establish and facilitate state, federal and tribal meetings necessary for the coordination of recovery activities.

11.3.4 Columbia River Estuary

The planning areas of the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) and the Oregon and Washington management unit plans overlap in the tidal reaches of the lower Columbia tributaries. The geographic overlap and the importance of improvements in intertidal rearing habitats for the recovery of some Lower Columbia River salmon and steelhead populations create a need in this subdomain for close coordination of estuary module implementation with implementation of the management unit plans.

Although not an officially designated management unit, the Columbia River estuary and plume, for implementation purposes, will be treated like a management unit. The Lower

Columbia Estuary Partnership and PC Trask and Associates, Inc., developed the estuary module under contract to NMFS.

Implementation of the 23 management actions in the module will require the efforts of a variety of federal, state, and local agencies, nonprofit organizations (such as watershed councils), private enterprises, and citizens. (Some potential implementers have been identified in Table 5-6 of the estuary module.) Although many of these entities have already been working to identify, prioritize, and implement salmon and steelhead recovery actions in the estuary and plume, effective implementation of all module actions will require additional coordination.

The first step in coordinated implementation of the module will be a conversation among all relevant entities and stakeholders to discuss near-term implementation priorities, with a goal of developing a 5-year implementation plan that provides specificity and certainty regarding near-term actions and that identifies lead entities for implementation of specific actions or projects. Given the complexities involved in implementing the full suite of module actions, this conversation also will be an opportunity to explore options for and recommend an organizational structure for coordinating and overseeing implementation of the estuary module. The Lower Columbia Estuary Partnership, a National Estuary Program established to bring about collaboration, would be an appropriate convener of this discussion.

11.4 Implementation Time Frames

The Oregon and Washington management unit plans are 25-year plans that schedule actions throughout that time frame. The estuary recovery plan also uses a 25-year time frame for implementing its 23 management actions. The White Salmon management unit plan uses a 10-year implementation time frame for planning purposes; however, the rate of change in the river now that PacifiCorp has removed Condit Dam may affect this timeline.

11.4.1 Oregon Management Unit Plan

In the Oregon management unit plan, many recovery actions are on 5-, 10-, 15-, 20-, and 25-year schedules. For priority actions, the plan requires 3-year implementation schedules with review and modifications, if needed, every 3 years. Members of the implementation team, watershed councils, and other implementing groups are encouraged to commit to the 3-year implementation schedule. Stratum teams, watershed councils, soil and water conservation districts, cities, counties, land managers and other implementers will use the action priorities outlined in the 3-year schedules to identify projects for implementation and to seek funding.

An implementation coordinator will develop a reporting process for gathering information from implementers, including government and funding entities, to develop annual reports on plan implementation that will be shared with implementers; funding entities; the implementation, recovery, and Oregon Plan teams; and the public. Annual reports will be used to assess the effectiveness of implementation at the population and ESU level. The implementation team will periodically (i.e., quarterly or annually) review progress toward implementation of priority actions and address local needs for more effective implementation. A major revision of the Oregon plan is called for after 12 years.

11.4.2 Washington Management Unit Plan

The Washington management unit plan calls for new implementation schedules to be prepared at 6-year intervals. This cycle will coincide with the 6-year adaptive management checkpoints and allow the schedules to incorporate needed modifications. Six-year schedules may be revised every 2 years based on the adaptive management implementation evaluation checkpoint.

Entities or partners already carrying out recovery actions will be asked to prepare an implementation schedule for their actions. These individual implementation work schedules will be melded into a regional implementation schedule. The LCFRB, in consultation with its steering committee, will develop a detailed template for 6-year implementation work schedules and will assist and advise partners in developing their schedule. The 6-year implementation work schedules submitted by each partner will set out tasks and schedules for addressing assigned recovery actions and document the partner's commitment to fulfilling its implementation responsibilities.

11.4.3 White Salmon Management Unit Plan

In the White Salmon management unit, the Washington Gorge Implementation Team (WAGIT) has developed a detailed implementation plan. The WAGIT meets annually to update information on ongoing actions and make recommendations regarding next steps. The annual meeting includes discussion of information gained through research, monitoring, and evaluation that will help in identifying priority recovery projects, facilitating efficient implementation of the White Salmon management unit plan, or identifying needed modifications in the plan. The implementation plan will be updated annually to reflect changes in understanding of within-subbasin processes affecting salmonid production and of the extent to which recolonization is occurring. The plan also will be updated to reflect actions initiated or completed in the prior year. Klickitat County maintains a database that tracks projects in the White Salmon subbasin.

11.4.4 Columbia River Estuary Recovery Plan Module

The *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) includes a schedule for implementing the 23 management actions and each action's component projects. Schedule considerations are based primarily on the specific actions and the timing of component projects that depend on other projects. According to the estuary module, "developing a critical path for implementation of actions collectively is premature." A more comprehensive schedule will require knowing the level of effort and funding that will be committed to carrying out the management actions. The plan also notes the difficulties associated with establishing time frames when some of the actions in the 25-year plan may take decades to produce measurable effects.

11.4.5 NMFS Time Frames

NMFS is required to review the status of listed species every 5 years, prepare biennial reports to Congress, and update key decision makers, such as elected officials and agency heads.

12. Site-Specific Management Actions and Cost Estimates

ESA section 4(f)(1)(B) directs 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" and "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."

Detailed information on management actions, schedules, and cost estimates are presented in the Washington, Oregon, and White Salmon management unit plans and the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (LCFRB 2010a, ODFW 2010, NMFS 2013, and NMFS 2011a; see Appendixes A through D). This chapter summarizes the information contained in those documents.

12.1 Site-Specific Management Actions

The management actions presented in the management unit plans are designed to address the limiting factors and threats to species and populations found in each management unit's respective geographic area of responsibility. Site-specific management actions are discussed in detail in the appended management unit plans. Site-specific actions with respect to the Columbia River estuary and plume, passage at Bonneville Dam, predation, and flow affecting conditions in the lower Columbia River, estuary, and plume are described in the 2008 FCRPS Biological Opinion (NMFS 2008f), its 2010 Supplement (NMFS 2010a), the recovery plan hydropower module (NMFS 2008a), and the estuary module (NFMS 2011a). The management actions presented in each management unit plan and the estuary module are summarized in the subsections below. In addition, Table 12-1 presents actions that are representative of the types of site-specific actions in the management unit plans (i.e., in Chapters 7, 8, and 9 of ODFW 2010, Chapters 5 and 10 of LCFRB 2010a, and Chapter 6 of NMFS 2013). The management unit leads will develop more detail on management actions during preparation of the implementation schedules described in Chapter 11 of this recovery plan.

Table 12-1
Representative Recovery Actions

Threat Category	Representative Actions	Limiting Factors Addressed
Tributary Habitat	• Restore degraded off-channel habitats • Streamline delivery of large wood to restoration sites • Restore degraded riparian areas through planting or fencing	Channel structure and form: Bed channel and form
	• Restore riparian areas to improve water quality, provide long-term supply of large wood to streams, and reduce impacts that alter other natural processes	Channel structure and form: Instream structural complexity
	• Place gravel for spawning (below dams) • Remove the Little Sandy River diversion (completed)	Sediment conditions and water quality[1]: Decreased sediment quantity (impaired sediment/sand routing and gravel recruitment)
	• Conduct sediment source analyses and reduce inputs • Develop/implement stormwater management plans for urban areas and roads • Identify and rectify problem legacy roads	Sediment conditions and water quality: Increased sediment quantity (turbidity from excessive fine sediment)
	• Protect intact riparian areas via easements and acquisition • Explore cooperative water conservation measures • Restore connectivity to small tributaries • Restore degraded off-channel and riparian habitat • Establish minimum ecosystem-based instream flows • Identify and halt illegal water withdrawals	Water quantity: Altered hydrology Water quantity: Decreased water quantity/downstream flows Water quantity: Altered flow timing
Estuary habitat	• Protect intact riparian areas in the estuary and restore riparian areas that are degraded • Protect remaining high-quality off-channel habitat from degradation and restore degraded areas with high intrinsic potential for high-quality habitat • Breach, lower, or relocate dikes and levees to establish or improve access to off-channel habitats • Reduce the export of sand and gravels via dredge operations by using dredged materials beneficially • Reduce entrainment and habitat effects resulting from main- and side-channel dredge activities and ship ballast intake in the estuary	Peripheral and transitional habitats: Estuary habitat quality (complexity and diversity) Peripheral and transitional habitats: Reduced macrodetrital inputs

[1] The data dictionary and limiting factors crosswalk consider turbidity as a subcategory of the water quality limiting factor and thus separately from sediment conditions, but the two limiting factors are presented together in this table because their mechanisms, causes, and effects in the lower Columbia River basin are so similar.

Threat Category	Representative Actions	Limiting Factors Addressed
	• Operate the hydrosystem to reduce the effects of reservoir surface heating, or conduct mitigation measures	Peripheral and transitional habitats: Estuary habitat quality (complexity and diversity) Peripheral and transitional habitats: Increased microdetrital inputs Water quality: Temperature
	• Protect or enhance estuary instream flows influenced by Columbia River tributary/mainstem water withdrawals and other water management actions in tributaries • Adjust the timing, magnitude, and frequency of flows (especially spring freshets) entering the estuary and plume to better reflect the natural hydrologic cycle, improve access to habitats, and provide better transport of coarse sediments and nutrients in the estuary and plume	Water quantity: Altered hydrology Habitat quantity: Anthropogenic barriers
	• Study and mitigate the effects of entrapment of fine sediment in reservoirs, to improve nourishment of the estuary and plume	Sediment conditions: Decreased sediment quantity
	• Reduce the square footage of over-water structures in the estuary • Reduce the effects of vessel wake stranding in the estuary	Peripheral and transitional habitats: Estuary habitat quality (complexity and diversity)
	• Implement pesticide and fertilizer best management practices to reduce estuarine and upstream sources of nutrients and toxic contaminants entering the estuary • Identify and reduce terrestrially and marine-based industrial, commercial, and public sources of pollutants • Restore or mitigate contaminated sites • Implement stormwater best management practices in cities and towns	Toxic contaminants in water and biota Water quality: Temperature
Hydropower	• Remove the Little Sandy water diversion (completed), Powerdale Dam on the Hood River (completed), and Condit Dam on the White Salmon River (completed) • Implement measures in the 2008 FRCRPS BiOp and its 2010 Supplement to improve adult and juvenile passage at Bonneville Dam • Maintain screens and fish passage structures • Reintroduce coho and spring Chinook salmon and winter steelhead upstream of tributary dams in the upper Cowlitz and North Fork Lewis subbasins (per FERC relicensing agreements) • Develop, maintain, and operate effective juvenile and adult passage facilities in the Cowlitz and Lewis subbasins	Habitat quantity: Access (anthropogenic barrier)

Threat Category	Representative Actions	Limiting Factors Addressed
	• Operate the hydro system in the North Fork Lewis and Cowlitz subbasins to provide appropriate flows for spawning and rearing habitat in areas downstream of the hydro system (i.e., maintain a flow regime that includes minimum flow requirements) • Maintain adequate water flows in Bonneville Dam tailrace and downstream habitats throughout salmon migration, incubation, and rearing periods	Water quantity: Altered hydrology
	• Implement PGE's FERC agreement for the Clackamas River Hydroelectric Project (includes downstream passage measures, placement of spawning gravel below River Mill Dam, and habitat mitigation and enhancement)	Habitat quantity: Access (anthropogenic barrier) Sediment conditions: Decreased sediment quantity Channel structure and form: Bed and channel form Channel structure and form: Instream structural complexity
	• Restore or create off-channel habitat or access to off-channel habitat (includes revegetation)	Water quantity: Altered hydrology Peripheral and transitional habitats: Side channel and wetland conditions Peripheral and transitional habitats: Floodplain condition Peripheral and transitional habitats: Estuary conditions Riparian condition, including large wood recruitment Water quality: Water temperature Toxic contaminants
	• Restore instream habitat complexity, including large wood placement	Channel structure and form: Bed and channel form Channel structure and form: Instream structural complexity
Hatcheries	• Maintain existing wild fish sanctuaries and limit hatchery-origin spawners to levels consistent with the target status of each population • Coded-wire tag enough fish from each hatchery to allow identification of the hatchery program of origin • Mark all hatchery-origin steelhead and coho and Chinook salmon (to facilitate mark-selective fishing) • Change acclimation or release strategies to reduce straying • Reduce or eliminate some hatchery releases • Shift some hatchery production to programs further downstream • Make use of conservation hatchery programs for reintroduction or supplementation; identify appropriate time period, stock, timing, and strategies • Integrate wild broodstock into hatchery programs • Provide or improve fish passage at hatcheries (and at road, railroad and I-84 crossings)	Population diversity: Impaired productivity and diversity

Threat Category	Representative Actions	Limiting Factors Addressed
Harvest	• Broaden the use of mark-selective fishing methods (e.g., develop new gear and methods for commercial fishing) • Refine the coho harvest matrix to ensure that it adequately accounts for weaker components of the ESU • Develop an abundance-based harvest approach for fall Chinook • Continue to review harvest rates and base future rates on observed indicators in populations • Manage Columbia River fisheries by time, area, and gear to target hatchery fish • Fill information gaps regarding hatchery-origin spawner escapement, natural productivity, and harvest impact rates	Direct mortality: Harvest
Ecological Interactions	• Redistribute nesting tern colonies in the Columbia River estuary • Reduce double-crested cormorant habitat in the Columbia River estuary and encourage dispersal to other locations • Reduce pinniped predation on salmon and steelhead • Manage pikeminnow and other piscivorous fish to reduce predation on salmonids (e.g., modify habitat, increase pikeminnow bounty program) • Evaluate ecological interactions between hatchery-origin and natural-origin salmon and steelhead in the Columbia River estuary	Direct mortality: Predation
	• Implement regulatory, control, and education measures to control introduced, invasive, or exotic species and prevent new invasions	Direct mortality: Predation, pathogens Food: Competition Food: Altered prey composition and diversity

12.1.1 Washington Management Unit Plan

The Washington management unit plan identifies 117 strategies (see Chapter 5, "Strategies and Measures," of LCFRB 2010a) and 365 actions (see the table in Chapter 10, "Implementation," Section 10.9, of LCFRB 2010a) that address threats in the following general categories:

- Tributary habitat
- Estuary/mainstem habitat
- Hydropower
- Harvest
- Hatcheries
- Ecological interactions (including predation)
- Climate and ocean conditions

These include the 23 actions called for in the *Columbia River Estuary ESA Recovery Plan Module* (NMFS 2011a). All actions are expected to be completed within 25 years, although the effects of the actions may not be realized for some time thereafter.

Management actions in the Lower Columbia Fish Recovery Board's geographic area of responsibility are discussed further in Chapters 5 and 10 ("Strategies and Measures" and "Implementation") of LCFRB (2010a).

12.1.2 Oregon Management Unit Plan

Like the Washington management unit plan, the Oregon management unit plan (ODFW 2010) orients its actions around threat categories. Actions are identified in the management unit plan—and costs estimated—for the following general categories of threats:

- Tributary habitat, including habitat protection and restoration
- Harvest
- Hatchery effects
- Predation

The Oregon management unit plan identifies 14 strategies and 308 management actions (see Tables 7-1, 7-3, and 9-3 in ODFW 2010). Of the 308 actions, 23 are actions called for in the estuary module (NMFS 2011a), and 18 are reasonable and prudent alternative actions brought forward from the 2008 FCRPS Biological Opinion (NMFS 2008f). All actions are expected to be completed within 25 years, although the effects of the actions may not be realized for some time thereafter.

Management actions in Oregon are discussed further in Chapters 7, 8, and 9 ("Strategies and Actions" "Research, Monitoring, and Evaluation," and "Implementation") of ODFW (2010).

12.1.3 White Salmon Management Unit Plan

The strategy for recovery actions in the White Salmon River consists of seven fundamental components:

- Assessment of pre-dam removal fish populations and habitat conditions
- Removal of Condit Dam
- Reintroduction of fish into the reaches formerly blocked by Condit Dam
- Assessment of actions needed for recovery once the dam is removed
- Habitat restoration of the reaches located under the current reservoir (Northwestern Lake) and below Condit Dam
- Habitat restoration in the reaches above Northwestern Lake to support reintroduced fish
- Assessments and monitoring of conditions to determine whether implemented actions are working and sufficient

The removal of Condit Dam is central and essential to the White Salmon recovery strategy. The decision to decommission the dam was made by the dam's owner (PacifiCorp) after comparing the benefits of continued operation with the cost to install fish ladders as proposed during relicensing negotiations with the Federal Energy Regulatory Commission. The dam's removal is considered a baseline action because it is not an action called for under the recovery plan and would occur regardless. Its removal presents an opportunity to reintroduce salmon into historical habitat blocked by the dam's original construction. The White Salmon plan's strategy and recovery management actions cannot succeed without the dam being removed.

The White Salmon management unit plan (NMFS 2013) identifies 14 strategies (see Table 6-1 of NMFS 2013) and 52 management actions (see Table 7-2 of NMFS 2013). Assessments will further inform actions needed for recovery. The majority of actions will be implemented within 5 years of removal of Condit Dam, which took place in September 2012. Additional actions may be identified after that time period, depending on the results of monitoring and evaluation activities. Recovery of the species in the White Salmon subbasin is expected to occur over decades. Natural recolonization is the preferred reintroduction option for spring Chinook, coho, and chum, while reintroduction using hatchery-origin adults is the preferred option for fall Chinook.

Management actions for the White Salmon subbasin are discussed further in Chapters 6 and 7 ("Recovery Actions and Strategies" and "Implementation and Cost Estimates") of the White Salmon management unit plan (NMFS 2013).

12.1.4 Estuary Module

The *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) presents 23 management actions or strategies, each supported by two to five programmatic "conceptual-level projects" (see Table 5-1 of NMFS 2011a). All actions are expected to be completed within 25 years, although the effects of the actions may not be realized for some time thereafter. Many of these actions and strategies call for a methodical approach of data collection, study, and careful design before projects are implemented on the ground so as to provide the maximum assurance that the actions implemented will be biologically effective. Consequently, the scope and nature of a project could change as better information is collected.

Because the actions in the estuary module have basinwide scope and are expected to benefit all 13 listed ESUs and DPSs in the Columbia Basin, the estuary module is incorporated by reference into all Columbia Basin salmon and steelhead recovery plans. For more information on management actions in the Columbia River estuary and plume, see Chapter 5 of the estuary module (NMFS 2011a).

12.2 Cost Estimates

This section provides 5-year and total cost estimates as called for under ESA and NOAA Interim Recovery Planning Guidance, version 1.3, dated June 2010.

Cost estimates for recovery projects were provided by the management unit planners where information was sufficient to allow reasonable estimates to be made. In some cases this was done in coordination with a NMFS economist at the Northwest Fisheries Science Center in Seattle and with input and review from in-house and/or regional experts.

Recovery planners developed cost estimates for recovery actions using the methods described in each management unit plan and summarized below. Although some management unit plans display the cost of baseline actions because they are necessary for recovery,[2] the costs of baseline actions are not included in the cost estimates.

Administrative costs are treated differently in each management unit plan. The administrative costs for actions identified in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) are embedded in the action cost estimate. The Washington management unit plan addresses administrative coordination, direction, and tracking as line-item costs. The Oregon and White Salmon management unit plans use mixed approaches, with some administrative costs specifically identified while others are embedded in action cost estimates.

Research, monitoring, and evaluation costs also vary among the management unit plans. In many cases, RME costs have yet to be determined. Those that can be estimated at this

---

[2] "Baseline actions" are those programs that are already in existence or that would occur regardless of recovery plans.

point are included in the management unit plans and incorporated into the estimates shown below.

All yearly costs identified in the management unit plans are presented in present-year dollars (that is, without adjusting for inflation). The total costs are the sum of the yearly costs without applying a discount rate.

The total estimated cost of recovery actions for the four threatened species found in the lower Columbia River over the next 25 years is about $2.1 billion, of which about $614 million is anticipated to be needed in the first 5 years (see Table 12-2). These estimates include expenditures by local, tribal, state, and federal governments, private business, and individuals in implementing capital projects and non-capital work, as well as administrative costs for supervision and coordination. The total costs in Table 12-2 include $592 million ($164 in the first 5 years) for implementation of actions in the estuary module (NMFS 2011a); these actions have basinwide scope and are expected to benefit all 13 listed ESUs and DPSs in the Columbia Basin but are included in Table 12-2 because of their shared geography with the Lower Columbia River ESUs. Not included in Table 12-2 are expenses associated with implementing the 2008 FCRPS Biological Opinion and its 2010 Supplement (NMFS 2008f and 2010a).

Note that all estimates in Table 12-2 and the subsequent discussion are rounded to the nearest million.

Table 12-2
Summary of Cost Estimates

Management Unit	5-Year Cost Estimate (millions)	25-Year Cost Estimate (millions)
Washington (LCFRB 2010a)[3]	$245	$738
Oregon (ODFW 2010)[4,5]	$189	$758
White Salmon (NMFS 2013)[6]	$16	$16
Estuary Module (NMFS 2011a)[7]	$164	$592
TOTAL	$614	$2,104

These estimates are based on the best available information at the time the management unit plans were completed and are expected to change as implementation plans are developed and actions are more clearly scoped and planned. It is therefore likely that estimated costs will increase substantially given the significant number of actions for which no costs could be estimated at the time of plan completion.

The cost estimates in each management unit plan are summarized below.

12.2.1 Washington Management Unit Plan

The Washington management unit plan (LCFRB 2010a) provides estimated costs for actions undertaken solely to address salmon recovery. The plan does not estimate baseline costs, i.e., costs for actions that may be critical to recovery efforts but are mandated by laws, regulations, or policy directives other than Endangered Species Act recovery plans and would thus occur irrespective of recovery planning efforts.

---

[3] The Washington management unit plan estimated costs for a short-term (10-year) and long-term (25-year) period. The 5-year estimate shown in Table 12-2 is extrapolated by dividing the 10-year estimate in half. NMFS worked with Washington recovery planners to add a 2 percent operations and maintenance cost factor to capital projects, beginning with the estimated project completion date. This addition made the Washington management unit plan consistent with the other management unit plans.
[4] The 5-year estimate was extrapolated from Table 9-3 of ODFW (2010). The estimate for the 25-year period includes a 2 percent maintenance cost factor added to capital projects, beginning with the estimated project completion date.
[5] Table 9-3 of ODFW (2010) indicates a number of actions scheduled to begin within the next 5, 10, 15, or 25 years. For the purposes of this table, unless otherwise specified, all are assumed to begin the first year the plan is put into effect.
[6] Most actions in the White Salmon management unit plan will occur within 5 years of removal of Condit Dam, which took place in September 2012. This table assumes that all actions, including the dam's removal, will occur within the first 5 years of plan implementation. Additional actions may be added pending the results of RME and assessment efforts.
[7] The 5-year estimate is extrapolated from Tables 5-6 and 6-7 of the estuary module (NMFS 2011a).

Dam operational improvements and predation management actions are addressed in the 2008 FCRPS Biological Opinion and its 2010 Supplement (NMFS 2008f and 2010a), NMFS hydropower module, and FERC licensing agreements and are considered baseline costs. Estuary costs are quoted from the estuary module cost estimates for informational purposes only; they are not included in the management unit plan totals indicated below or in the Washington management unit costs in Table 12-2.

Research and monitoring needs are expected to be met largely through a combination of new and ongoing efforts by federal and state agencies, local governments, and research organizations, the outlays for which are considered baseline costs. Additional research and monitoring are anticipated to fill information gaps not addressed by existing programs. The costs for this additional effort will be estimated once more complete information is available. (LCFRB 2010a, Volume I, Section 11.7)

The costs for stream habitat restoration are estimated on a cost-per-mile basis developed from habitat project assessments conducted for selected subbasins in the region (the Lower Cowlitz River [Lower Columbia Fish Recovery Board 2007], Lower East Fork Lewis River [Lower Columbia Fish Recovery Board 2009b], Abernathy and Germany Creeks [Lower Columbia Fish Recovery Board 2009a], and Grays River [Lower Columbia Fish Recovery Board 2009c]). For each subbasin, habitat improvement targets identified for each species were used to estimate miles of stream treatment consistent with recovery. Estimates included initial project implementation and long-term maintenance costs. Costs for fishery- and hatchery-related recovery costs were estimated for those actions outside of baseline fishery and hatchery management programs from data provided by the Washington Department of Fish and Wildlife and its draft Conservation and Sustainable Fishery Plan. Estimates for implementation coordination and administration are provided.

The Washington management unit plan envisions a 25-year implementation period and provides cost estimates for the near term (the first 10 years) and long term (years 11 through 25). The total estimated cost for the 25-year implementation period for recovery-related habitat, fishery, and hatchery actions and associated coordination and administration is $703 million (LCFRB 2010a, Volume I, Section 11.8). For this roll-up plan, NMFS added post-construction maintenance costs, estimated at 2 percent per year for 15 years, to the costs for habitat restoration, for a total of $738 million.[8] The estimated cost for the 2010-2014 period is $245 million.

Cost estimates are discussed further in Chapter 11, "Costs," of LCFRB (2010a).

12.2.2 Oregon Management Unit Plan

The Oregon management unit plan envisions a 25-year time frame for recovery and conservation action implementation, with a formal assessment planned at the 12-year point. Action implementation is presented as occurring currently (i.e., "ongoing"); immediately after plan adoption; in 5-, 10-, 15-, and 25-year time frames; or in a specific

[8] These maintenance costs were added to achieve consistency among management unit plans and were developed in coordination with Washington recovery planners.

year (such as 2010). Cost estimates are provided for new actions or current program expansions that are called for in the recovery plan, unless there is not enough information for an estimate. Actions required under other statutes or programs are considered baseline costs and not included, although their successful implementation is considered necessary for the overall recovery effort.

Actions called for in the 2008 FCRPS Biological Opinion and its 2010 Supplement (NMFS 2008f and 2010a) are included in the management unit plan for informational purposes but not included in the management plan costs, which are indicated in Table 12-2 above or in Table 9-3 of ODFW (2010). Actions from the estuary module (NMFS 2011a) are presented in the Oregon management unit plan, but their costs are not included in the management unit plan totals below or in the Oregon management unit costs in Table 12-2..

The cost estimating methodologies for tributary habitat actions consisted of either (a) calculation of the quantity of actions necessary and determination of unit costs, (b) expert opinion, or (c) applicable estimates from other plans. Costs for harvest, hatchery, and predation actions were based on the expert opinion and professional judgment of the Oregon Department of Fish and Wildlife. The cost estimate includes a 2 percent maintenance cost for capital projects for 20 years.

The total cost for the 25-year implementation period, not including baseline estuary or hydropower actions, is estimated to be $758 million. The estimated cost for the first 5 years is $189 million.

For further discussion of Oregon management unit plan cost estimates, see Chapter 9 ("Implementation") of ODFW (2010), including, Section 9.1 ("Action Details: Locations, Schedule, Costs, and Potential Implementers") and Table 9-3.

12.2.3 White Salmon Management Unit Plan

The decommissioning and removal of Condit Dam is central to the White Salmon recovery strategy. The costs of dam removal are being born by the PacifiCorp power company.

Removal of Condit Dam and associated reintroduction and habitat improvement actions are estimated to cost between $12 and $15 million. Additional habitat restoration and harvest and hatchery management actions are estimated to cost about $14 million.

Numerous RME actions are identified in the White Salmon management unit plan. The results of studies will help with prioritization of actions within the subbasin. It is estimated that the RME actions will cost roughly $2 million over a 5-year period.

Because dam removal is considered a baseline action, Table 12-2 includes only the additional habitat restoration and harvest and hatchery management action and RME cost estimates. The total estimated cost for the first 5-year period for restoring anadromous populations in the White Salmon River, not counting the baseline action of Condit Dam removal, is estimated to be about $16 million.[9]

Additional costs for recovery are likely to be incurred beyond the initial 5-year period. These costs cannot be estimated until the RME has been completed.

For further discussion of cost estimates for the White Salmon subbasin, see Chapter 7 of NMFS (2013), specifically Section 7.2 ("Costs") and Tables 7-1 and 7-2.

12.2.4 Estuary Module

Cost estimates in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) address direct, incremental costs of actions over and above baseline activities. Most of the estimates provided were developed by the consulting firm PC Trask & Associates, Inc., and members of the Lower Columbia Estuary Partnership, based on action implementation experience and historical records. Other estimates were provided by federal agency experts, most notably NMFS and the U.S. Army Corps of Engineers.

Total costs for actions in the estuary module are estimated at $528 million over the module's 25-year planning horizon. This estimate includes the costs of actions that are currently being implemented or that have already been completed, with implementation having begun in 2006. The cost estimate for the 5-year period 2010 to 2014, extrapolated from Table 5-6 of the estuary module, is $149 million.

Some of the module actions identified above include RME projects and associated cost estimates that are included in the estuary action cost estimates identified above. Table 6-6 of the estuary module identifies additional monitoring needs not directly associated with other actions. The estimated cost of these additional RME actions is $64 million over the module's 25-year planning horizon. The portion of this cost occurring over the period 2010 to 2014, as extrapolated from Table 6-7 of the estuary module, is about $15 million.

The total estimate for estuary actions and RME is $592 over the module's 25-year planning horizon, with $164 million estimated for the period 2010 to 2014. Although costs of implementing estuary module actions are included in this recovery plan for Lower Columbia River ESUs, the actions in the estuary module are expected to benefit all 13 listed ESUs and DPSs in the Columbia Basin and the estuary module is incorporated by reference into all Columbia Basin salmon and steelhead recovery plans.

For further discussion of the estuary module's cost estimates, see Table 5-6 of the module (NMFS 2011a).

---

[9] Totals do not sum because of rounding.

12.3 Time Estimate

There are unique characteristics and challenges in estimating the time required for salmon and steelhead recovery given the complex relationship of these fish to their environment and to human activities in the water and on land. Examples of the uncertainties that preclude a more precise estimate of time include biological and ecosystem responses to recovery actions and the unknown impacts of future economic, demographic, and social developments.

Consequently, the management unit plans provide a 25-year period for action implementation. The management unit authors believe, and NMFS concurs, that it may take longer than 25 years for the biological effects of management actions to be fully realized and for recovery of Lower Columbia River salmonid species to occur. Rather than speculate on conditions that may or may not exist that far into the future, this recovery plan relies on ongoing monitoring and periodic plan review regimes to add, eliminate, or modify actions through adaptive management as information becomes available and until such time as the protection of the Endangered Species Act is no longer required.

NMFS believes it most appropriate to focus on the first 5 years of implementation and in 5-year intervals thereafter, with the understanding that before the end of each 5-year implementation period, specific actions and costs will be estimated for subsequent years.

13. References

Allee, B. 2011. Cumulative Impact of Hatchery Origin Fish on Natural Origin Fish in the Columbia River Estuary. National Marine Fisheries Service Northwest Region, Portland OR.

Barnhart, R.A. 1986. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Southwest) — Steelhead. U.S. Army Corps of Engineers, TR EL-B2-4. USFWS Biological Report 82(11.60), 21 pp.

Beacham, T.D., and C.B. Murray. 1987. Adaptive Variation in Body Size, Age, Morphology, Egg Size, and Developmental Biology of Chum Salmon (*Oncorhynchus keta*) in British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 44:244-261.

Beamer, E., A. McBride, C. Greene, R. Henderson, G. Hood, K. Wolf, K. Larsen, C. Rice, and K. Fresh. 2005. Delta and Nearshore Restoration for the Recovery of Wild Skagit River Chinook Salmon: Linking Estuary Restoration to Wild Chinook Salmon Populations. Skagit River System Cooperative, LaConner, Washington.

Beamesderfer, R.C., D.L. Ward, and A.A. Nigro. 1996. Evaluation of the Biological Basis for a Predator Control Program on Northern Pikeminnow (*Ptychochelius oregonensis*) in the Columbia and Snake Rivers. Canadian Journal of Fisheries and Aquatic Sciences 53:2898-2908.

Beechie, T.J., M. Ruckelshaus, E. Buhle, A. Fullerton, and L. Holsinger. 2006. Hydrologic Regime and the Conservation of Salmon Life History Diversity. Biological Conservation 130(4):560-572.

Behnke, R.J. 1992. Native Trout of Western North America. American Fisheries Society Monograph. 6, 275 p. American Fisheries Society, Bethesda, Maryland.

Berejikian, B.A., and M.J. Ford. 2004. Review of Relative Fitness of Hatchery and Natural Salmon. NOAA Technical Memorandum NMFS-NWFSC-61, 28 pp.

Berejikian, B.A., Tatara, C.P., and Lee, J.S.F. 2009. Status of Science of Ecological Interactions between Hatchery and Natural Origin Anadromous Pacific Salmonids: Mechanisms, Spatial Scales and Information Gaps. 14 p.

Bilby, R.E., B.R Fransen, and P.A. Bisson. 1996. Incorporation of Nitrogen and Carbon from Spawning Coho Salmon into the Trophic System of Small Streams. Canadian Journal of Fisheries and Aquatic Sciences 53: 164-173.

Bonneville Power Administration, U.S. Bureau of Reclamation, and U.S. Army Corps of Engineers. 2004. Final Updated Proposed Action for the FCRPS Biological Opinion Remand. Portland, OR.

Bottom, D.L., C.A. Simenstad, J. Burke, A.M Baptista, D.A. Jay, K.K. Jones, E. Casillas, and M.H. Schiewe. 2005. Salmon at River's End: The Role of the Estuary in Decline and

Recovery of Columbia River Salmon. U.S. Dept. Commerce, NOAA technical memorandum. NMFS-NWFSC-68, 246p.

Bottom, D.L., G. Anderson, A. Baptista, J. Burke, M. Burla, M. Bhuthimethee, L. Campbell, E. Casillas, S. Hinton, K. Jacobson, D. Jay, R. McNatt, P. Moran, G.C. Roegner, C.A. Simenstad, V. Stamatiou, D. Teel, and J. E. Zamon. 2008. Salmon Life Histories, Habitat, and Food Webs in the Columbia River Estuary: An Overview of Research Results, 2002-2006. Northwest Fisheries Science Center, National Marine Fisheries Service, Seattle, WA.

Burgner, R.L., J.T. Light, L. Margolis, T. Okazaki, A. Tautz, and S. Ito. 1992. Distribution and Origins of Steelhead Trout (*Oncorhynchus mykiss*) in Offshore Waters of the North Pacific Ocean. Bulletin No. 51, International North Pacific Fisheries Commission, Vancouver, British Columbia, Canada.

Busack, C., and K. P. Currens. 1995. Genetic Risks and Hazards in Hatchery Operations: Fundamental Concepts and Issues. American Fisheries Society Symposium 15:71-80.

Busby, P.J., T.C. Wainwright, E.J. Bryant, L.J. Lierheimer, R.S. Waples, F.W. Waknitz, and I.V. Lagomarsino. 1996. Status Review of West Coast Steelhead from Washington, Idaho, Oregon, and California. NOAA Technical Memorandum 27.

Busch, D. S., M. Sheer, K. Burnett, P. McElhany, and T. Cooney. 2011. Landscape-Level Model to Predict Spawning Habitat for Lower Columbia River Fall Chinook Salmon (*Oncorhynchus tshawytscha).* River Research and Applications. Published online in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/rra.1597.

Carter, J.A., G.A. McMichael, I.D. Welch, R.A. Harnish, and B.J. Bellgraph. 2009. Seasonal Juvenile Salmonid Presence and Migratory Behavior in the Lower Columbia River. PNNL 18246, Pacific Northwest National Laboratory, Richland, WA. Prepared for the U.S. Army Corps of Engineers, Portland District.

Cederholm, C.J., M.D. Kunze, T. Murota, and A. Sibatani. 1999. Pacific Salmon Carcasses: Essential Contributions of Nutrients and Energy for Aquatic and Terrestrial Ecosystems. Fisheries 24 (10): 6-15.

Center for Whale Research. Photo-identification of Southern Resident Killer Whales. www.whaleresearch.com/research.html. Viewed January 27, 2012.

Chang, H., and J. Jones. 2010. Climate Change and Freshwater Resources in Oregon. Pages 69-149 in Oregon Climate Assessment Report, Oregon Climate Change Research Institute, K.D. Dello and P.W. Mote, editors. College of Oceanic and Atmospheric Sciences, www.occri.net/OCAR.

Chilcote, M.W. 1999. Conservation Status of Lower Columbia River Coho Salmon. Oregon Department of Fish and Wildlife, Fish Division Information Report 99-3, 41p. Department of Fish and Wildlife, Salem, Oregon.

Chilcote, M.W., K.W. Goodson, and M.R. Falcy. 2011. Reduced Recruitment Performance in Natural Populations of Anadromous Salmonids Associated with Hatchery-reared Fish. Canadian Journal of Fisheries and Aquatic Sciences 68:511-522.

Climate Impacts Group. 2004. Overview of Climate Change Impacts in the U.S. Pacific Northwest. University of Washington. Seattle, WA www.cses.washington/edu/cig.

Climate Impacts Group. 2009. The Washington Climate Change Impacts Assessment. M. Elsner, J. Littell, and L. Whitely Binder (eds). Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle, Washington. Available at: http://www.cses.washington.edu/db/pdf/wacciareport681.pdf.

Collis, K., and D.D. Roby. 2006. Research, Monitoring, and Evaluation of Avian Predation on Salmonid Smolts in the Lower and Mid-Columbia River. Bonneville Power Administration and U.S. Army Corps of Engineers. Draft 2005 season summary.

Columbia Basin Fish and Wildlife Authority. 1990. Review of the History, Development, and Management of Anadromous Fish Production Facilities in the Columbia River Basin. Unpublished manuscript, 52 p., U.S. Fish & Wildlife Service.

Columbia Basin Fish and Wildlife Authority. 2010. Revised Work Plan for Coordinated Assessments for Salmon and Steelhead. June 17, 2010.

Cooney, T.D., and D. Holzer. 2011. Lower Columbia Tule Chinook Populations: Estimating Intertidal Rearing Capacities and Survival Rates. March 4, 2011. NMFS Northwest Fisheries Science Center.

Cramer, D.P., and S.P. Cramer. 1994. Status and Population Dynamics of Coho Salmon in the Clackamas River. Technical Report, Portland General Electric Company, Portland, Oregon.

Crawford, B.A., and S.M. Rumsey. 2011. Guidance for Monitoring Recovery of Pacific Northwest Salmon & Steelhead listed under the Federal Endangered Species Act. National Marine Fisheries Service, Northwest Region. January 2011. Available at http://www.nwr.noaa.gov/Salmon-Recovery-Planning/upload/RME-Guidance.pdf.

Crozier, L. 2011. Literature Review for 2010 Citations for BIOP: Biological Effects of Climate Change. Attachment 1 of FCRPS Biological Opinion 2010 Annual Progress Report (p. 148-203). Available at: http://www.salmonrecovery.gov/ Files/BiologicalOpinions/2010/2010_FCRPS_APR_Section_2_Final.pdf.

Currens, K. P., A.R. Hemmingsen, R.A. French, D.V. Buchanan, C.R. Schreck, and H.W. Li. 1997. Introgression and Susceptibility to Disease in a Wild Population of Rainbow Trout. North American Journal of Fisheries Management 17:1065-1078.

Dawley, E.M., R.D. Ledgerwood, T.H. Blahm, C.W. Sims, J.T. Durkin, R.A. Kim, A.E. Rankin, G.E. Monan, and F.J. Ossiander. 1986. Migrational Characteristics, Biological Observations, and Relative Survival of Juvenile Salmonids Entering the Columbia River

Estuary, 1966-1983. Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, WA.

Dorcey, A.H.J., T.G. Northcote, and D.V. Ward. 1978. Are the Fraser River Marshes Essential to Salmon? University of British Columbia Press, Vancouver, Canada.

Elsner, M.M., L. Cuo, N. Voisin, J.S. Deems, A.F. Hamlet, J.A Vano, K.E.B. Michelson, S. Lee, and D.P. Lettenmaier. 2009. Implications of 21st Century Climate change for the Hydrology of Washington State. Pages 69–106 in M.M. Elsner, J. Littell, and L.W. Binder (editors). The Washington Climate Change Impacts Assessment. Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle.

Emmett, R. L., R. D. Brodeur, and P. M. Orton. 2004. The Vertical Distribution of Juvenile Salmon (Oncorhynchus spp.) and Associated Fishes in the Columbia River Plume. Fisheries Oceanography. 13:392–402.

Feely, R., C. Sabine, J. Hernandez-Ayon, D. Ianson, and B. Hales. 2008. Evidence for Upwelling of Corrosive "Acidified" Water onto the Continental Shelf. Science 320: 1490-1492.

Flagg, T.A., B.A. Berejikian, J.E. Colt, W.W. Dickhoff, L.W. Harrell, D.J. Maynard, C.E. Nash, M.S. Strom, R.N Iwamoto, and C.V.W. Mahnken. 2000. Ecological and Behavioral Impacts of Artificial Production Strategies on the Abundance of Wild Salmon Populations. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC- 41, 92 pp. http://www.nwfsc.noaa.gov/publications/techmemos/tm41/tm41.htm.

Flagg, T.A., F.W. Waknitz, D.J. Maynard, G.B. Milner, and C.V. Mahnken. 1995. The Effect of Hatcheries on Native Coho Salmon Populations in the Lower Columbia River. In: Schramm, H.I. and Piper, R.G., eds. Uses and Effects of Cultured Fishes in Aquatic Ecosystems. American Fisheries Society Symposium 15. Bethesda, Maryland.

Ford, J.K., G.M. Ellis., P. F. Olesiuk, and K.C. Balcomb III. 2009. Linking Killer Whale Survival and Prey Abundance: Food Limitation in the Oceans' Apex Predator? Biology Letters doi:10.1098/rsbl.2009.0468.

Ford, J.K.B., and G.M. Ellis. 2006. Selective Foraging by Fish-eating Killer Whales *Orcinus orca* in British Columbia. Marine Ecology Progress Series. Volume 316, pages 185 to 199.

Ford, J.K.B., G.M. Ellis, and K.C. Balcomb. 2000. Killer Whales: The Natural History and Genealogy of *Orcinus orca* in British Columbia and Washington State. 2nd ed. UBC Press, Vancouver, British Columbia.

Ford, M., N. Sands, P. McElhany, R. Kope, D. Simmons, P. Dygert. 2007. Analyses to Support a Review of an ESA Jeopardy Consultation on Fisheries Impacting Lower Columbia River Tule Chinook Salmon. National Marine Fisheries Service. October 5.

Ford, M.J. (Ed.). 2011. Status Review Update for Pacific Salmon and Steelhead Listed Under the Endangered Species Act: Pacific Northwest. U.S. Department of Commerce, NOAA Technical Memorandum NOAA-NWFSC-113, 281 pp. November 2011.

Fresh, K. L., and S. L. Schroder. 1987. Influence of the Abundance, Size, and Yolk Reserves of Juvenile Chum Salmon (*Oncorhynchus keta*) on Predation by Freshwater Fishes in a Small Coastal Stream. Canadian Journal of Fisheries and Aquatic Sciences 44.

Fresh, K.L. 1997. The Role of Competition and Predation in the Decline of Pacific Salmon and Steelhead. In D.J. Stouder, P.A. Bisson, and R.J. Naiman (editors), Pacific Salmon and Their Ecosystems: Status and Future Options, pp. 245-275. Chapman Hall, New York.

Fresh, K.L., E. Casillas, L.L. Johnson, and D.L. Bottom. 2005. Role of the Estuary in the Recovery of Columbia River Basin Salmon and Steelhead: An Evaluation of the Effects of Selected Factors on Salmonid Population Viability. NOAA technical memorandum, Northwest Fisheries Science Center, National Marine Fisheries Service. Seattle, WA. 136 pp.

Friesen, T.A., and D.L. Ward. 1999. Management of Northern Pikeminnow and Implications for Juvenile Salmonid Survival in the Lower Columbia and Snake Rivers. North American Journal of Fisheries Management 19:406-420.

Fritts, A., and T. Pearsons. 2008. Can Non-native Smallmouth Bass, *Micropterus dolomieu*, Be Swamped by Hatchery Fish Releases to Increase Juvenile Chinook Salmon, *Oncorhynchus tshawytscha*, Survival? Environmental Biology of Fishes 83(4):485-494.

Garrison, R.C., and M.M. Rosentreter. 1981. Stock Assessment and Genetic Studies of Anadromous Salmonids. Pages 66. Federal Aid Progress Rpts Fisheries, 1980. Oregon Dept. Fish and Wildlife, Fish Div, Portland.

Geiger, R.D. 1973. Streamflow Requirements for Salmonids. OR Wildl. Comm., Job. Final Rep. Proj. AFS 62-1, Portland, Oregon. 117p.

Genovese, P.V., and R.L. Emmett. 1997. Desktop Geographic Information System for Salmonid Resources in the Columbia River Basin. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-34.

Gilbreath, L., and E. Prentice. 1999. Post Construction Evaluation of the Modified Bonneville Dam Second Powerhouse Juvenile Bypass System. In Abstracts, Anadromous Fish Evaluations Program 1999 Annual Research Review, November 1999. (Available from U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, WA.)

Glick, P., J. Clough, and B. Nunley. 2007. Sea-level Rise and Coastal Habitats in the Pacific Northwest: An Analysis for Puget Sound, Southwestern Washington, and Northwestern Oregon. National Wildlife Federation, Western Natural Resource Center 6 Nickerson Street, Suite 200 Seattle, Washington 98109. Available at: http://www.nwf.org/~/media/PDFs/Water/200707_PacificNWSeaLevelRise_Report.ashx.

Goede, R.W. 1986. Management Considerations in Stocking of Diseased or Carrier Fish. Pages 349-355 in R. H. Stroud, ed. Fish Culture in Fisheries Management. American Fisheries Society, Bethesda, MD.

Hamm, D.E. 2012. Development and Evaluation of a Data Dictionary to Standardize Salmonid Habitat Assessments in the Pacific Northwest. Fisheries. Volume 37, Issue 1, 2012.

Hanson, B., J. Hempelmann-Halos, and D. Van Doornik. 2010b. Species and Stock Identification of Scale/Tissue Samples from Southern Resident Killer Whale Predation Events Collected off the Washington Coast during PODs 2009 Cruise on the McArthur II. Unpublished memorandum. March 16, 2010.

Hanson, M.B., R.W. Baird, C. Emmons, J. Hempelmann, G.S. Schorr, J. Sneva, and D.Van Doornik. 2007. Summer Diet and Prey Stock Identification of the Fisheating "Southern Resident" Killer Whales: Addressing a Key Recovery Need Using Fish Scales, Fecal Samples, and Genetic Techniques. Abstract from the 17th Biennial Conference on the Biology of Marine Mammals, Capetown, South Africa.

Hanson, M.B., R.W. Baird, J.K.B. Ford, J. Hempelmann-Halos, D.M. Van Doornik, J.R. Candy, C. K. Emmons, G.S. Schorr, B. Gisborne, K.L. Ayres, S.K. Wasser, K.C. Balcomb, K. Balcomb-Bartok, J.G. Sneva, and M.J. Ford. 2010a. Species and Stock Identification of Prey Consumed by Endangered Southern Resident Killer Whales in Their Summer Range. Endangered Species Research. Volume 11, pages 69 to 82.

Hatchery Scientific Review Group. 2006. Columbia River Hatchery Reform Project Progress Report. April 17, 2006.

Hatchery Scientific Review Group. 2007. Preview of Key Findings for Lower Columbia River Hatchery Programs. Memo prepared by the Hatchery Scientific Review Group for the Columbia River Hatchery Reform Steering Committee. July 18, 2007.

Hatchery Scientific Review Group. 2009. Columbia River Hatchery Reform System-wide Report. February 2009. Available at: http://www.hatcheryreform.us/hrp/reports/system/welcome_show.action.

Healey, M.C. 1982. Juvenile Pacific Salmon in the Estuaries: The Life Support System. In Estuarine Comparisons. Academic Press, Inc., New York.

Hixon, M.A., S. Gregory, and W. Robinson. 2010. Oregon's Fish and Wildlife in a Changing Climate. Pages 256-358 in K.D. Dello and P.W. Mote (editors). Oregon Climate Assessment Report. Oregon Climate Change Research Institute, College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR. www. occri.net/OCAR.

Hulett, P.L., R.H. Bradford, C.W. Wagemann, and S.A. Leider. 1993. Studies of Hatchery and Wild Steelhead in the Lower Columbia Region. Washington Department of Fish and Wildlife Management Division 93-12. (Available from WDFW, 600 Capital Way N., Olympia, WA 98501).

Huppert, D., A. Moore, and K. Dyson. 2009. Impacts of Climate Change on the Coasts of Washington State. P. 285-309. In: M. Elsner, J. Littell, and L. Whitely Binder (eds). The Washington Climate Change Impacts Assessment. Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle, Washington. Available at: http://www.cses.washington.edu/db/pdf/wacciareport681.pdf.

Independent Scientific Advisory Board. 2007a. Climate Change Impacts on Columbia River Basin Fish and Wildlife. ISAB Climate Change Report, ISAB 2007-2. Prepared by the Independent Scientific Advisory Board for the Northwest Power and Conservation Council, Columbia River Basin Indian Tribes, and National Marine Fisheries Service. May 11, 2007.

Independent Scientific Advisory Board. 2007b. Human Population Impacts on Columbia Basin Fish and Wildlife. ISAB Report 2007-3. Prepared by the Independent Scientific Advisory Board for the Northwest Power and Conservation Council, Columbia River Basin Indian Tribes, and National Marine Fisheries Service. June 8, 2007.

Integrated Hatchery Operations Team. 1995. Policy and Procedures for Columbia Basin Anadromous Salmonid Hatcheries. Annual report 1994 to the Bonneville Power Administration, Portland, Oregon. Project # 93-043.

Intergovernmental Panel on Climate Change. 2007a. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller [eds.]). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp. Available at: http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg1_report_the_physical_science_basis.htm.

Intergovernmental Panel on Climate Change. 2007b. Glossary. Annex 1 In: B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds). Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA.

Intergovernmental Panel on Climate Change. 2007c. Glossary. Appendix I In: M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, 976 pp.

Interior Columbia TRT. 2005. Viability Criteria for Application to Interior Columbia Basin Salmonid ESUs. Interior Columbia Technical Recovery Team NOAA-NWFSC, Seattle, WA.

Iwamoto, R.N., and J.G. Williams. 1993. Juvenile Salmonids Passage and Survival Through Turbines. Report to U.S. Army Corps of Engineers, Portland, OR, Contract E86920049, 27 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Jay, D.A., and P. Naik. 2002. Separating Human and Climate Impacts on Columbia River Hydrology and Sediment Transport. Pp. 38-48 in G. Gelfenbaum and G. Kaminsky, eds., Southwest Washington Coastal Erosion Workshop Report 2000, U.S. Geological Survey Open File Report, 02-229. 308 pp.

Jay, D.A., and T. Kukulka. 2003. Impacts of Columbia River Discharge on Salmonid Habitat. Manuscript submitted to the Journal of Geophysical Research. Revised 2003.

Jeffries, S.J. 1984. Marine Mammals of the Columbia River Estuary. Final report on the marine mammals work unit of the Columbia River estuary data development program. Washington Department of Game. Olympia, WA.

Jeffries, S.J., P.J. Gearin, H.R. Huber, D.L. Saul, and D.A. Pruett. 2000. Atlas of Seal and Sea Lion Haulout Sites in Washington. Washington Department of Fish and Wildlife, Olympia, Washington.

Johnson, G.E., H.L. Diefenderfer, B.D. Ebberts, C. Tortorici. T. Yerxa, J. Leary, and J.R. Skalski. 2008. Research, Monitoring, and Evaluation for the Federal Columbia River Estuary Program Prepared for the Bonneville Power Administration by the Pacific Northwest National Laboratory under a Related Services Agreement with the U.S. Department of Energy Contract DE-AC05-76RL01830 in conjunction with NOAA Fisheries and the U.S. Army Corps of Engineers, Portland District with the collaboration of the Lower Columbia River Estuary Partnership. January 31, 2008.

Johnson, G.E., R.M. Thom, A.H. Whiting, G.B. Sutherland, T. Berquam, B.D. Ebberts, M. Ricci, J.A. Southard, and J.D. Wilcox. 2003. An Ecosystem-based Approach to Habitat Restoration Projects with Emphasis on Salmonids in the Columbia River Estuary. Final draft prepared by the Pacific Northwest National Laboratory, Columbia River Estuary Study Taskforce, Lower Columbia River Estuary Partnership, Bonneville Power Administration, and U.S. Army Corps of Engineers.

Joint Columbia River Management Staff (Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife). 2011. 2011 Joint Status Report: Stock Status and Fisheries for Fall Chinook Salmon, Coho Salmon, Chum Salmon, Summer Steelhead and White Sturgeon. Oregon Department of Fish and Wildlife and Washington Department of Fish and Wildlife. July 13, 2011.

Jones, Rob. 2011. 2010 5-Year Reviews: Updated Evaluation of the Relatedness of Pacific Northwest Hatchery Programs to 18 Salmon Evolutionarily Significant Units and Steelhead Distinct Population Segments Listed Under the Endangered Species Act. Memo to Donna Darm. June 29, 2011.

Karl, T.R., J.M. Melillo, and T.C. Peterson (eds.). 2009. Global Climate Change Impacts in the United States. Cambridge University Press. Available at: http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts.

Knudsen, E.E. 2002. Ecological Perspectives on Pacific Salmon: Can We Sustain Biodiversity and Fisheries? Pages 277-320 In K.D. Lynch, M.L. Jones, and W.W. Taylor, editors. Sustaining North American Salmon: Perspectives across Regions and Disciplines. American Fisheries Society, Bethesda, Maryland.

Krahn, M.M., et al. 2002. Status Review of Southern Resident Killer Whales (*Orcinus orca*) under the Endangered Species Act. NOAA Technical Memorandum. NMFS-NWFSC-54.

Krahn, M.M., J.J. Ford, W.F. Perrin, P.R. Wade, R.P. Angliss, M.B. Hanson, B.L. Taylor, G.M. Ylitalo, M.E. Dahlheim, J.E. Stein, and R.S. Waples. 2004. 2004 Status Review of Southern Resident Killer Whales (*Orcinus orca*) under the Endangered Species Act. NOAA Technical Memorandum NMFS-NWF-SC-62, National Marine Fisheries Service, Northwest Region, Seattle, Washington.

Krahn, M.M., M.B. Hanson, R.W. Baird, R.H. Boyer, D.G. Burrows, C.E. Emmons, J.K.B. Ford, L.L. Jones, D.P. Noren, P.S. Ross, G.S. Schorr, and T.K. Collier. 2007. Persistent Organic Pollutants and Stable Isotopes in Biopsy Samples (2005/2006) from Southern Resident Killer Whales. Marine Pollution Bulletin. Volume 54, pages 1903 to 1911.

Lampman, B. 1946. The Coming of the Pond Fishes. Benford and Mart, Portland, OR.

Lee, K.N. 1993. Compass and Gyroscope: Integrating Science and Politics for the Environment. Island Press, Washington, D.C

Lee, K.N. 1999. Appraising Adaptive Management. Conservation Ecology 3(2): 3. Available at http://www.consecol.org/vol3/iss2/art3/

Leider, S.A., M.W. Chilcote, and J L. Loch. 1986. Comparative Life History Characteristics of Hatchery and Wild Steelhead Trout (*Salmo gairdneri*) of Summer and Winter Races in the Mid-Columbia Kalama River, Washington. Canadian Journal of Fisheries and Aquatic Sciences 43:1398–1409.

Loge, F.J, M.R. Arkoosh, T.R. Ginn, L.L. Johnson, and T.K. Collier. 2005. Impact of Environmental Stressors on the Dynamics of Disease Transmission. Environmental Science and Technology. 39:7329-7336.

Lohn, D. Robert. 2003. Testimony of D. Robert Lohn, Regional Administrator, Northwest Region, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, before the Committee on Indian Affairs, United States Senate, on Tribal Fish and Wildlife Management Programs in the Pacific Northwest. June 4, 2003.

Lohn, D. Robert. 2006. Personal communication. Letter from D. Robert Lohn, NMFS Regional Administrator, to Governor Christine Gregoire, Jeff Koennings, and George Trott regarding approval of the Lower Columbia Fish Recovery Board plan. February 3, 2006.

Lower Columbia Fish Recovery Board. 2007. Lower Cowlitz River and Floodplain Habitat Restoration Project Siting and Design. Final revised report. Prepared for the Lower Columbia Fish Enhancement Group and Lower Columbia Fish Recovery Board by Tetra Tech, Inc. December 2007. Available at http://www.lcfrb.gen.wa.us/document_library_studies.htm.

Lower Columbia Fish Recovery Board. 2009a. Abernathy and Germany Creeks Intensively Monitored Treatment Plan. Prepared for the Lower Columbia Fish Recovery Board, Longview, Washington, by HDR, Inc., and Cramer Fish Sciences. January 2009. Available at http://www.lcfrb.gen.wa.us/document_library_studies.htm.

Lower Columbia Fish Recovery Board. 2009b. Lower East Fork Lewis River Habitat Restoration Plan. Prepared by the East Fork Lewis Working Group. April 2009.

Lower Columbia Fish Recovery Board. 2009c. Grays River Habitat Restoration Technical Report. Prepared by Tetra Tech, Inc., ENTRIX, Inc., and Waterfall Engineering, LLC. December 2009. Available at http://www.lcfrb.gen.wa.us/document_library_studies.htm.

Lower Columbia Fish Recovery Board. 2010a. Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan. Lower Columbia Fish Recovery Board, Washington. May 28, 2010.

Lower Columbia Fish Recovery Board. 2010b. Research, Monitoring, and Evaluation Program for Lower Columbia Salmon and Steelhead. June 2010.

Lower Columbia River Estuary Partnership. 2007. Lower Columbia River and Estuary Ecosystem Monitoring: Water Quality and Salmon Sampling Report.

Mantua, N., I. Tohver, and A. F. Hamlet. 2009. Impacts of Climate Change on Key Aspects of Freshwater Salmon Habitat in Washington State. Pages 217-254 in M.M. Elsner, J. Littell, and L.W. Binder (eds.). The Washington Climate Change Impacts Assessment. Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle.

Mantua, N., I. Tohver, and A. Hamlet. 2010. Climate Change Impacts on Streamflow Extremes and Summertime Stream Temperature and Their Possible Consequences for Freshwater Salmon Habitat in Washington State. Climatic Change 102:187-223.

McCabe, G. T., Jr., W. D. Muir, et al. 1983. Interrelations Between Juvenile Salmonids and Nonsalmonid Fish in the Columbia River Estuary. Fish Bulletin 81.

McCabe, G.T., R.L. Emmett, W.D. Muir, and T.H. Blahm. 1986. Utilization of the Columbia River Estuary by Subyearling Chinook Salmon. Northwest Science 60:113-124.

McElhany, P., M. Ruckelshaus, M.J. Ford, T.C. Wainwright, and E.P. Bjorkstedt. 2000. Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-42, 156 pp. June 2000.

McElhany, P. 2005. Columbia River Chum Salmon ESU. In T.P. Good, R.S. Waples, and P. Adams, editors. Updated Status of Federally Listed ESUs of West Coast Salmon and Steelhead. NOAA Northwest Fisheries Science Center, Seattle, WA.

McElhany, P. 2010. Personal communication with Patty Dornbusch. August 9, 2010.

McElhany, P., and 11 coauthors. 2003. Interim Report on Viability Criteria for Willamette and Lower Columbia Basin Pacific Salmonids. Willamette/Lower Columbia Technical Recovery Team Interim Report. NOAA Fisheries, Portland.

McElhany, P., and 11 coauthors. 2006. Revised Viability Criteria for Salmon and Steelhead in the Willamette and Lower Columbia Basins. Willamette/Lower Columbia Technical Recovery Team and Oregon Department of Fish and Wildlife. NOAA Fisheries, Portland. Review draft. April 1, 2006.

McElhany, P., M. Chilcote, J. Myers, and R. Beamesderfer. 2007. Viability Status of Oregon Salmon and Steelhead Populations in the Willamette and Lower Columbia Basins. Prepared for the Oregon Department of Fish and Wildlife and National Marine Fisheries Service. September 2007.

McElhany, P., M.H. Ruckelshaus, M.J. Ford, T.C. Wainwright, and E.P. Bjorkstedt. 2000. Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units. U.S. Department of Commerce, NOAA technical memorandum. NMFS-NWFSC-42, 156 p.

McElhany, P., T. Backman, C. Busack, S. Kolmes, J. Myers, D. Rawding, A. Steel, C. Steward, T. Whitesel, and C. Willis. 2004. Status Evaluation of Salmon and Steelhead Populations in the Willamette and Lower Columbia River Basins. Willamette/Lower Columbia Technical Recovery Team report. Northwest Fisheries Science Center, NOAA Fisheries, Seattle. July 2004.

McMichael, G.A., R.A. Harnish, J.R. Skalski, K.A. Deters, K.D. Ham, R.L. Townsend, P.S. Titzler, M.S. Hughes, J. Kim, and D.M. Trott. 2011. Migratory Behavior and Survival of Juvenile Salmonids in the Lower Columbia River, Estuary, and Plume in 2010. Prepared by the Pacific Northwest National Laboratory for U.S. Army Corps of Engineers, Portland District, Portland Oregon.

Miles, E.L., A.K. Snover, A.F. Hamlet, B.M. Callahan, and D.L. Fluharty. 2000. Pacific Northwest Regional Assessment: The Impacts of Climate Variability and Climate Change on the Water Resources of the Columbia River Basin. Journal of the American Water Resources Association 36(2):399-420.

Mote, P., A. Petersen, S. Reeder, H. Shipman, and L.W. Binder. 2008. Sea Level Rise in the Coastal Waters of Washington State. University of Washington Climate Impacts Group and Washington Dept. of Ecology. Available at: http://cses.washington.edu/db/pdf/moteetalslr579.pdf.

Mote, P.W., and E.P. Salathe, Jr. 2009. Future Climate in the Pacific Northwest. Pages 21–43 in M.M. Elsner, J. Littell, and L.W. Binder, editors. The Washington Climate Change Impacts Assessment. Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle.

Mote, P.W., D. Gavin, and A. Huyer. 2010. Climate Change in Oregon's Land and Marine Environments. Pages 1-45 in Oregon Climate Assessment Report, Oregon Climate Change Research Institute, K.D. Dello and P.W. Mote (eds). College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR. www.occri.net/OCCAR.

Mote, P.W., D.J. Canning, D.L. Fluharty, R.C. Francis, J.F. Franklin, A.F. Hamlet, M. Hershman, M. Holmberg, K.N. Ideker, W.S. Keeton, D.P. Lettenmaier, L.R. Leung, N.J. Mantua, E.L. Miles, B. Noble, H. Parandvash, D. W. Peterson, A.K. Snover, and S.R. Willard. 1999. Impacts of Climate Variability and Change, Pacific Northwest. NOAA Office of Global Programs, and JISAO/SMA Climate Impacts Group, Seattle, WA. 110p.

Mote, P.W., E.A. Parson, A.F. Hamlet, K.N. Ideker, W.S. Keeton, D.P. Lettenmaier, N.J. Manua, E.L. Miles, D.W. Peterson, D.L. Peterson, R. Slaughter, and A.K. Snover. 2003. Preparing for Climate Change: The Water, Salmon, and Forests of the Pacific Northwest. Climatic Change 61:45-88.

Myers, J., C. Busack, D. Rawding, A. Marshall, D. Teel, D.M. Van Doornik, and M.T. Maher. 2006. Historical Population Structure of Pacific Salmonids in the Willamette River and Lower Columbia River Basins. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-NWFSC-73, 311 pp. February 2006.

Naish, K.A., Taylor, J.E., Levin, P.S., Quinn, T.P., Winton, J.R., Huppert, D., and Hilborn, R. 2008. Advances in Marine Biology 53:61-141.

Narver, D.W. 1976. Stream Management for West Coast Anadromous Salmonids. Pages 7-13 in Stream Management of Salmonids. Trout, Winter 1976 Suppl.

National Marine Fisheries Service 2009c. FCRPS Adaptive Management Implementation Plan. 2008-2018 Federal Columbia River Power System Biological Opinion. September 11, 2009.

National Marine Fisheries Service. 1996. Endangered and Threatened Species: Proposed Endangered Status for Five ESUs of Steelhead and Proposed Threatened Status for Five ESUs of Steelhead in Washington, Oregon, Idaho, and California. Federal Register [Docket No. 960730210-6210-01, 9 August 1996]. Volume 61(155), page 41558.

National Marine Fisheries Service. 1997. Investigation of Scientific Information on the Impacts of California Sea Lions and Pacific Harbor Seals on Salmonids and on the Coastal Ecosystems of Washington, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-28.

National Marine Fisheries Service. 1999. Updated Review of the Status of the Upper Willamette River and the Middle Columbia River ESUs of Steelhead (*Oncorhynchus mykiss*). January 12, 1999, NMFS-NWFSC Status Review Update Memo, Available on the Internet at: http://www.nwr.noaa.gov/Publications/Biological-Status-Reviews/upload/SR1999-steelhead.pdf.

National Marine Fisheries Service. 2000a. White Paper: Passage of Juvenile and Adult Salmonids Past Columbia and Snake River Dams. Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, Washington, 98112-2097.

National Marine Fisheries Service. 2000b. Biological Opinion, Reinitiation of Consultation on the Operation of the Federal Columbia River Power System, Including the Juvenile Fish Transportation Program, and 19 Bureau of Reclamation Projects in the Columbia Basin.

National Marine Fisheries Service. 2004a. Interim Endangered and Threatened Species Recovery Planning Guidance, Version 1.0. October 2004.

National Marine Fisheries Service. 2004b. Salmonid Hatchery Inventory and Effects Evaluation Report. Technical Memorandum NMFS-NWR/SWR (NMFS 2004b). An Evaluation of the Effects of Artificial Propagation on the Status and Likelihood of Extinction of West Coast Salmon and Steelhead under the Federal Endangered Species Act. May 28, 2004.

National Marine Fisheries Service. 2005a. Draft Interim Regional Recovery Plan for Portions of Three Evolutionarily Significant Units (ESUs) of Salmon and Steelhead—Columbia River Chinook (Onchorhynchus tshawytscha), Columbia River Chum (Onchorhynchus keta), and Lower Columbia River Steelhead (Onchorhynchus mykiss)—within the Washington Lower Columbia Management Unit. National Oceanic and Atmospheric Administration's National Marine Fisheries Service Supplement to the Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan. Prepared by National Marine Fisheries Service Northwest Region. April 15, 2005.

National Marine Fisheries Service. 2005b. Green Sturgeon (*Acipenser medirostris*) Status Review Update. NOAA Fisheries Biological Review Team, Santa Cruz Laboratory, Southwest Fisheries Science Center. February 2005.

National Marine Fisheries Service. 2005c. Final Assessment of NOAA Fisheries' Critical Habitat Analytical Review Teams for 12 Evolutionarily Significant Units of West Coast Salmon and Steelhead, Appendix J: CHART Assessment for the Middle Columbia River Steelhead ESU. Prepared by NMFS Protected Resources Division. August, 2005. Available at http://www.nwr.noaa.gov/Salmon-Habitat/Critical-Habitat/Redesignations/upload/F-CHART-STMCR.PDF.

National Marine Fisheries Service. 2007. Adaptive Management for ESA-Listed Salmon and Steelhead Recovery: Decision Framework and Monitoring Guidance. Prepared by National Marine Fisheries Service Northwest Region and Northwest Fisheries Science Center. May 1, 2007. Available at http://www.nwr.noaa.gov/Salmon-Recovery-Planning/.

National Marine Fisheries Service. 2008a. Recovery Plan Module: Mainstem Columbia River Hydropower Projects. September 24, 2008.

National Marine Fisheries Service. 2008b. NOAA Fisheries 2008-2017 United States v. Oregon Management Agreement. May 5, 2008.

National Marine Fisheries Service. 2008c. Supplemental Comprehensive Analysis of the Federal Columbia River Power System and Mainstem Effects of U.S. Bureau of Reclamation Upper Snake and Other Tributary Actions. NMFS, Portland, Oregon. May 5, 2008. Available at http://www.nwr.noaa.gov/Salmon-Hydropower/Columbia-Snake-Basin/upload/Final_SCA_Ch1_7.pdf.

National Marine Fisheries Service. 2008d. Memo: Northwest Region Recovery Implementation Strategy. NMFS Northwest Region. February 26, 2008.

National Marine Fisheries Service. 2008e. Draft Environmental Assessment: Reducing the Impact on At-Risk Salmon and Steelhead by California Sea Lions in the Area Downstream of Bonneville Dam on the Columbia River, Oregon and Washington. NMFS Northwest Region. January 11, 2008.

National Marine Fisheries Service. 2008f. Endangered Species Act Section 7(a)(2) Consultation Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation on Remand for Operation of the Federal Columbia River Power System, 11 Bureau of Reclamation Projects in the Columbia Basin and ESA Section 10(a)(1)(A) Permit for Juvenile Fish Transportation Program. NMFS, Portland, Oregon.

National Marine Fisheries Service. 2008g. Questions and Answers on the NOAA Fisheries Service Decision to Conduct an Endangered Species Act Status Review for the West Coast Eulachon (Smelt). March 2008. Available at http://www.nwr.noaa.gov/Other-Marine-Species/eulachon.cfm. Web site accessed March 16, 2010.

National Marine Fisheries Service. 2008h. Biological Opinion: Endangered Species Act (ESA) Section 7 Consultation Number F/NRW/2008/00486: Assessment of Impacts from Sea Lion Removal Program. National Marine Fisheries Service, Northwest Region. Protected Resources Division, Portland, Oregon.

National Marine Fisheries Service. 2008i. Recovery Plan for Southern Resident Killer Whales (*Orcinus orca*). National Marine Fisheries Service, Northwest Region, Seattle, Washington.

National Marine Fisheries Service. 2008k. Recovery Plan for the Steller Sea Lion: Eastern and Western Distinct Population Segments (*Eumetopias jubatus*). National Marine Fisheries Service, Northwest Region, Seattle, Washington.

National Marine Fisheries Service. 2009a. Middle Columbia River Steelhead Distinct Population Segment ESA Recovery Plan. National Marine Fisheries Service, Northwest Region. November 30, 2009.

National Marine Fisheries Service. 2009b. Designation of Critical Habitat for the Threatened Southern Distinct Population Segment of North American Green Sturgeon. Final biological report. NMFS, Southwest Region, Protected Resources Division, Long Beach, CA.

National Marine Fisheries Service. 2010a. Endangered Species Act—Section 7 Consultation Supplemental Biological Opinion. Supplemental Consultation on Remand for Operation of the Federal Columbia River Power System, 11 Bureau of Reclamation Projects in the Columbia Basin, and ESA Section 10(a)(1)(A) Permit for Juvenile Fish Transportation Program. NMFS, Portland, Oregon. Available at https://pcts.nmfs.noaa.gov/pls/pctspub/pcts_upload.summary_list_biop?p_id=124302.

National Marine Fisheries Service. 2010b. Status Review Update for Eulachon in Washington, Oregon, and California. Prepared by the Eulachon Biological Review Team, NMFS, January 20, 2010. Available at http://www.nwr.noaa.gov/Other-Marine-Species/eulachon.cfm. Web site accessed March 16, 2010.

National Marine Fisheries Service. 2010c. Draft Environmental Impact Statement to Inform Columbia River Basin Hatchery Operations and the Funding of Mitchell Act Hatchery Programs.

National Marine Fisheries Service. 2011a. Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead. NMFS Northwest Region. Portland, OR. Prepared for NMFS by the Lower Columbia River Estuary Partnership (contractor) and PC Trask & Associates, Inc. (subcontractor). January 2011.

National Marine Fisheries Service. 2013. ESA Recovery Plan for the White Salmon River Watershed. June 2013.

National Marine Fisheries Service. 2011b. 5-Year Review: Summary & Evaluation of Lower Columbia River Chinook, Columbia River Chum, Lower Columbia River Coho, Lower Columbia River Steelhead. Northwest Region. Portland, OR. Available at http://www.nwr.noaa.gov/ESA-Salmon-Listings/5-yr-rpts.cfm.

National Marine Fisheries Service. 2011c. Effects of Hatchery Programs on Salmon and Steelhead Populations: Reference Document for NMFS ESA Hatchery Consultations. March 7, 2011. NMFS Northwest Regional Office, Salmon Management Division. Portland, Oregon, 50p.

National Research Council. 1996. Upstream: Salmon and Society in Pacific Northwest. National Academy Press. Washington, D.C. 452 pp.

National Research Council. 2004. Managing the Columbia River: Instream Flows, Water Withdrawals, and Salmon Survival. The National Academies Press. Washington, D.C.

Natural Resources Conservation Service. 2006. Bull Trout (*Salvelinus confluentus*). Wildlife Habitat Council. Fish and Wildlife Habitat Management Leaflet No. 36. January 2006.

Noren, D.P. 2010. Estimated Field Metabolic Rates and Prey Requirements of Resident Killer Whales. Marine Mammal Science. 27:60–77.

Normandeau Associates Inc., J.R. Skalski, and Mid-Columbia Consulting Inc. 1995. Turbine Passage Survival of Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) at

Lower Granite Dam, Snake River, Washington. Report to U.S. Army Corps of Engineers. Contract DACW68-95-C-0031, 78 p. (Available from U.S. Army Corps of Engineers, Walla Walla, WA 99362.)

Normandeau Associates Inc., J.R. Skalski, and Mid-Columbia Consulting Inc. 1996. Draft Report on Potential Effects of Spillway Flow Deflectors on Fish Condition and Survival at the Bonneville Dam, Columbia River. Report to the U.S. Army Corps of Engineers, Contract DACW57-95-C-0086, 51 p. plus App. (Available from U.S. Army Corps of Engineers, Portland, OR 97208.)

Normandeau Associates Inc., J.R. Skalski, and Mid-Columbia Consulting Inc. 1999. Relative Passage Survival and Injury Mechanisms for Chinook Salmon Smolts Within the Turbine Environment at McNary Dam, Columbia River. Draft Report to U.S. Army Corps of Engineers, Contract DACW68-96-D-003. (Available from U.S. Army Corps of Engineers, Walla Walla, WA 99362.)

Northwest Fisheries Science Center (NFWSC). 2010. Lower Columbia River Tule Chinook Salmon Life-Cycle Modeling. Draft report. National Marine Fisheries Service. February 10.

Northwest Power and Conservation Council. 2001. Dams and Hydropower. Personal communication (e-mail). Portland, OR.

Northwest Power and Conservation Council. 2004a. Mainstem Lower Columbia River and Columbia River Estuary Subbasin Plan. In Columbia River Basin Fish and Wildlife Program. Portland, OR. Available at http://www.nwcouncil.org/fw/subbasinplanning/Default.htm.

Northwest Power and Conservation Council. 2004b. White Salmon Subbasin Plan. In Columbia River Basin Fish and Wildlife Program. Portland, OR. May 28, 2004. Available at http://www.nwcouncil.org/fw/subbasinplanning/Default.htm.

Omernik, J.M. 1987. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers. 77(1): 118-125.

Oregon Climate Change Research Institute. 2010. Oregon Climate Assessment Report. K.D. Dello and P.W. Mote (eds). College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR. Available at: www.occri.net/OCAR.

Oregon Department of Energy. 2009. Report to the Legislature: Oregon Global Warming Commission. January 2009. Available at: http://www.oregon.gov/ENERGY/GBLWRM/GWC/docs/09CommissionReport.pdf.

Oregon Department of Fish and Wildlife and National Marine Fisheries Service Northwest Region. 2011. Upper Willamette River Conservation and Recovery Plan for Chinook Salmon and Steelhead. August 5, 2011.

Oregon Department of Fish and Wildlife. 2005. 2005 Oregon Native Fish Status Report. Oregon Department of Fish and Wildlife, Salem, Oregon.

Oregon Department of Fish and Wildlife. 2010. Lower Columbia River Conservation and Recovery Plan for Oregon Populations of Salmon and Steelhead. August 6, 2010. Available at http://www.dfw.state.or.us/fish/CRP/lower_columbia_plan.asp.

Oregon Department of Land Conservation and Development. 2010. The Oregon Climate Change Adaptation Framework. December 2010. Available at: http://www.oregon.gov/LCD/docs/ClimateChange/Framework_Final.pdf?ga=t

Pacific Northwest Fish Health Protection Committee. 1989. Model Comprehensive Fish Health Protection Program. Olympia, Washington. 33 pp.

Portland General Electric Company. 2006. Settlement Agreement Concerning the Relicensing of the Clackamas River Hydroelectric Project – FERC Project No. 2195. Exhibit D, Fish Passage and Protection Plan. March 2006.

Quinn, T.P. 2005. The Behavior and Ecology of Pacific Salmon and Trout. University of Washington Press. 363 pp.

Recovery Implementation Science Team (RIST). 2009. Hatchery Reform Science: A Review of Some Applications of Science to Hatchery Reform Issues. April 9, 2009.

Reischel, T.S., and T.C. Bjornn. 2003. Influence of Fishway Placement on Fallback of Adult Salmon at the Bonneville Dam on the Columbia River. North American Journal of Fisheries Management 23:1215-1224.

Reisenbichler, R.R., and J.D. McIntyre. 1977. Genetic Differences in Growth and Survival of Juvenile Hatchery and Wild Steelhead Trout, *Salmo gairdneri*. Journal of the Fisheries Research Board of Canada 34: 123-128.

Roby, D.D., D.P. Craig, K. Collis, and S.L. Adamany. 1998. Avian Predation on Juvenile Salmonids in the Lower Columbia River, 1997 Annual Report. Bonneville Power Administration Contract 97BI33475 and U.S. Army Corps of Engineers Contract E96970049. 70 pp.

Roegner, G.C., D.L. Bottom, A. Baptista, S. Hinton, C.A. Simenstad, E. Casillas, and K. Jones. 2004. Estuarine Habitat and Juvenile Salmon: Current and Historical Linkages in the Lower Columbia River and Estuary, 2003. Northwest Fisheries Science Center, National Marine Fisheries Service, Seattle, WA.

Roelofs, T.D. 1983. Current Status of California Summer Steelhead (*Salmo gairdneri*) Stocks and Habitat, and Recommendations for Their Management. Submitted to USDA Forest Service, Region 5, 77 p. (Available from Protected Resources Division, National Marine Fisheries Service, 1201 E Lloyd Blvd., Suite 1100, Portland, Oregon 97232.)

Roni, P., G.R. Pess, T.J. Beechie, and S.A. Morley. 2011. Estimating Salmon and Steelhead Response to Watershed Restoration: How Much Restoration Is Enough? North American Journal of Fisheries Management, 30:1469 1484.

Ruggiero, P., C. Brown, P. Komar, J. Allan, D. Reusser, and H. Lee. 2010. Impacts of Climate Change on Oregon's Coasts and Estuaries. P. 209-265 In: K.D. Dello and P.W.

Mote (eds). Oregon Climate Assessment Report. Oregon Climate Change Research Institute, College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR. Available at: www.occri.net/OCAR.

Ryan, B.A., S.G. Smith, J.M. Butzerin, and J.W. Ferguson. 2003. Relative Vulnerability to Avian Predation of Juvenile Salmonids Tagged with Passive Integrated Transponders in the Columbia River Estuary, 1998-2000. Transactions of the American Fisheries Society 132:275-288.

Ryman, N., and L. Laikre. 1991. Effects of Supportive Breeding on the Genetically Effective Population Size. Conservation Biology 5:325-329.

Salathe, E.P, L. R. Leung, Y. Qian, and Y. Zhang. 2009. Regional Climate Model Projections for the State of Washington. Pages 45–67 in M. M. Elsner, J. Littell, and L.W. Binder, editors. The Washington Climate Change Impacts Assessment. Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle.

Salathe, E.P. 2005. Downscaling Simulations of Future Global Climate with Application to Hydrologic Modelling. International Journal of Climatology 25(4):419-436.

Sandercock, F. K. 1991. Life History of Coho Salmon (*Oncorhynchus kisutch*). Pacific Salmon Life Histories. C. Groot and L. Margolis. University of British Columbia Press, Vancouver. 395-446.

Shapovalov, L. and A.C. Taft. 1954. The Life Histories of the Steelhead Rainbow Trout (*Salmo gairdneri*) and Silver Salmon (*Oncorhynchus kisutch*) with Special Reference to Waddell Creek, California, and Recommendations Regarding Their Management. Calif. Dept. Fish and Game, Fish Bull. No. 98. 373 pp.

Sherwood, C.R., D.A. Jay, R.B. Harvey, P. Hamilton, and C.A. Simenstad. 1990. Historical Changes in the Columbia River Estuary. Pages 299-352 in M.V. Angel and R.L. Smith eds., Columbia River: Estuarine System. Progress in Oceanography 25(1-4).

Snover, A.K., A.F. Hamlet, and D.P. Lettenmaier. 2003. Climate Change Scenarios for Water Planning Studies: Pilot Applications in the Pacific Northwest. Bulletin of the American Meteorological Society 84(11):1513-1518.

Stansell, R.J., K.M. Gibbons, W.T. Nagy, and B.K. van der Leeuw. 2011. 2011 Field Report: Evaluation of Pinniped Predation on Adult Salmonids and Other Fish in the Bonneville Dam Tailrace, 2011. U.S. Army Corp. of Eng., Portland Dist., Fish. Field. Unit, Bonneville Lock and Dam, Cascade Locks, OR 97014. 29 pp.

State of Oregon Office of Economic Analysis. 2004. Forecasts of Oregon's County Populations and Components of Change, 2000—2040.

Steel, E. A., and M. B. Sheer. 2003. Appendix I: Broad-Scale Habitat Analyses to Estimate Fish Densities for Viability Criteria. In Willamette/Lower Columbia Technical Recovery

Team, Interim Report on Viability Criteria for Willamette and Lower Columbia Basin Pacific Salmonids. Northwest Fisheries Science Center, NMFS, Seattle, WA.

Steward, C.R., and T.C. Bjornn. 1990. Supplementation of Salmon and Steelhead Stocks with Hatchery Fish: A Synthesis of Published Literature. Tech. Report 90-1. Bonneville Power Administration.

Steward, I.T., D.R. Cayan, and M.D. Dettinger. 2004. Changes in Snowmelt Runoff Timing in Western North America Under a "Business as Usual" Climate Change Scenario. Climatic Change 62:217-232.

Stock, C. A., M. Alexander, N. Bond, K. Brander, W. Cheung, E. Curchitser, T. Delworth, J. Dunne, S. Griffies, M. Haltuchg, J. Hare, A. Hollowed, P. Lehodey, S. Levin, J. Link, K. Rose,R. Rykaczewski, J. Sarmienton, R. Stouffer, F. Schwingo, G. Vecchi, and F. Werner. 2011. On the Use of IPCC-class Models to Assess the Impact of Climate on Living Marine Resources. Progress in Oceanography 88: 1-27.

Stout, H.A., P.W. Lawson, D. Bottom, T. Cooney, M. Ford, C. Jordan, R. Kope, L. Kruzic, G.Pess, G. Reeves, M. Scheuerell, T. Wainwright, R. Waples, L. Weitkamp, J. Williams and T. Williams. 2011. Scientific Conclusions of the Status Review for Oregon Coast Coho Salmon (*Oncorhynchus kisutch*). Draft revised report of the Oregon Coast Coho Salmon Biological Review Team. NOAA/NMFS/NWFSC, Seattle, WA. Available at: http://www.nwr.noaa.gov/ESA-Salmon-Listings/Salmon-Populations/Alsea-Response/upload/OCC-review-2011.pdf.

Trombulak, S.C., K.S. Omland, J.A. Robinson, J.J. Lusk, T.L. Fleischner, G. Brown, and M. Domroese. 2004. Principles of Conservation Biology: Recommended Guidelines for Conservation Literacy from the Education Committee of the Society for Conservation Biology. Conservation Biology 18:1180-1190.

Turner, Richard. 2011. Personal communication with Richard Turner, Fisheries Biologist, Salmon Recovery Division, NOAA Fisheries. Portland, Oregon.

Tymchuk, W. E., C. Biagi, R. E. Withler, and R. H. Devlin. 2006. Growth and Behavioral Consequences of Introgression of a Domesticated Aquaculture Genotype into a Native Strain of Coho Salmon. Transactions of the American Fisheries Society 135:442-455.

U.S .Fish and Wildlife Service, National Oceanographic and Atmospheric Administration, and New York State Division of Fish, Wildlife, and Marine Resources (Co-lead agencies). 2012. National Fish, Wildlife and Plants Climate Adaptation Strategy, Public Review Draft. January 2012. Available at: http://www.wildlifeadaptationstrategy.gov/pdf/public_review_draft.pdf.

U.S. Army Corps of Engineers. 2007. Status Report—Pinniped Predation and Hazing at Bonneville Dam in 2007. Fisheries Field Unit CENWPOP-SRF Bonneville Lock and Dam, Cascade Locks, Oregon.

U.S. Army Corps of Engineers. 2011a. 2011 Field Report: Evaluation of Pinniped Predation on Adult Salmonids and Other Fish in the Bonneville Dam Tailrace. Portland

District, Fisheries Field Unit. Prepared by Robert J. Stansell, Karrie M. Gibbons, William T. Nagy, and Bjorn K. van der Leeuw.

U.S. Army Corps of Engineers. 2011b. Survival and Passage of Juvenile Chinook Salmon and Steelhead Passing Through Bonneville Dam, 2010. Draft Final Report. Prepared for the U.S. Army Corps of Engineers, Portland District, by Pacific Northwest National Lab, under an Interagency Agreement with the U.S. Department of Energy, Contract DE-AC05-76RLO1830. PNNL 20835. October 2011.

U.S. Department of Agriculture and U.S. Department of Interior. 1994. Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents within the Range of the Northern Spotted Owl. Washington, D.C.

U.S. Fish and Wildlife Service. 1995. Fish Health Policy and Implementation, 713 FW., U.S. Fish and Wildlife Service Manual (FWM). U.S. Fish & Wildlife Service, Washington, D.C.

U.S. Fish and Wildlife Service. 1998. Bull Trout Facts. Public Affairs Office, USFWS, Portland Oregon. May 1998.

U.S. Fish and Wildlife Service. 2004. Fish Health Policy and Implementation, 713 FW 1-5, U.S. Fish and Wildlife Service Manual (FWM) U.S. Fish & Wildlife Service, Washington, D.C.

U.S. Fish and Wildlife Service. 2005. Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary. Final environmental impact statements. Portland, Oregon.

U.S. Fish and Wildlife Service. 2006. Revised Hawaiian Forest Birds Recovery Plan. Available at: http://www.fws.gov/pacificislands/recoveryplans.html.

U.S. Fish and Wildlife Service. 2008. Bull Trout (*Salvelinus confluentus*) 5-Year Review: Summary and Evaluation. U.S. Fish and Wildlife Service, Portland, Oregon.

U.S. Fish and Wildlife Service. 2010. Bull trout background information (biology, species description, proposed critical habitat description, species profile). Available at http://www.fws.gov/pacific/bulltrout/. Website accessed March 31, 2010.

Volkman, J.M. 1997. A River in Common: The Columbia River, the Salmon Ecosystem, and Water Policy. A report to the Western Water Policy Review Advisory Commission. Springfield, VA: National Technical Information Service.

Waples, R.S., R.P. Jones, Jr., B.R. Beckman, and G.A. Swan. 1991. Status Review for Snake River Fall Chinook Salmon. United States Department of Commerce, National Oceanic and Atmospheric Administration.

Ward, B.R., and P.A. Slaney. 1988. Life History and Smolt-to-Adult Survival of Keogh River Steelhead Trout (*Salmo gairdneri*). Canadian Journal of Fisheries and Aquatic Sciences 45:1110-1122.

Washington Department of Ecology. 2011. Interim Recommendations from Topic Advisory Group 3: Species, Habitats and Ecosystems, February, 2011. Washington State Integrated Climate Change Response Strategy. Available at: http://www.ecy.wa.gov/climatechange/2011TAGdocs/E2011_interimreport.pdf.

Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife. 2002. Status Report: Columbia River Fish Runs and Fisheries, 1938-2000. July 2002. 324 pg.

Washington Department of Fish and Wildlife, Western Washington Treaty Indian Tribes, and Northwest Indian Fisheries Commission. 1995. Dungeness River Chinook Salmon Rebuilding Project Progress Report 1992-93. C.J. Smith and P. Wampler, Editors.

Washington Department of Fish and Wildlife and Western Washington Treaty Indian Tribes. 1998. Salmonid Disease Control Policy of the Fisheries Co-Managers of Washington State. Olympia, Washington.

Washington Department of Fish and Wildlife. 1996. Fish Health Manual. Fish Health Division, Hatcheries Program. Washington Department of Fish and Wildlife, Olympia, Washington.

Washington State Department of Transportation. Population Growth in Relation to the State's Counties. Website accessed November 29, 2011. http://www.wsdot.wa.gov/planning/wtp/datalibrary/population/PopGrowthCounty.htm.

Washington State Natural Resources Cabinet. 1999. Statewide Strategy to Recover Salmon: Extinction Is Not an Option. Washington Governor's Salmon Recovery Office. Olympia, WA.

Welander, A.D. 1940. Notes on the Dissemination of Shad, *Alosa sapidissima* (Wilson), along the Pacific Coast of North America. Copeia 1940(4): 221-223.

Welch, K.F., M. Yinger and K. Callahan. 2002. WRIA 29: Hydrology and Geology Assessment. Review draft. Prepared for Envirovision Corp. and WRIA 29 Planning Unit.

Western Regional Climate Center. 2003. National Oceanic and Atmospheric Organization, National Climatic Data Center. http://www.wrcc.dri.edu/index.html.

Whitney, R.R., L. Calvin, M. Erho, and C. Coutant. 1997. Downstream Passage for Salmon at Hydroelectric Projects in the Columbia River Basin: Development, Installation, and Evaluation. U.S. Department of Energy, Northwest Power Planning Council, Portland, Oregon. Report 97-15. 101 pp.

Wiles, G.J. 2004. Washington State Status Report for the Killer Whale. Washington Department of Fish and Wildlife. March 2004.

Wiley, M.W. 2004. Analysis Techniques to Incorporate Climate Change Information into Seattle's Long Range Water Supply Planning. Master's Thesis, Department of Civil and Environmental Engineering, University of Washington; Seattle, WA.

Wipfli, M.S., J.P. Hudson, D.T. Chaloner, and J.P. Caouette. 1999. Influence of Salmon Spawner Densities on Stream Productivity in Southeast Alaska. Canadian Journal of Fisheries and Aquatic Sciences 56:1600-1611.

Withler, R.E. 1988. Genetic Consequences of Fertilizing Chinook Salmon (*Oncorhynchus tshawytscha*) Eggs with Pooled Milt. Aquaculture 68: 15-25.

Zamon, J.E., T.J. Guy, K. Balcomb, and D. Ellifrit. 2007. Winter Observations of Southern Resident Killer Whales (*Orcinus Orca*) near the Columbia River Plume during the 2005 Spring Chinook Salmon (*Oncorhynchus Tshawytscha*) Spawning Migration. Northwestern Naturalist. Volume 88, pages 193 to 198.