Proposed ESA Recovery Plan for Snake River Fall Chinook Salmon *(Oncorhynchus tshawytscha)*

September 2015


Photo: U.S. Fish & Wildlife

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Acronyms and Abbreviations

A/P	abundance and productivity
BiOp	Biological Opinion
BOR	US Bureau of Reclamation
BPA	Bonneville Power Administration
BRT	Biological Review Team
CA	Comprehensive Analysis
COE	US Army Corps of Engineers
Council	Northwest Power and Conservation Council
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
CWT	coded-wire-tagging
DPS	distinct population segment
EDT	Ecosystem Diagnosis and Treatment
ESA	Endangered Species Act
ESU	evolutionarily significant unit
FCRPS	Federal Columbia River Power System
FERC	Federal Energy Regulatory Commission
FMEP	Fisheries Management and Evaluation Plan
FR	Federal Register
GIS	Geographic Information System
GNRO	Governor’s Natural Resources Office (Oregon)
GSRO	Governor's Salmon Recovery Office (Washington State)
HCP	Habitat Conservation Plan
HGMP	Hatchery and Genetic Management Plan
IDFG	Idaho Department of Fish and Game
ICTRT/ICBTRT	Interior Columbia (Basin) Technical Recovery Team
IPC	Idaho Power Company
LCREP	Lower Columbia River Estuary Partnership
MPG	major population group
MSA	major spawning areas
N/A	Not Applicable
NGO	non-governmental organizations
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPCC or NWPCC	Northwest Power and Conservation Council
NPT	Nez Perce Tribe
NPTH	Nez Perce Tribal Hatchery
ODFW	Oregon Department of Fish and Wildlife
OR	Oregon
pHOS	proportion of hatchery-origin spawners
PNI	proportion of natural influence (in hatchery broodstock)

RIST	Recovery Implementation Science Team
RM	river mile
SCA	Supplemental Comprehensive Analysis
SRSRB	Snake River Salmon Recovery Board
SS/D	spatial structure and diversity
TDG	total dissolved gas
TRT	Technical Recovery Team
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
VSP	viable salmonid population
WDFW	Washington Department of Fish and Wildlife
WRIA	Water Resource Inventory Area

Terms and Definitions

Abundance	In the context of salmon recovery, abundance refers to the number of natural-origin adult (excluding jacks) fish returning to spawn.
Acre-feet	A common measure of the volume of water in the river system. It is the amount of water it takes to cover one acre (43,560 square feet) to a depth of one foot.
Adaptive Management	The process of adjusting management actions and/or directions based on new information.
All-H Approach	The idea that actions could be taken to improve the status of a species by reducing adverse effects of the hydrosystem, predators, hatcheries, habitat, and/or harvest.
Anadromous Fish	Species that are hatched in freshwater migrate to and mature in salt water, and return to freshwater to spawn.
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 outside the recovery planning process, generally by fisheries managers (state and tribal entities), that go beyond the requirements for delisting, to address, for example, other legislative mandates or social, economic and ecological values.
Brood Cycles	Salmon and steelhead mature at different ages so their progeny return as spawning adults over several years. When all progeny at all ages have returned to spawn, the brood cycle is complete.
Compliance Monitoring	Monitoring to determine whether a specific performance standard, environmental standard, regulation, or law is met.
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.
Distinct Population Segment (DPS)	A listable entity under the ESA that meets tests of discreteness and significance according to USFWS and NOAA Fisheries 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. Analogous to ESU.
Diversity	All the genetic and phenotypic (life history, behavioral, and morphological) variation within a population. Variations could include anadromy versus lifelong residence in freshwater, fecundity, run timing, spawn timing, juvenile behavior, age at smolting, age at

	maturity, egg size, developmental rate, ocean distribution patterns, male and female spawning behavior, physiology, molecular genetic characteristics, etc.
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.
Effectiveness Monitoring	Monitoring set up to test cause-and-effect hypotheses about RPA actions intended to benefit listed species and/or designated critical habitat. 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. Equivalent to a distinct population segment and treated as a species under the Endangered Species Act. Analogous to DPS.
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.
Fish Ladder	A series of stair-step pools that enables adult salmon and steelhead to migrate upstream past a dam. Swimming from pool to pool, adult salmon and steelhead work their way up the ladder to the top where they continue upriver.
Flow Augmentation	Water released from system storage at targeted times and places to increase streamflows to benefit migrating juvenile salmon and steelhead
Functionally Extirpated	Describes a species 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.

Implementation Monitoring	Monitoring to determine whether an activity was performed and/or completed as planned.
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	Productivity at very low population size; unconstrained by density.
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 (usually a land use) that continue to affect a stream or watershed in the present day.
Limiting Factors	Impaired physical, biological, or chemical features (e.g., inadequate spawning habitat, high water temperature, insufficient prey resources) 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 (or major population group's or species') ability to reach its desired status.
Major Population Group (MPG)	An aggregate of independent populations within an ESU that share similar genetic and spatial characteristics.
Management Unit	A geographic area defined for recovery planning purposes on the basis of state 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.
Minor Spawning Area (MiSA)	A river system with one or more branches that contains sufficient spawning and rearing habitat to support 50 – 500 spawners (defined using intrinsic potential analysis).
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.
Peak Flow	The maximum rate of flow occurring during a specified time period at a particular location on a stream or river.
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	Describes any animal that preys on fish for food.
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.
Reach	A length of stream between two points.
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. These goals may go beyond the requirements of ESA de-listing by including other legislative mandates or social values.
Recovery Plan Supplement	A NMFS supplement to a locally developed recovery plan that describes how the plan addresses ESA requirements for recovery plans. The supplement also proposes ESA delisting criteria for the ESUs addressed by the plan, since a determination of these criteria is a NMFS decision.
Recovery Scenarios	Scenarios that describe a target status for populations that make up an ESU, generally consistent with ICTRT recommendations for ESU viability.
Recovery Strategy	A statement that identifies the assumptions and logic—the rationale—for the species' recovery program.
Recruit	An individual fish that survives into a defined life stage, for example spawner recruit.
Redd	A nest constructed by female salmonids in streambed gravels where eggs are deposited and fertilization occurs.
Resident Fish	Fish that are permanent inhabitants of a water body. Resident fish include trout, bass, and perch.
Riparian Area	Area with distinctive soils and vegetation between a stream or other body of water and the adjacent upland. It includes wetlands and those portions of floodplains and valley bottoms that support riparian vegetation.
Salmonid	Of, belonging to, or characteristic of the family Salmonidae, which includes salmon, steelhead, trout, and whitefish. In this document, it refers to listed steelhead distinct population segments (DPS) and salmon evolutionarily significant units (ESU).

Self-sustaining	A self-sustaining viable population has a negligible risk of extinction due to reasonably foreseeable changes in circumstances affecting its abundance, productivity, spatial structure, and diversity characteristics over a 100- year period and achieves these characteristics without dependence upon artificial propagation. Artificial propagation may be used to benefit threatened and endangered species and a self-sustaining population may include artificially propagated fish, but a self-sustaining population must not be dependent upon propagation measures to achieve its viable characteristics. Artificial propagation may contribute to but is not a substitute for addressing the underlying factors (threats) causing or contributing to a species' decline.
Smolt	A juvenile salmon or steelhead migrating to the ocean and undergoing physiological changes to adapt from freshwater to a saltwater environment.
Spatial structure	The geographic distribution of a population or the populations in an ESU.
Stray	Hatchery or naturally produced fish returning to population area other than the one that it originated in.
Stakeholders	Agencies, groups, or private individuals with an interest in the FCRPS or the management of natural resources affected by the FCRPS or relevant to its mitigation.
Technical Recovery Team (TRT)	Teams convened by NOAA Fisheries to develop technical products related to recovery planning. Technical Recovery Teams are complemented by planning forums unique to specific states, tribes, or regions, which use TRT and other technical products to identify recovery actions. See SCA Section 7.3 for a discussion of how TRT information is considered in these Biological Opinions.
Threatened Species	A species likely to become endangered within the foreseeable future throughout all or a significant portion of its range.
Threats	Human activities or natural events (e.g., dams, road building, floodplain development, fish harvest, hatchery influences, volcanoes) that cause or contribute to limiting factors. Threats may exist in the present or be likely to occur in the future.
Viability criteria	Criteria defined by NOAA Fisheries-appointed Technical Recovery Teams based on the biological parameters of abundance, productivity, spatial structure, and diversity, which describe a viable salmonid population (VSP) (an independent population with a negligible risk of extinction over a 100-year time frame) and which describe a general framework for how many and which populations within an ESU should be at a particular status for the ESU to have an acceptably low risk of extinction. See SCA Section 7.3 for a discussion of how TRT information is considered in these Biological Opinions.
Viability Curve	A curve describing combinations of abundance and productivity that yield a particular risk of extinction at a given level of variation over a specified time frame.
Viable Salmonid Population (VSP)	An independent population of Pacific salmon or steelhead that has a negligible risk of going extinct as a result of genetic change, demographic stochasticity (i.e., random effects when abundance is low), or normal levels of environmental variability.

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

Snake River Fall Chinook Salmon Recovery Plan

Introduction

This recovery plan (plan) serves as a blueprint for the protection and recovery of Snake River fall-run Chinook salmon. NOAA's National Marine Fisheries Service (NMFS) first listed Snake River fall-run Chinook salmon, an evolutionarily significant unit (ESU) of Chinook salmon (*Oncorhynchus tshawytscha*), as a threatened species under the Endangered Species Act (ESA) on April 22, 1992 (NMFS 1992, 57 FR 14658). NMFS reaffirmed the listing status on June 28, 2005 (NMFS 2005a, 70 FR 37160), and reaffirmed the status again in NMFS' 2010 Five-Year Review of Snake River listed species (NMFS 2011a).

At one time the run numbered half a million strong. Historically, this mighty run of fall Chinook salmon traveled more than 300 miles up the Columbia River to the Snake River each year and spawned throughout the 600-mile reach of the mainstem Snake River downstream of Shoshone Falls, a natural 212-foot barrier, and in several major tributaries. The fish run began to decline toward the end of the 19th century due to overharvest and other factors. The run continued to drop until the 1990s, leading to its ESA listing and triggering many changes to stem the decline and return the run to a healthy level.

Today, thanks to improvements made throughout its life cycle, the fish run is making a comeback. Many more fall Chinook salmon now return to the Snake River than in the 1990s. In recent years at least 50,000 hatchery- and natural-origin adult fall Chinook salmon combined have passed over Lower Granite Dam into the Snake River basin each year. Nevertheless, substantial uncertainty remains regarding the status of the species' productivity and diversity, and whether the ESU could be self-sustaining over the long term. This plan identifies actions designed to take the ESU the remaining distance to reach a naturally self-sustaining level.

The listed ESU includes all natural-origin fall-run Chinook salmon from the mainstem Snake River below Hells Canyon Dam (the lowest of three impassable dams that form the Hells Canyon Complex) and from the Tucannon River, Grande Ronde River, Imnaha River, Salmon River, and Clearwater River subbasin. Also, fall-run Chinook salmon from four artificial propagation programs: Lyons Ferry Hatchery Program, Fall Chinook salmon Acclimation Ponds Program, Nez Perce Tribal Hatchery Program, and the Oxbow (Idaho Power Company) Hatchery Program (Figure ES-1).

Historically, the ESU also included fall Chinook salmon that spawned in the middle mainstem Snake River and tributaries above Hells Canyon. This area upstream of Hells Canyon supported the majority of historical Snake River fall Chinook salmon production until the area became inaccessible due to dam construction. The fish could also access nine major tributaries that joined the middle Snake River ─ Salmon Falls Creek and the Owyhee, Bruneau, Boise, Payette, Weiser, Malheur, Burnt, and Powder Rivers ─ but the tributaries were likely less important to the species than the mainstem spawning areas. The loss of this upstream habitat and inundation of downstream mainstem spawning areas by reservoirs associated with the Hells Canyon Complex and three lower Snake River dams reduced spawning habitat for the species to approximately 20 percent of the historically available area.

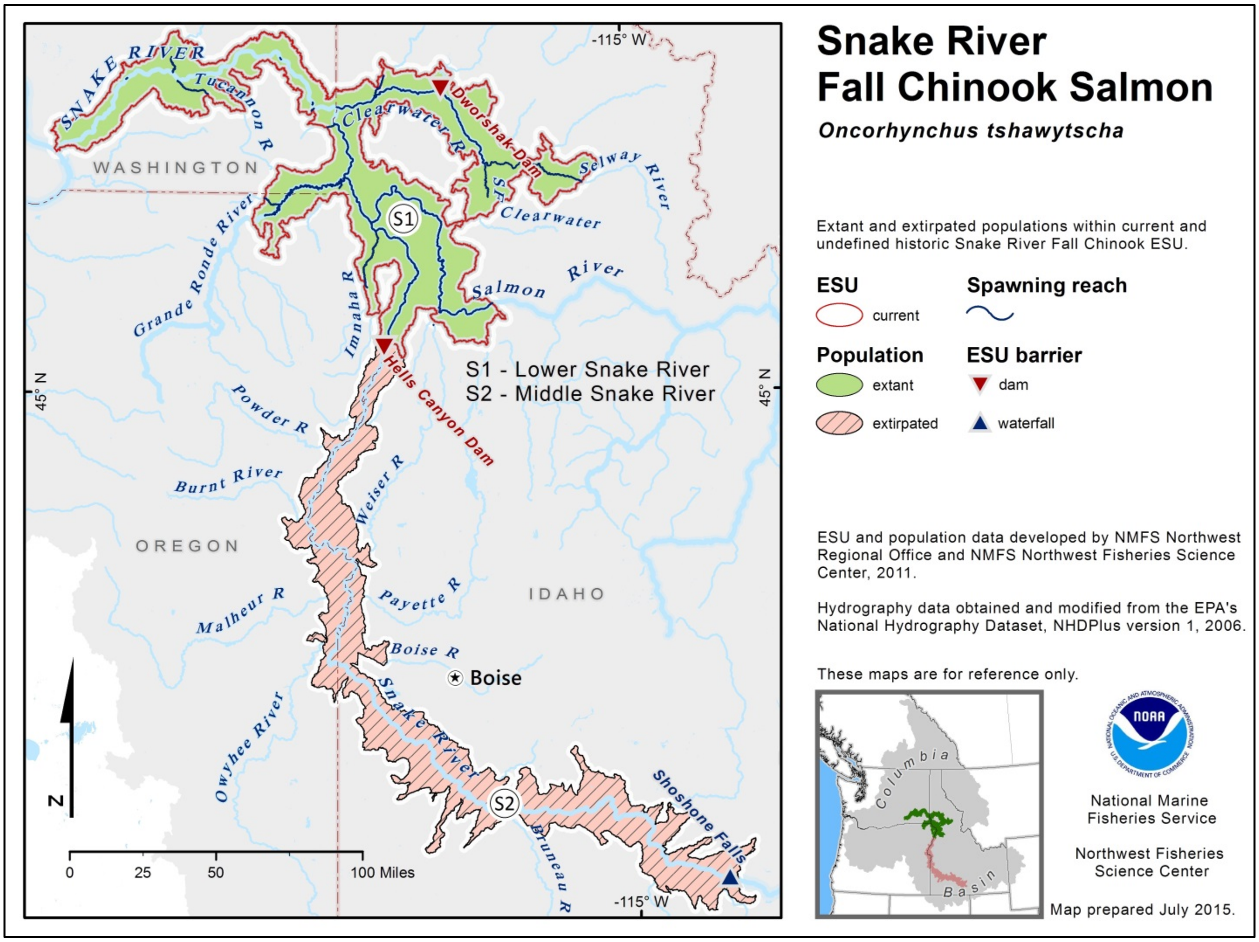

Figure ES-1. Snake River fall Chinook salmon ESU and historical spawning range in the Middle Snake River mainstem.

About This Recovery Plan

The ESA requires NMFS to develop recovery plans for species listed under the ESA. The plan provides information required to satisfy section 4(f) of the ESA. It describes: (1) recovery goals and objectives, measurable criteria which, when met, will result in a determination that the species be removed from the threatened and endangered species list; (2) site-specific management actions necessary to achieve the plan's goals; and (3) estimates of the time required and cost to carry out the actions. NMFS intends to use the recovery plan to organize and coordinate recovery of the species in partnership with state, tribal, and federal resource managers.

The plan also provides other information that can help frame Snake River fall Chinook salmon conservation, recovery, and research efforts. It summarizes ESU viability, and describes the limiting factors and threats that impact viability and recovery. It identifies a set of strategies and actions to address the limiting factors and threats, and achieve ESU recovery. It also describes an adaptive management framework, direction for research, monitoring, and evaluation (RM&E), and an implementation framework to fine-tune the course towards recovery.

Several appendices to the plan provide additional information about Snake River fall Chinook salmon: Appendix A ─ Current ESU Viability Assessment; Appendix B ─ Research, Monitoring & Evaluation for Adaptive Management; and Appendix C ─ Temperature in the Lower Snake River during Fall Chinook Salmon Egg Incubation, Fry Emergence, Shoreline Rearing, and Early Seaward Migration. The plan also incorporates as appendices four modules produced by NMFS with details of conditions faced by this and other Snake River salmon and steelhead: Appendix D ─ *Module for the Ocean Environment* (Ocean Module) (Fresh et al. 2014), Appendix E ─ *Supplemental Recovery Plan Module for Snake River Salmon and Steelhead Mainstem Columbia River Hydropower Projects* (Hydro Module) (NMFS 2008, 2014a), Appendix F ─ *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (Estuary Module) (NMFS 2011b), and Appendix G ─ *Snake River Harvest Module* (Harvest Module) (NMFS 2014b). NMFS will update these modules periodically to reflect new data.

Why a recovery plan?

Snake River fall Chinook salmon, which spawn and rear in the lower mainstem Snake River and several tributaries below the Hells Canyon Complex of dams, remain at risk of extinction. The once strong salmon run historically returned primarily to the middle Snake River above the Hells Canyon Complex. The fish run began to decline in the late 1800s due to overharvest and other factors. It continued to decline until the 1990s, persuading NMFS to list the fish as Threatened under the Endangered Species Act and triggering many actions to stop the decline and return the run to a healthy level.

Many more fall Chinook salmon now return to the Snake River than at the time of ESA listing but it remains uncertain whether recent increases in natural-origin abundance can be sustained over the long run. More work is needed to take the species the remaining distance and ensure its long-term survival.

What is needed to reach recovery?

The recovery strategy aims to establish a self-sustaining, naturally spawning fall Chinook salmon population that is sufficiently abundant, productive, and diverse and likely to persist in the long term, defined as the next 100 years.

Historical Context

Historically, most fall Chinook salmon returning to the Snake River spawned in the middle mainstem, an area fed by springs delivering warm water from the Eastern Snake River Aquifer. Extensive spring releases from the aquifer, including from a large spring complex known as Thousand Springs, contributed about 4,000 cubic feet per second of flow at an average temperature of approximately 15.5 °C (60 °F) to the reach and influenced water temperatures in the river over about 86 miles (Figure ES-2). The area once provided prime spawning, incubation, and early rearing conditions for fall Chinook salmon. In comparison, only limited spawning occurred below RM 273, where most fall Chinook salmon spawn today.

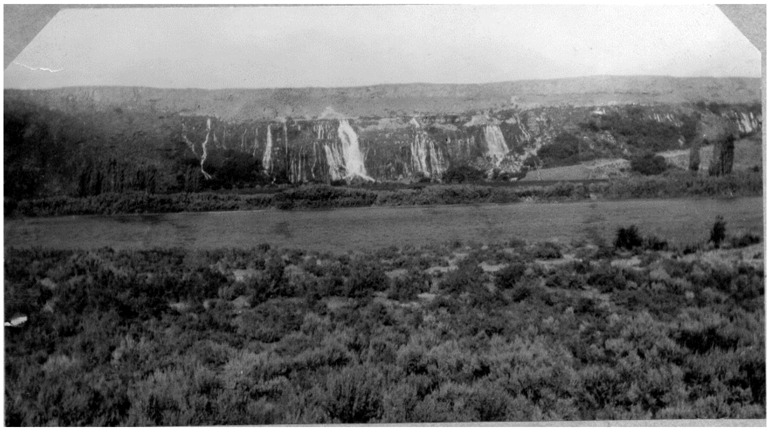

Figure ES-2. The area known as Thousand Springs (RM 584).

The Fish Run's Decline, ESA Listing and Progress towards Recovery

As late as the late 1800s, approximately 408,500 to 536,180 fall Chinook salmon are believed to have returned annually to the Snake River. The run began to decline in the late 1800s and then continued to decline through the early and mid-1900s as a result of overfishing and other human activities, including the construction of major dams (Table ES-1).

The drastic decline in Snake River fall Chinook salmon led NMFS to list the species under the ESA in 1992. NMFS status reviews (NMFS 1991, 1999a, 2005a; Waples et al. 1991; Busby 1999; Good et al. 2005) that led to the original listing decision and subsequent affirmations of threatened status cite loss of primary spawning and rearing areas upstream of the Hells Canyon Complex, the effects of the FCRPS below Hells Canyon and through the estuary, the increase in nonlocal hatchery contribution to adult escapement over Lower Granite Dam, and the relatively high aggregate harvest impacts by ocean and in-river fisheries as the factors causing the steady and severe decline in abundance of Snake River fall Chinook salmon (Good et al. 2005). The 1991 status review (Waples et al. 1991) and most recent status reviews (ICTRT 2010 and NMFS 2011a) added concerns about effects on natural-origin productivity and diversity from hatchery operations and increasing proportions of hatchery-origin fish on the spawning grounds.

Since the listing, combined management actions implemented by different entities to reverse the decline have boosted adult and juvenile survival through the hydropower system, reduced losses to harvest, lowered predation rates, improved habitats, reduced straying of out-of-ESU hatchery fish, and increased natural production using hatchery supplementation. Implemented RM&E now provides critical information on the run and the effectiveness of different actions.

Table ES-1. History of Activities Contributing to Snake River Fall Chinook Salmon decline and recovery.

Date	Human Activities Affecting Snake River Fall Chinook Salmon	Habitat and Harvest Status	Estimated Fish Abundance
Late 1800s	Mainstem and tributary habitat degradation begins due to mining, timber harvest, agriculture, livestock production, and other activities.		Annual return of 408,500 to 536,180 adult fall Chinook salmon to Snake River mouth
1890s	Commercial harvest of Columbia River salmon turns from spring and summer Chinook to fall Chinook	Harvest peaks near 80% of returning fall Chinook adults	Run begins decline
1901-1902	Swan Falls Dam constructed on Snake River (RM 457.7) First full-scale hatchery constructed at Swan Falls (1902); operated 1902-1909	Access blocked to 157 miles mainstem	Substantial reduced abundance in middle mainstem Snake River
1904-1925	Harvest regulations on lower Columbia. Commercial fisheries move above Celilo Falls in 1904. Fish wheels outlawed: Oregon (1928) and Washington (1935).		Run continues decline
1927	Lewiston Dam constructed on Clearwater River (RM 6)	Access blocked to Clearwater R. 1927-73	
1938-1947	Bonneville Dam completed in 1938 on Columbia River (RM 146)	Columbia River harvest rate on returning fall Chinook adults at 64.1% to 80.2%	89,800-197,300 SR fall Chinook return yearly to Columbia River; 47,600 highest annual return to Snake River
1950s	McNary Dam completed in 1953 on Columbia River (RM 292) The Dalles Dam completed in 1957 on Columbia River (RM 191.5)		29,000 adults average annual return
1958-1967	Hells Canyon Complex dams constructed on middle Snake River: Brownlee (1958), Oxbow (1961), and Hells Canyon (1967) (RM 285, 273, and 247 respectively)	Access blocked to 210 miles of habitat.	Fall Chinook salmon population in the Middle Snake River is extirpated
1960-1975	Four dams constructed on lower Snake River: Ice Harbor (1961), Lower Monumental (1969), Little Goose (1970), Lower Granite (1975)	Dams inundate 135 more miles of mainstem; 83% of mainstem habitat lost.	Abundance declines further.
1964-1968	John Day Dam completed in 1968 on Columbia River (RM 215.6)		12,720 adults average annual return to Snake River
1969-1976	Lower Snake River Compensation Plan starts compensation for losses (1976).		2,814 adults return to Snake River in 1974; 2,558 in 1975
1975-1980	Transportation of juvenile fall Chinook past lower Snake River dams begins late 1970s.		610 adults average annual return, reaches low or 100 adults in 1978
1980s	Hatcheries begin to play major role in production of Snake River fall Chinook salmon. Lyons Ferry Hatchery begins fall Chinook production in 1984.		
Late1980s to mid-90s	Hatchery production increases. Agreements reduce harvest impact from ocean/Columbia River fisheries.	Total exploitation rate on run averages 62% (1988-94)	100 +/- natural-origin adults average annual return. Stray out-of-ESU hatchery fish major risk.
1990-1992	Snake River fall Chinook salmon listed under the ESA as threatened (1992).		350 adults return, includes 78 natural-origin fish (1990)
1993	Corps of Engineers begins drafting Dworshak Dam to enhance juvenile migration.		
1995	Fall Chinook Acclimation Program implemented.		
1996-2001	Actions in 1995 FCRPS BiOp implemented in 1996. Improve dam passage/operations for migration.		2,164 average annual adult return to Snake River; includes 1,055 natural-origin fish (1997-2001)
2000-02	Oxbow Hatchery program begins in 2000. Nez Perce Tribal Hatchery program begins in 2002. Together, four hatchery programs release up to 5.5 million fish.		Abundance increases.
2000-2007	Actions in 2000 FCRPS BiOp implemented. Improve dam passage/ operations for migration (include increased summer spill from 2005 Court Order.)		Abundance increases.
2003-08	Snake River fall Chinook salmon ESA listing reaffirmed (2005). Agreements further reduce harvest impact from ocean/Columbia River fisheries.	Total exploitation rate on run averages 31% (2003-10)	11,321 average annual adult return to Snake River; includes 2,291 natural-origin fish
2008-2014	Actions in 2008 FCRPS BiOp implemented to improve dam passage/ operations for migration. Include increased summer spill and final installations of surface passage routes (spillway weirs, sluiceways, corner collectors) at all mainstem dams. Snake River fall Chinook salmon ESA listing reaffirmed (2011).		50,000+ average annual adult return to Snake River; includes 6,418 natural-origin annual return (2005-2014)

Life History

Snake River fall-fun Chinook salmon exhibit an ocean-type life history pattern, with many young salmon rearing in their natal habitat for only a short time before migrating downstream to the mainstem Snake and Columbia Rivers and estuary. The fish emerge from spawning redds from April to June, depending on the areas, and most begin migrating downstream in June and July; juveniles in the Clearwater River begin migrating in late summer and may even overwinter in the Clearwater or Snake Rivers. Once in the Columbia River and estuary, some juvenile fish enter the plume and ocean as subyearlings, while others overwinter and enter the ocean as yearlings. The salmon spend one to four years in the Pacific Ocean and return to the Columbia River in August and September. Adults enter the Snake River between early September and mid-October, and spawn through early December.

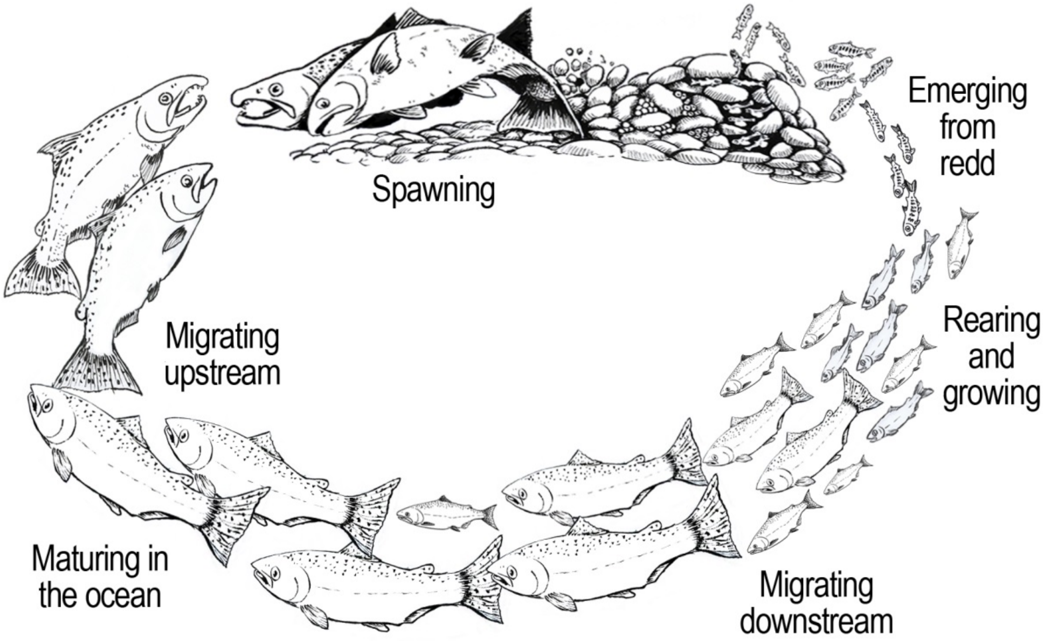

Figure ES-3. Snake River fall Chinook salmon Life Cycle.

Egg incubation, emergence timing, and other early life history stages of Snake River fall Chinook salmon are significantly influenced by water temperature. Historically, the warm spring-fed reaches of the middle mainstem Snake River supported rapid incubation and emergence, and likely produced more food for juveniles. Early emerging juveniles in the middle Snake River fed and grew in their natal areas and then migrated downstream before summer water temperatures rose to potentially lethal levels. In comparison, fall Chinook salmon produced from colder reaches, such as the Clearwater River and Hells Canyon reach of the Snake River, emerged later than juveniles in the middle mainstem, and had less food and time to rear before migrating.

Today, water temperature and growth opportunity during egg incubation and early rearing continue to create variations in early life history among fish in the five major spawning areas. The mainstem Snake River from Hells Canyon Dam to the mouth of the Salmon River is more conducive to fall Chinook salmon production, with warmer flows during egg incubation fostering an earlier emergence than historically due to releases from the Hells Canyon Complex.

Scientific Foundation

NMFS' belief that it is critically important to base recovery plans on a solid scientific foundation set the stage for developing recovery plans. NMFS appointed teams of scientists with geographic, species and/or topical expertise to provide a solid scientific foundation for recovery plans. The team responsible for the Snake River fall Chinook salmon ESU, the Interior Columbia Technical Recovery Team (ICTRT), included biologists from NMFS and several states, tribal entities, and academic institutions.

The scientific foundation recognizes that, historically, most salmon or steelhead species contained multiple populations connected by some small degree of genetic exchange with spawners from other areas. Thus, the overall biological structure of a species is hierarchical.

The Snake River fall Chinook salmon evolutionarily significant unit (ESU) reflects this hierarchical structure. The ESU is essentially a metapopulation of Pacific salmon that is (1) substantially reproductively isolated from other groups of the same species, and (2) represents an important component of the evolutionary legacy of the species. The ESU structure reflects the species' geographic range and genetic, behavioral, and other traits. The ICTRT defined Snake River fall Chinook salmon as a single major population group (MPG) within the Snake River fall Chinook salmon ESU. The MPG contains one extant natural-origin population (Lower Mainstem Snake River population). The ICTRT identified five major spawning areas (MaSAs) within the Lower Mainstem Snake River population (Figure ES-4). A major spawning area is defined as a system of one or more branches containing sufficient habitat to support at least 500 spawners.

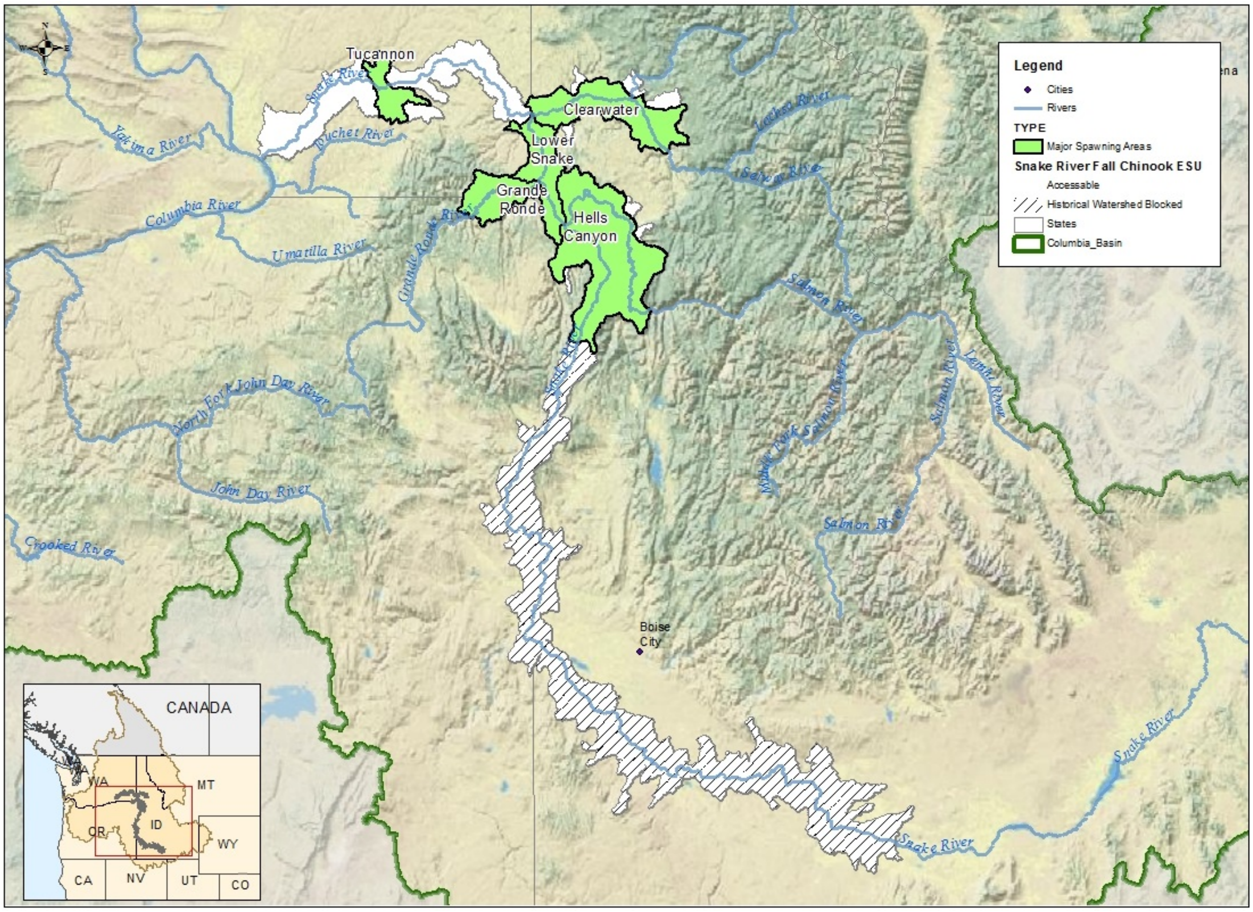

Figure ES-4. Current Snake River fall Chinook salmon Major Spawning Areas.

Recovery Goals, Objectives and Criteria

The recovery plan provides recovery goals, objectives, and criteria that NMFS will use in future status reviews of the Snake River fall-run Chinook salmon ESU. The primary goal for the species is recovery to a self-sustaining condition. NMFS's approach to recovery aims to achieve this goal while recognizing federal legal obligations, mitigation goals, and other social, cultural, and economic values regarding the listed species. Section 3 describes the ESA recovery goal and broad sense goals.

ESA Recovery Goal: The primary goal of the recovery plan is the ESA recovery goal for the Snake River fall Chinook salmon ESU. This goal is that:

- *The ecosystems upon which Snake River fall Chinook salmon depend are conserved such that the ESU is self- sustaining in the wild and no longer needs ESA protection.*

A self-sustaining viable ESU depends on the status of its populations and the ecosystems (e.g. habitats) that support them. A self-sustaining viable population has a negligible risk of extinction due to reasonably foreseeable changes in circumstances affecting its abundance, productivity, spatial structure, and diversity characteristics over a 100- year time frame and achieves these characteristics without dependence upon artificial propagation.

Artificial propagation may be used to benefit threatened and endangered species, and a self-sustaining population may include artificially propagated fish, but a self-sustaining population must not be dependent upon propagation measures to maintain its viable characteristics. Artificial propagation may contribute to, but is not a substitute for, addressing the underlying factors (threats) causing or contributing to a species' decline.

ESA Recovery Objectives: The ESA recovery objectives define the conditions necessary to meet the ESA recovery goal.

Abundance and productivity: Population-level persistence in the face of year-to-year variations in environmental influences.

- ESU- and population-level combination of abundance and productivity sufficient to maintain genetic, life history, and spatial diversity and sufficient to exhibit demographic resilience to environmental perturbations.

Spatial Structure: Resilience to the potential impact of catastrophic events.

- Spatial structure of populations and spawning aggregations distributed in a manner that insulates against loss from a local catastrophic event and provides for recolonization of a population or aggregations that is affected by such an event.

Diversity: Long-term evolutionary potential.

- Patterns of phenotypic, genotypic, and life history diversity that sustain natural production across a range of conditions, allowing for adaptation to changing environmental conditions.

Threats: The underlying causes of decline have been addressed.

- The primary threats to the species have been ameliorated and regulatory mechanisms are in place that should help prevent a recurring need to re-list Snake River fall Chinook salmon as threatened or endangered.

Broad Sense Goals: While the primary goal of this plan is ESA delisting of the species, the plan intends to achieve ESA recovery in a manner that takes into account other federal legal obligations, mitigation goals, and other broad sense goals to provide social, cultural, or economic values. These broader or 'broad sense' goals go beyond the requirements for delisting. The broad sense goals include: (1) subbasin visions for healthy ecosystems with abundant, productive, and diverse species and habitats that also support the social, cultural, and economic well-being; (2) treaty and trust obligations to the Columbia Basin tribes with treaty-reserved rights to take salmon at their usual and accustomed fishing places and implement Secretarial Order # 3206, American Indian Tribal Rights, Federal-Tribal Trust Responsibilities, and the Endangered Species Act; (3) federally authorized requirements for hatchery-origin and natural-origin returns of Snake River fall Chinook salmon to mitigate for losses due to Snake River hydropower development and help maintain fisheries and enhance biological diversity of existing wild stocks;

and (4) reintroduction of fall Chinook salmon passage and populations above Hells Canyon Dam.

Criteria to determine when the Species is Recovered: Under the ESA, listing and delisting of marine species, including salmon, are the responsibility of NMFS. If a fish or other species is listed as threatened or endangered, legal requirements to protect it come into play. When NMFS decides through scientific review that the species is doing well enough to survive without ESA protection, NMFS will “delist” it. The decision must reflect the best available science concerning the current status of the species and its prospects for long-term survival.

NMFS uses two types of criteria to determine whether a species has met the recovery objectives and can be delisted:

1. Biological viability criteria define population or demographic parameters. The NMFS Technical Memorandum *Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units* (McElhany et al. 2000) provides guidance for defining biological viability criteria. Consistent with this guidance, the ICTRT defined viable salmonid populations (VSPs) in terms of four parameters: population abundance, productivity, spatial structure, and diversity.
2. Threats criteria. At the time of a delisting decision for the Snake River fall Chinook salmon ESU, NMFS will examine whether five listing factors (or threats) detailed in section 4(a)(1) of the ESA have been addressed: (a) Present or threatened destruction, modification, or curtailment of [the species’] habitat or range; (b) Over-utilization for commercial, recreational, scientific, or educational purposes; (c) Disease or predation; (d) Inadequacy of existing regulatory mechanisms; or (e) Other natural or human-made factors affecting [the species’] continued existence. Before delisting can occur, the listing factors need to have been addressed to the point that delisting is not likely to result in their re-emergence.

Addressing these criteria will help to ensure that underlying causes of decline have been addressed and mitigated before Snake River fall Chinook salmon are considered for delisting and that adequate regulatory mechanisms are in place that ensure continued persistence of a viable species beyond ESA recovery and delisting. NMFS expects that if the proposed actions described in the plan are implemented, they will make substantial progress toward meeting the biological viability and threats criteria and, thus, the recovery objectives.

Potential Snake River Fall Chinook Salmon Viability Scenarios

As with most ESUs, there is more than one path to achieve viability of the Snake River fall Chinook salmon ESU. The ESU has unique characteristics that provide opportunities to consider alternative combinations of viable populations and policy choices. While the ESU is presently reduced from two historical populations to just one extant population, the remaining population is well distributed across a large area that is spatially complex, with successful spawning and rearing across a diverse set of habitats in five major spawning areas. The population maintains the historically predominant subyearling life history strategy and demonstrates an additional yearling life history strategy adaptation. Population abundance of this population has grown substantially since ESA listing.

The ESU’s unique characteristics may allow recovery with just the one extant Lower Mainstem Snake River population. However, continued exploration and work toward establishing passage and a second population above Hells Canyon Dam would safeguard against further decline. It would also provide a buffer, greater resilience, and a potential longer-term ESA recovery option, in case the single population does not achieve and/or sustain ESU-level viability.

The plan describes two potential viability scenarios that would meet viability objectives for ESU recovery: Scenario A is for multiple populations (Lower Mainstem Snake River and the extirpated Middle Snake population above the Hells Canyon Complex). Scenario B achieves viability with the single extant population (Lower Mainstem Snake River). In addition, the plan describes necessary components for potential additional scenarios that could be developed to achieve viability with the single-population scenario. These additional scenarios would create Natural Production Emphasis Areas to produce high numbers of natural-origin spawners. Table ES-2 and Section 3 (Section 3.2.2) describes the scenarios in more detail.

The scenarios represent a broad spectrum of potential strategies suitable as targets for implementation and can be pursued simultaneously for the near future through actions across the life cycle. They will be revised and updated through adaptive management to address remaining uncertainties and respond to new information and as habitat conditions improve over time.

Table ES-2. Potential ESA Viability Scenarios for Snake River fall Chinook salmon.

Potential ESA Viability Scenarios and Viability Criteria for Snake River Fall Chinook Salmon
Scenario A: Multiple Populations. At least two populations; one highly viable the other viable.
Viability Criteria: 1. a) Lower Mainstem Snake River population has a combination of natural-origin abundance and productivity with a 50 percent probability of achieving Highly Viable status (1% risk of extinction over 100 years). b) Middle Snake River population has a combination of natural-origin abundance and productivity with a 50 percent probability of achieving Viable status (5% or lower risk of extinction over 100 years). 2. Two populations exhibiting robust spatial distribution of spawning aggregations. 3. All major habitat types occupied within a population. 4. Patterns of genetic and life history diversity reflect historically dominant patterns. 5. Any difference(s) from historical diversity patterns represent positive natural adaptations to prevailing environmental conditions. 6. Evolutionary trajectory of population is dominated by natural-selective processes.
Scenario B: Single Population Measured in the Aggregate. One population that is highly viable with high certainty and naturally produced fish well distributed and measured in the aggregate across multiple MaSAs.
Viability Criteria: 1. Combination of natural-origin abundance and productivity exhibits an 80 percent or higher probability of achieving Highly Viable status (1% risk of extinction over 100 years). 2. All major habitat types occupied within a population. 3. Patterns of genetic and life history diversity reflect historically dominant patterns. 4. Any difference(s) from historical diversity patterns represent positive natural adaptations to prevailing environmental conditions. 5. Evolutionary trajectory of population is dominated by natural-selective processes.
Placeholder: Natural Production Emphasis Area Scenario. One population that is highly viable with a substantial proportion of the ESUs natural-origin adult spawners from one or more major spawning areas with low proportion of hatchery-origin spawners.
Components would include: 1. The single population meets the ESU Viable Salmonid Population (VSP) objectives and achieves Highly Viable status (1% risk of extinction over 100 years). 2. Achievement of VSP objectives is based on population performance in one or more Natural Production Emphasis Areas (NPEAs). 3. One of the NPEAs would be the major spawning area in the mainstem Snake River above the Salmon River confluence because of its historical dominance. 4. The remaining major spawning areas that are not NPEAs should also produce natural-origin returns, but could have higher acceptable levels of hatchery-origin spawners.

Current ESU Biological Status

Snake River fall Chinook salmon abundance has increased significantly since ESA listing in the 1990s. Nevertheless, while the number of natural-origin fall Chinook salmon has been high, substantial uncertainty remains about the status of the species' productivity (the number adults returning per spawner) and diversity (the natural patterns of phenotypic and genotypic expression that ensure that populations can withstand environmental variation in the short and long terms).

NMFS assessed the current biological status of the one extant population, the Lower Mainstem Snake River fall Chinook salmon population, using the ICTRT biological viability criteria and information available in the spring of 2015. The viability assessment for the population focuses on status relative to potential ESA Viability Scenario B (single population aggregate) described above and in Section 3. Section 4 summarizes the current biological status assessment, which is described in more detail in Appendix A.

Current Risk Rating

The Lower Mainstem Snake River fall Chinook salmon population is currently rated as **Viable,** at low (1-5%) risk of extinction within 100 years, based on current population abundance/ productivity and spatial structure/ diversity. The population is rated at low risk for abundance/ productivity. The geometric mean abundance for the most recent 10 years of annual spawner escapement estimates (2005-2014) is 6,418 natural-origin adults. The estimated productivity is 1.5 (1999-2009 brood years), which indicates remaining uncertainty that current increases in natural-origin abundance can be sustained over the long run. The population is currently rated at moderate risk for structure/diversity. This rating reflects the widespread distribution of hatchery returns across the major spawning areas within the population and the lack of specific information supporting differential hatchery vs. natural spatial distributions. The potential for selective pressure imposed by current hydropower operations and cumulative harvest impacts also contribute to the current rating level.

Gap between Current Status and Desired Status for Delisting

Under the viability criteria for delisting with a single population, discussed in Section 3, the one extant population must achieve a viability rating of Highly Viable, at very low (< 1%) risk, with a high degree of certainty before the ESU may be delisted. This overall risk rating will require that the population demonstrate a very low risk rating for abundance/productivity and at least a low risk rating for spatial structure/ diversity. Achieving a very low risk rating with a high degree of certainty under Viability Scenario B would require a combination of natural-origin abundance and productivity that exhibits an 80 percent or higher probability of exceeding the viability curve for a 1 percent risk of extinction over 100 years. Given information available through spring 2015, attaining the desired level for delisting would require an increase in estimated productivity (or a decrease in the year-to-year variability associated with the estimate), assuming that natural-origin abundance of the single extant Snake River fall Chinook salmon population remains relatively high. To achieve low risk for spatial structure/diversity, one or more major spawning areas would need to produce a significant level of natural-origin spawners with low influence by hatchery-origin spawners relative to the other major spawning areas.

Limiting Factors and Threats

Snake River fall Chinook salmon threats and limiting factors operate across all stages of the life cycle. Each factor independently affects the status of the ESU. Together, they also have cumulative effects.

Many human activities contributed to Snake River fall Chinook salmon's threatened status. Listing reasons included overharvest; blockage to, and inundation of, primary spawning and rearing areas; effects of the FCRPS hydropower system on juvenile and adult migrants; and genetic risks posed by high levels of non-local hatchery fish on spawning grounds.

What are limiting factors and threats?

Limiting factors are the biological and physical conditions that limit a species' viability (e.g. high water temperature).

Threats are the human activities or natural processes that cause the limiting factors.

The term "threats" carries a negative connotation; however, they are often legitimate and necessary activities that at times may have unintended negative consequences on fish populations. These activities can be managed to minimize or eliminate the negative impacts.

Today, some threats that contributed to the original listing of Snake River fall Chinook salmon now present little harm to the ESU while others continue to threaten viability. Fisheries are now better regulated through ESA-listing constraints and management agreements, significantly reducing harvest-related mortality. Threats posed by straying out-of-ESU hatchery fish have declined due to improved management. Still, large reaches of historical habitat remain blocked and inundated, and the mainstem Snake and Columbia River hydropower system, while less of a constraint than in the past, continues to cause juvenile and adult losses. The number of hatchery-origin fall Chinook salmon on the spawning grounds continues to threaten natural-origin fish productivity and genetic diversity. Further, the combined and relative effects of the different threats across the life cycle ─ including threats from climate change ─ remain poorly understood. Key threats and limiting factors are summarized below. Section 5 of the plan provides a detailed discussion of these limiting factors and threats. The modules also present more detailed discussions.

Hydropower and Habitat

This section summarizes the effects of hydro operations and other threats on mainstem Snake and Columbia River habitat by population and river reach. It also summarizes limiting factors and threats in the Columbia River estuary, plume, and ocean.

Historical Middle Mainstem Snake River Population Upstream of Hells Canyon Complex ─ The Hells Canyon Complex of dams and reservoirs blocks access to 367 miles of once productive spawning habitat in the middle and upper Snake River mainstem. Currently, however, the mainstem habitat in the blocked area is too degraded to support a fall Chinook salmon population. Water quality factors include altered thermal regime, excessive nutrients, and anoxic or hypoxic conditions. Other factors affecting habitat quality include altered flows, inundated habitat, interruption of geomorphological processes (entrapment of sediment), and low dissolved oxygen. In addition, the loss of the historical fall Chinook salmon population from the middle mainstem Snake River reach influenced the species' life history strategy. Earlier emerging fish from the middle Snake River would have progressed through the early life stages earlier than fish from the contemporary spawning areas, and likely migrated at much larger sizes.

Lower Mainstem Snake River Population — Habitat conditions in the Lower Mainstem Snake River population's five major spawning areas limit population viability:

> Upper Mainstem Snake River MaSA (below Hells Canyon Dam to the mouth of the Salmon River): Operation of the Hells Canyon Complex affects Snake River fall Chinook salmon in several ways: (1) Operations reduce outflow and alter water quality in this reach. Many adults that migrate, hold, and spawn in the reach are exposed to warmer temperatures for longer periods than occurred historically; however, research indicates that the altered thermal regime accelerates incubation and fry emergence compared to historical conditions, and that the warmer temperatures do not significantly affect spawning success and egg and fry viability. Low dissolved oxygen and elevated total dissolved gas levels also reduce water quality in the reach at certain times of the year and may affect Snake River fall Chinook. (2) Altered flows (on a seasonal, daily, and hourly basis) result in altered migration patterns, juvenile fish stranding and entrapment. (3) Interruption of geomorphological processes (entrapment of sediment) results in reduced turbidity, higher predation.
>
> Lower Mainstem Snake River MaSA (mouth of Salmon River to Lower Granite Dam Reservoir): The Lower Hells Canyon Complex operations affect fall Chinook salmon production in this reach by altering flow and thermal regimes. Long-term flow fluctuations have altered riparian vegetation, and daily and hourly fluctuations can potentially strand fry in the shallows. The Lower Granite Dam reservoir inundates mainstem and shallow-water rearing areas. High water temperatures can limit fall Chinook salmon use in the reach, but the effects are substantially reduced by flow contributions from the Salmon and Grande Ronde Rivers. The warmer water temperatures may also reduce survival and growth of late juvenile outmigrants, including fish from the Clearwater River, but once the juveniles reach Lower Granite Reservoir they usually move through the water column to maintain an optimum body temperature. Altered conditions in Lower Granite Reservoir increase habitat for non-native fish that prey on migrating juvenile fall Chinook salmon, especially subyearlings. Land uses adjacent to the lower Snake River and tributaries also affect the fish by degrading water quality and reducing habitat diversity.
>
> Lower Clearwater River MaSA: The flow and water temperature downstream from the confluence of the North Fork Clearwater River is dominated by the outflow of Dworshak Dam, creating winter flows that are slightly warmer than historically and summer flows are significantly colder. Limiting factors for fall Chinook salmon spawning and rearing in the lower Clearwater River include high water temperatures upstream of the North Fork Clearwater, increased sediment, entrapment and stranding due to altered flows (variability and base flows), excessive nutrients, and pollutants.
>
> Lower Grande Ronde River MaSA: Limiting factors for fall Chinook salmon spawning and rearing in the lower Grande Ronde River include lack of habitat quantity and diversity (primary pools, large wood, glides, and spawning gravels), excess fine sediment, degraded riparian

conditions, low summer flows, and poor water quality (high summer water temperatures, nutrients).

Lower Tucannon River MaSA: Limiting factors for fall Chinook salmon in the Tucannon River include excess sediment, loss of habitat, and reduced habitat diversity and channel stability.

Mainstem Migration Corridor Habitat — Federal Columbia River Power System (FCRPS) Dams and Reservoirs on Lower Snake and Columbia Rivers — The Columbia and Snake River hydropower system remains a threat to Snake River fall Chinook viability. Four federal dams on the lower Snake River mainstem (Lower Granite, Little Goose, Lower Monumental, and Ice Harbor) and four federal dams on the lower Columbia River mainstem (McNary, John Day, The Dalles, and Bonneville) limit passage for juveniles migrating to the ocean and for adults returning to spawn. All eight dams are part of the FCRPS. In addition to blocking access to or inundating historical fall Chinook salmon production areas, hydropower system development and operations also reduce mainstem habitat quality and affect both juvenile and adult migration.

Specific limiting factors for adult fall Chinook salmon in the migration corridor include: difficulty finding fish ladders, mortality and delayed/ blocked upstream migration, fallback, high water temperatures, and reduced spawning area. Limiting factors for juvenile fish include slowed downstream migration, increased mortality, altered hydrograph and riverine habitat, sublethal injuries or stress, increased predation by birds, pinnipeds, and non-native fish species, disrupted homing ability of transported fish. Migrating fall Chinook salmon are also exposed to agricultural and industrial chemicals.

Columbia River Estuary, Plume and Ocean — The cumulative impacts of past and current land use (including dredging, filling, diking, and channelization) and alterations to the Columbia River flow regimes have reduced the quality and quantity of estuarine and plume habitat.

Estuary: Snake River fall Chinook salmon subyearling migrants that access and use shallow, nearshore areas and other floodplain habitats are particularly affected by the loss of habitat and reduced habitat quality. Changes in sediment transport processes and flow have increased exposure of fall Chinook salmon to predatory fish and birds. Changes in flow also contributed to increased water temperature in the estuary. A number of other limiting factors and threats to fall Chinook salmon in the estuary are less understood. These include shifts in the food web and species interactions (including competition and predation), overwater and instream structures, and ship-wake stranding of juveniles.

Plume: Snake River fall Chinook salmon that pause in the plume to feed and acclimate to salt water can also be affected by changes in flow and sediment in these areas. High concentrations of urban and industrial contaminants in some areas of the lower Columbia River estuary and plume also affect fish health and behavior.

Ocean: Ocean conditions and food availability contribute significantly to the health and survival of Snake River fall Chinook salmon. Early ocean life is a critical period for the fish, and most early marine mortality likely occurs during two critical periods: predation-based mortality during the first few weeks to months and lack of food availability/ starvation during and following the first winter at sea. From the end of their first year until they return to the Columbia River as adults, little is known about the ocean life of the species; however, conditions in the ocean ecosystem strongly influences the health and survival of the fish during their time in the ocean, and their condition upon returning to the Columbia River.

Future Implications from Climate Change

Likely changes in temperature, precipitation, wind patterns, and sea-level height due to climate change have implications for survival of Snake River fall Chinook salmon in both freshwater and marine habitats. Stream flows and temperatures ─ the environmental attributes that climate change will affect ─ already limit fall Chinook salmon productivity in some reaches of the mainstem Snake and Columbia Rivers and tributaries. In the ocean, climate-related changes 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 is currently poorly understood. All other threats and conditions remaining equal, future deterioration of water quality, water quantity, and/or physical habitat due to climate change could reduce viability or survival of naturally produced fall Chinook salmon. Potential limiting factors include passage delays, gamete viability, and pre-spawn mortality; however, the effects of climate change will depend on how Snake River fall Chinook salmon migration, spawn timing, emergence, and dispersal are influenced by the changes. Presently, it is not clear how fall Chinook salmon will respond.

Harvest

Snake River fall Chinook salmon are exposed to various fisheries throughout their range, but are primarily affected by fisheries in the mainstem Columbia and Snake Rivers and ocean. In recent years, there has also been increasing interest and harvest of Snake River fall Chinook salmon in fisheries above Lower Granite Dam. Harvest effects on natural Snake River fall Chinook salmon include mortality of fish that are caught and retained in non-selective fisheries, caught and released, encounter fishing gear but are not landed, or are harvested incidentally to the target species or stock. Indirect effects might include genetic, growth, or reproductive changes when fishing rates are high and selective by size, age, or run timing.

Predation

Avian Predation. In the estuary, the number and/or predation effectiveness of Caspian terns, double-crested cormorants, and a variety of gull species has increased because of habitat modification and an influx of avian predators to the Columbia River Basin from other locations. Tern, cormorant, and gulls from colonies on islands in the Columbia River and the Lower Snake River also prey on juvenile salmonids, but predation in the estuary is a greater threat.

Pinnipeds. Marine mammals (pinnipeds) prey on winter and spring migrating adult salmon in the lower Columbia River and as they attempt to pass over Bonneville Dam. However, Snake River fall Chinook salmon generally migrate when marine mammals are not abundant and are likely much less affected by the predators than are spring or summer Chinook salmon.

Non-native Fish Predation: Predation on fall Chinook salmon by non-salmonid fish remains a significant concern. Northern pikeminnow and non-native predatory species (e.g., smallmouth bass, walleye, channel catfish, etc.) congregate near dams or at hatchery release sites to feed on migrating smolts. The largest portion of salmon lost to fish predators is in the reservoirs.

Other Ecological Interactions – Food Web, Prey Availability, and Competition

The productivity of juvenile Snake River fall Chinook salmon depends in part on the food web that supports growth and survival, and the interaction with predators and competitors. They are affected by changes in the prey communities that support them, which vary between riverine and reservoir habitats. Competition with other native fishes will also affect juvenile fall Chinook salmon productivity. The growth rate of fall Chinook salmon rearing in Lower Granite Reservoir has declined in recent years compared to in the 1990s when the juvenile population was at low abundances, and increased competition or changes in food resources may be contributing to this decline. Competition can occur between hatchery-origin and natural-origin salmonids, and between salmonids and non-native species.

Hatcheries

Two general types of hatchery programs affect Snake River fall Chinook salmon: programs that produce fish intended to return to areas outside of the Snake River (out-of-ESU programs) and programs that produce fish intended to return to the Snake River and that are also part of the listed Snake River fall Chinook salmon ESU (within-ESU programs). Until recently, out-of-ESU hatchery programs were a major concern because the returning adult fish strayed into the Snake River and mixed with both Snake River fall Chinook hatchery spawning programs and with the natural spawning population. Strays from out-of-ESU programs have been reduced substantially. Within-ESU hatchery programs have been an asset, reducing the short-term risk to Snake River fall Chinook by increasing abundance and spatial structure, but the size of the programs relative to the level of natural-origin production and consequent high proportion of hatchery-origin fish on the spawning grounds raises concerns about natural-origin productivity and diversity.

Considerable uncertainty remains about the effect of the Snake River fall Chinook salmon hatchery programs on the Lower Mainstem Snake River population. Much of this uncertainty reflects the fact that the remaining population is very difficult to study because of geographic extent, habitat, and logistics. The uncertainties, however, are more important in the case of Snake River fall Chinook salmon than in many other populations because the current population is the only extant population in the ESU, and it must reach a level of high viability for ESU recovery.

Toxic Pollutants

Throughout its migration corridor and in some rearing and spawning rearing areas, Snake River fall Chinook salmon are exposed to chemical contaminants from agricultural, industrial, and urban land uses that may disrupt behavior and growth, reduce disease resistance, and potentially increase mortality. Our understanding of contaminant exposure and uptake in Snake River fall Chinook salmon, and associated risks, remains incomplete.

Recovery Strategy and Actions

Overall Recovery Strategy

The recovery strategy for Snake River fall Chinook salmon is designed to rebuild the ESU to a level where it can be self-sustaining in the wild over the long term and can be delisted under the ESA. It also aims to be consistent with broad sense recovery goals for the number of fall Chinook salmon needed in the Snake River system to help maintain tribal, commercial, and sport fisheries on a sustaining basis, and for reintroducing Snake River fall Chinook salmon above the Hells Canyon Complex.

The general strategy for achieving ESU recovery centers on improving the status of the extant Lower Mainstem Snake River population. The recovery strategy takes a life-cycle approach to achieve the recovery objectives. It focuses on protecting and restoring viable salmonid population characteristics and the ecosystems on which the population depends throughout its life cycle. Thus, the recovery strategy provides the building blocks and site-specific actions to recover the one remaining population to a status of Highly Viable, and the ESU to a level where it is self-sustaining and viable.

At the same time, the recovery strategy actively pursues the potential for a second population above the Hells Canyon Complex. Many of the actions identified for the Lower Mainstem Snake population ─ particularly those addressing passage and migration habitat, rearing habitat, and predation in the mainstem Snake and Columbia Rivers ─ would also create conditions that benefit the potential population above Hells Canyon. Successfully reestablishing a population in the historically productive middle mainstem Snake River, however, would require substantial effort to improve habitat conditions in the reach, which are now severely degraded. In addition, providing safe and effective downstream passage for migrating smolts remains a substantial technical challenge to overcome. It may take decades to restore fall Chinook salmon above the Hells Canyon Complex.

ESU Adaptive Management Framework

1. Establish recovery goals and viability and threats criteria for delisting (Section 3).
2. Determine the species' present status and the gaps between the present status and viability criteria (Section 4).
3. Assess the threats and limiting factors across the life cycle that are contributing to the gaps between present status and viability objectives (Section 5).
4. Implement management strategies and actions (Section 6) that target the limiting factors and threats.
5. Implement RM&E actions (Section 7) to evaluate the status and trend of the species and the status and trend of limiting factors and threats, including action implementation and action effectiveness.
6. Identify contingency processes and actions to be implemented in the event of a significant decline in species status (Section 6.4).
7. Review progress and identify best opportunities to improve viability. Regular major reviews of implementation progress, species response, and new information are needed (Section 8).
8. Adjust actions according to progress reviews.
9. Repeat the adaptive management cycle.

Adaptive Management Framework

The recovery plan uses an adaptive management framework that prioritizes implementation of site-specific actions based on the best available science, identifies monitoring to improve the science, and recommends updating actions based on new knowledge. Our overarching hypothesis is that the management actions recommended for the near- and mid-term in this plan will be effective in improving viability; however, uncertainties remain about their feasibility and effectiveness. Consequently, we include complementary RM&E actions to improve our understanding of the species status and management action effectiveness, and to help guide us in better defining opportunities to achieve recovery. We also employ a life-cycle context to determine the best ways for closing the gap between the species' status and achieving viability objectives.

Prioritization Considerations

Priority recovery strategies and management actions aim to protect and restore ecological processes throughout the entire life cycle to conserve the ESU and the productive capacity of its habitat. Conserving existing habitat that supports core production and primary life history types, as well as quality migration habitats, is a critical priority. Given that they are primarily mainstem spawners, Snake River fall Chinook salmon spawning and rearing habitat is affected by large-scale hydropower and water management actions more so than other Snake River salmon and steelhead species. The species is also affected by substantial levels of ocean and river harvest and hatchery production. It is a priority for hydropower, fishery, and hatchery management actions to be consistent with recovery objectives.

Prioritizing Site-Specific Management Actions

Management actions include both ongoing actions that are essential for conserving the species and potential additional actions that would bring the ESU closer to achieving viability and maintaining viability into the future. The following types of management actions are considered high priority and are classified as follows:

Ongoing management actions that are essential for present and continued conservation

These actions have improved the extant population's status since listing and it is essential they continue as they are presently designed until or unless RM&E effectiveness monitoring or other information demonstrates issues with their effectiveness that warrant changes. These actions must be partnered with RM&E for evaluating their effectiveness.

Potential additional management actions to bring the ESU closer to viability

Potential additional actions are identified to bring the ESU closer to achieving ESA recovery. Many of these potential improvements have already been analyzed, and funding and implementation is proceeding. Others are now being assessed through ongoing studies and there are commitments to build implementation of the actions into management programs. There are also cases where evaluations and implementation have not begun and the actions present new ideas. In all cases, these actions are not yet affecting the fish and influencing the species' viability. Additional actions should be implemented in the following sequence.

1. Actions most likely to provide the best and most timely opportunities for achieving ESU viability with the single extant population.
2. Actions to reestablish a population above the Hells Canyon Complex.
3. Actions that may not be necessary to achieve ESA viability but that could further enhance and secure viability of the extant population and the ESU. These potential actions warrant additional evaluations.

The sequencing and rate at which additional actions are implemented are key variables that will influence how quickly the gaps are narrowed between the Snake River fall Chinook salmon ESU's present viability status and achieving VSP objectives. The plan suggested two general time frames, near-term and mid-term, for implementation of the additional management actions. The near term corresponds roughly to the next five years of implementation (2016-2020). The mid-term time frame corresponds generally to the succeeding twenty years. If delisting were not achieved within the 25-year time frame envisioned for implementation of this plan, it is possible that additional actions would need to be identified and implemented.

Priority RM&E actions (described in Section 7) promote understanding the status of the species; the effectiveness of existing management actions, best opportunities for improving the species' status; and the biological and management feasibility of alternative viability scenarios.

Site-Specific Management Actions

The site-specific management actions - ongoing and potential additional actions - address the threats and priority limiting factors described in Section 5. The actions are organized by two main subcategories: (1) actions for the extant lower Snake Mainstem Snake population and (2) actions for the extirpated population above the Hells Canyon Dam Complex. Actions are further organized under ten management strategies. Management strategies describe what needs to be done to protect and restore Snake River fall Chinook salmon, and the actions describe how to implement those strategies through site-specific actions. The management strategies address hydropower; mainstem, tributary, and estuary habitat; harvest; predation, prey base, competition, and other ecological interactions; hatcheries; and toxic pollutants. The site-specific actions are discussed in Section 6. Table 6-1 in Section 6 links the ongoing and potential additional site-specific actions to limiting factors and viable salmonid parameters addresses, and identifies potential associated timing, costs, and implementing entities.

Management Strategies and Site-Specific Actions for the Lower Mainstem Snake River Population

Management Strategy 1. Develop tools, including life-cycle models, for evaluating and understanding the relative effects of actions in different threat categories across the life cycle.

This strategy addresses uncertainty regarding whether the recent increase in Snake River fall Chinook abundance will persist in coming years, and whether existing patterns of diversity will sustain the Lower Mainstem Snake River population across a range of changing environmental conditions. Tools such as multi-stage life-cycle models are needed to gain this understanding and help us target and prioritize recovery actions and RM&E accordingly.

Management Strategy 2: Maintain and enhance suitable spawning, incubation, rearing, and migration conditions by continuing ongoing actions and implementing additional actions in the mainstem Snake and Columbia Rivers and tributaries from Hells Canyon Complex to Bonneville Dam.

The strategy continues evaluations of mechanisms leading to the relatively recent increases in apparent survival related to passage through the hydropower system and lower Columbia River mainstem. Ongoing RM&E is evaluating management options that could further increase survival associated with rearing and migration through the mainstem Columbia and Snake River corridors. The strategy will maintain and enhance suitable spawning, incubation, rearing habitats, and migration conditions by continuing ongoing actions and implementing potential additional actions in the mainstem and tributaries.

Management Strategy 3: Address lack of access to estuary habitat; altered food web; and altered flow regime by continuing ongoing actions and implementing potential additional actions identified in the Estuary Module (NMFS 2011b), FCRPS Biological Opinion (NMFS 2014c) and this recovery plan.

Actions here continue ongoing actions and implement potential additional actions to increase access to estuary habitat, improve habitat quality and the food web, reduce predation, and address flow concerns. Actions are identified in the Estuary Module, FCRPS Biological Opinion, Ocean Module and this recovery plan.

Management Strategy 4: Continue ongoing actions and implement potential additional actions that will conserve Snake River fall Chinook salmon in the face of emerging climate change.

Potential effects from climate change remain poorly understood. Actions focus on gaining a better understanding of the potential impacts of climate change during freshwater and ocean life stages. They also monitor changes in temperatures and flows that result from climate change, and implement adaptive management by taking actions that respond to changing conditions.

Management Strategy 5: Implement harvest programs in a manner that protects and restores Snake River fall Chinook salmon.

Actions continue to implement and monitor harvest programs to protect and restore Snake River fall Chinook salmon. Annual assessments of the performance of existing management regimes and periodic reassessments of the efficacy of the overall harvest management framework in contributing to achieving viability objectives are key components of the strategy.

Management Strategy 6: Continue ongoing actions and implement potential additional actions that address predation, prey base, competition and other ecological interactions.

Actions continue to reduce or disperse bird colonies that prey on juvenile Snake River fall Chinook salmon in both the interior Columbia and the estuary. Actions also address non-native fish predation and evaluate plume and ocean conditions that influence predator fish populations and predation rates during the early ocean life stage. Actions will also evaluate and address impacts of competition and density dependence on natural-origin Snake River fall chinook.

Management Strategy 7: Continue ongoing actions and implement potential additional actions that reduce the impact of hatchery fish on Snake River fall Chinook salmon.

Actions continue ongoing programs to reduce impacts form hatchery fish on the natural-origin fish population. They also continue to address uncertainties regarding potential impacts on efforts to achieve ESU viability. Potential additional actions will be implemented as needed.

Management Strategy 8: Reduce potential effects of toxic contaminants on Snake River fall Chinook salmon.

Actions aim to gain a better understanding of how exposure to toxins may negatively affect production, and implement steps to reduce toxin exposure.

Management Strategies and Actions for the Extirpated Population above Hells Canyon Complex

Management Strategy 9: Evaluate feasibility of adult and juvenile fish passage to and from spawning and rearing areas above Hells Canyon Complex.

Action focus on completing feasibility studies for upstream and downstream passage over the Hells Canyon Complex, and for reintroduction of the species. The timing of the feasibility studies and implementation of their results should be determined through the ongoing Hells Canyon Complex relicensing proceedings.

Management Strategy 10. Restore habitat conditions that can support Snake River fall Chinook salmon spawning and rearing above Hells Canyon Complex by encouraging local governments and stakeholders to implement actions to reduce nutrients and sediment to improve mainstem habitat.

The strategy calls for local governments, organizations, and other stakeholders to take necessary steps to restore historic habitats above the Hells Canyon Complex.

Adaptive Management, Research, Monitoring and Evaluation

Section 7 summarizes the research, monitoring and evaluation (RM&E) plan, and the role of RM&E in adaptive management for Snake River fall Chinook salmon. Adaptive management works by binding decision making with data collection and evaluation. Successful adaptive management requires that monitoring and evaluation plans are 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.

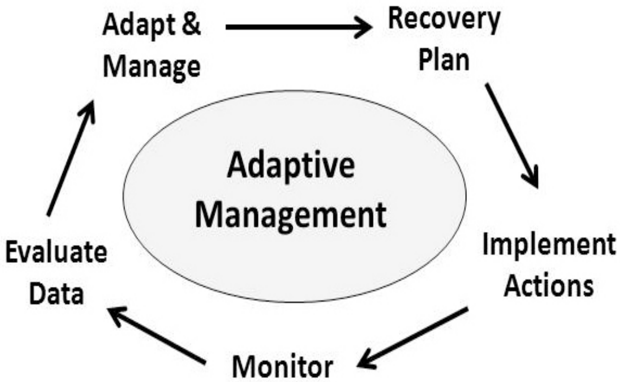

Figure ES-5. The adaptive management process.

The RM&E plan described in Section 7 identifies the level of monitoring and evaluation needed to determine the effectiveness of recommended actions, and whether they are leading to improvements in population viability. The RM&E plan also identifies critical data gaps in species and habitat knowledge. The data obtained through RM&E implementation will be used to assess and, where necessary, correct current strategies and actions. The RM&E strategy builds on current monitoring efforts for Snake River fall Chinook salmon.

Implementation

Ultimately, the recovery of Snake River fall Chinook salmon depends on the commitment and dedicated actions of the many groups and individuals who share responsibility for the species' future. Section 8 describes an implementation framework to coordinate and define the actions that will take us to this goal.

Implementation of recovery actions have been improving Snake River fall Chinook salmon viability since ESA-listing in 1992. Today, multiple forums manage the species and its habitat throughout its life cycle. This recovery plan seeks to build upon the successful conservation efforts by these different forums by providing a full life-cycle context for assessing the collective and relative effectiveness of ongoing actions, evaluating uncertainties, and identifying the most effective actions for the species and delisting.

Section 8 provides a suggested framework for implementing coordinated evaluation and reporting and management actions. It also proposes some additions to existing management structures with the objective of facilitating coordinated recovery implementation across the forums and across the life cycle, and to ensure the species will remain viable after delisting.

Time and Cost Estimates

It is important to consider the unique challenges of estimating time and cost for Snake River fall Chinook salmon recovery, given the complex relationship of these fish to the environment and to human activities. The recovery plan contains an extensive list of actions to recover the populations; however, it recognizes that there are many uncertainties involved in predicting the course of recovery and in estimating total costs. Such uncertainties include the rate at which new actions are implemented, biological and ecosystem responses to recovery actions, unforeseen changes in climate or ocean conditions, as well as long-term and future funding.

The time to recover Snake River fall Chinook salmon depends on the continued implementation of ongoing actions and the timeliness of implementing potential additional actions to close the gap between present status and viability. It also depends on decisions regarding a viability scenario. Scenario A would most likely take at least 25 years to achieve because it depends on the establishment of a viable population above the Hells Canyon Complex, in addition to improving the extant population to highly viable status. Scenario B and potential additional scenarios with Natural Production Emphasis Areas could conceivably achieve recovery in shorter time frames with the single population.

NMFS believes that, due to the many uncertainties, it is most appropriate to focus costs on the first five years of implementation, with the understanding that before the end of each five-year implementation period, specific actions and costs will be estimated for subsequent years. Table 6-1 (in Section 6) provides the estimated costs for actions identified in this recovery plan, where information was sufficient to provide these estimates. Section 9 discusses cost estimates for the actions. It estimates the total cost of recovery actions during the five-year period from 2016 to 2020, and the total cost of recovery actions for Snake River fall Chinook salmon over the next 25 years. .

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1. Introduction

This is an Endangered Species Act (ESA) recovery plan for Snake River fall-run Chinook salmon (Snake River fall Chinook salmon), an evolutionarily significant unit (ESU) of Chinook salmon (*Oncorhynchus tshawytscha*). NOAA's National Marine Fisheries Service (NMFS) first listed Snake River fall Chinook salmon as a threatened species under the ESA on April 22, 1992 (NMFS 1992, 57 FR 14658). NMFS reaffirmed the listing status in June 28, 2005 (NMFS 2005a, 70 FR 37160), and reaffirmed the status again in its 2010 Five-Year Review of Snake River listed species (NMFS 2011a).

At one time approximately one-half million adult fall Chinook salmon traveled up the Columbia River and into the Snake River basin each year (Connor et al. 2015). The fish spawned throughout the 600-mile reach of the mainstem Snake River downstream of Shoshone Falls, a natural 212-foot barrier, as well as in several major tributaries. This once mighty fish run began to decline in the late 1800s and then continued to decline through the early and mid-1900s as a result of overfishing and other human activities, including the construction of major dams on the mainstem Snake and Columbia Rivers and several tributaries.

The drastic decline in Snake River fall Chinook salmon led NMFS to list the species under the ESA in 1992. NMFS based its original listing decision, and subsequent affirmations of the species' threatened status, on the results of status reviews conducted by its biological review team (NMFS 1991, 1999a, 2005a; Waples et al. 1991; Busby 1999; Good et al. 2005). These status reviews cite the loss of primary spawning and rearing areas upstream of the Hells Canyon Complex of dams on the Snake River, the effects of the Federal Columbia River Power System (FCRPS) on the mainstem Snake and Columbia Rivers, the increase in nonlocal hatchery contribution to adult escapement, and the relatively high aggregate harvest impacts by ocean and in-river fisheries as the factors causing the steady and severe decline in abundance of Snake River fall Chinook salmon (Good et al. 2005). The 1991 status review (Waples et al. 1991) and most recent status reviews (ICTRT 2010 and NMFS 2011a) added concerns about effects on natural-origin productivity and diversity from hatchery operations and increasing proportions of hatchery-origin fish on the spawning grounds.

Since the ESA listing, combined management actions implemented by different entities to reverse the species' decline have succeeded in increasing Snake River fall Chinook salmon abundance. While historical spawning and rearing habitat upstream of Hells Canyon remains inaccessible, the implemented actions have boosted adult and juvenile survival through the hydropower system, reduced losses to harvest, lowered predation rates, improved habitats, reduced straying of out-of-ESU hatchery fish, and increased natural production using hatchery supplementation. Consequently, many more fall Chinook salmon now return to the Snake River than in the 1990s. Research, monitoring, and evaluation (RM&E) activities are also now providing critical information on the run and the effectiveness of different actions. While the combined actions have brought us a long way toward recovering the species, more work is needed to ensure the viability of Snake River fall Chinook salmon. Uncertainty remains regarding the status of the species' productivity and diversity, and whether the ESU could be self-sustaining in the wild over the long term. This Plan identifies actions to improve the ESU so that it is naturally self-sustaining.

The listed ESU includes all natural-origin fall-run Chinook salmon originating from the mainstem Snake River below Hells Canyon Dam (the lowest of three impassable dams that form the Hells Canyon Complex) and from the Tucannon River, Grande Ronde River, Imnaha River, Salmon River, and Clearwater River subbasins. The listed ESU also includes fall-run Chinook salmon from four artificial propagation programs: Lyons Ferry Hatchery Program, Fall Chinook Acclimation Ponds Program, Nez Perce Tribal Hatchery Program, and the Oxbow (Idaho Power Company) Hatchery Program.

Historically, the ESU also included fall Chinook salmon that spawned in the middle mainstem Snake River and tributaries above Hells Canyon (Figure 1-1) (ICTRT 2005a; 2010)[1]. This area upstream of Hells Canyon supported the majority of all Snake River fall Chinook salmon production until the area became inaccessible due to dam construction. The loss of this upstream habitat and inundation of downstream spawning areas by reservoirs associated with the Hells Canyon Complex and the three lower Snake River dams reduced spawning habitat for the species to approximately 20 percent of the historically available area.

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[1] The ICTRT (2005) identified two historical populations above the current Hells Canyon dam site. As part of the ESA five-year status review underway at the time of this proposed recovery plan, NMFS determined that the two relatively continuous spawning aggregations above the current Hells Canyon Dam site were more likely part of a single population. We made this determination based on information submitted to us by the US Fish and Wildlife Service and summarized in Connor et al. 2015. To ensure that this proposed plan uses best available information, we incorporated this change in historical population structure. Appendix A of this proposed plan presents draft material from this ongoing 5-year status review. Appendix A is also summarized in Section 4 of this plan.

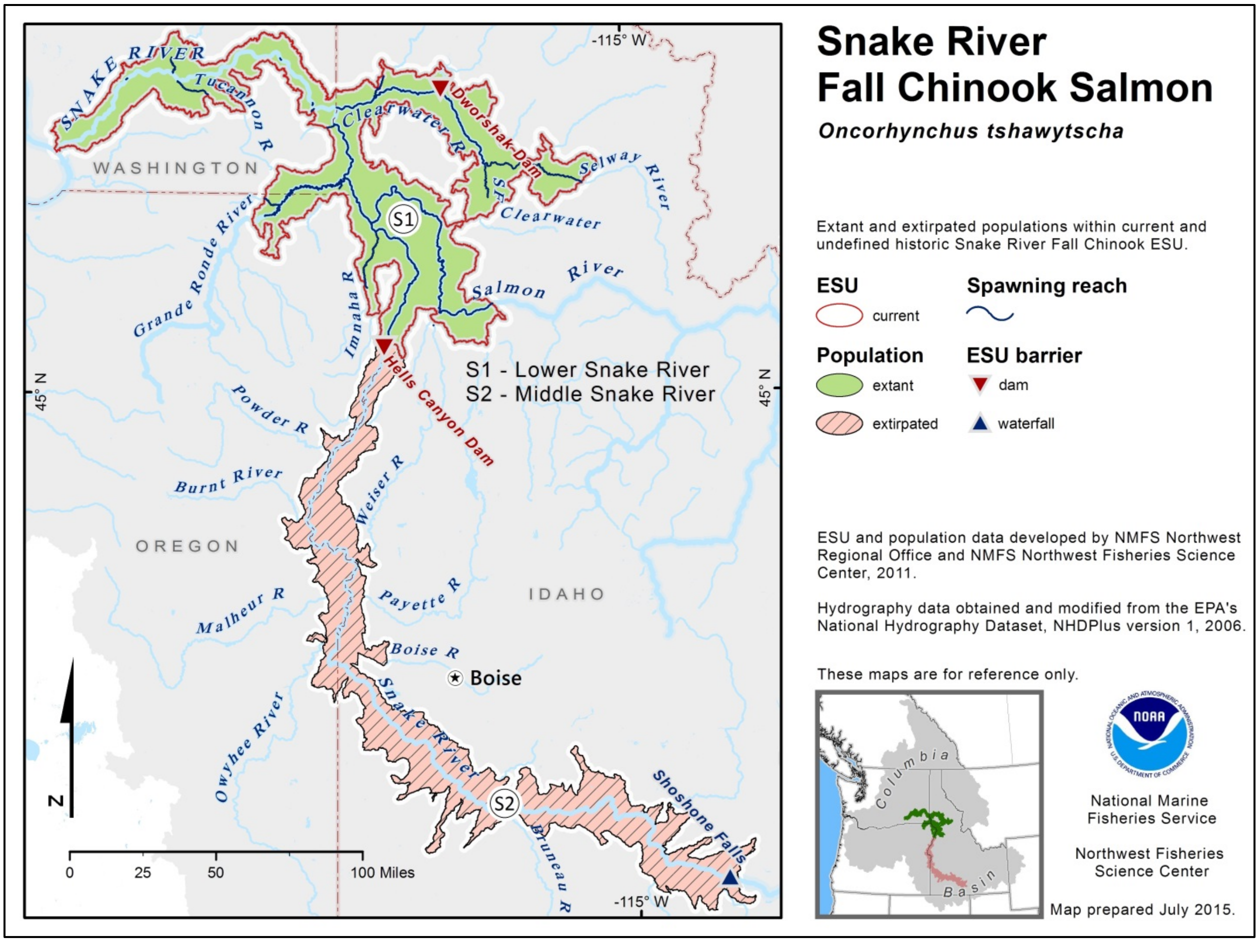

Figure 1-1. Snake River fall Chinook salmon ESU and historical spawning range in the Middle Snake River mainstem.

1.1 Purpose of the Plan

NMFS' goal is to improve the viability of Snake River fall Chinook salmon to the point that ESA protection is no longer required. The purpose of this recovery plan is to provide a roadmap for recovery of the Snake River fall Chinook salmon ESU It lays out where we need to go and how best to get there. It includes strategies and actions that address the factors that led to the initial decline and those that now impede recovery.

The recovery plan is based on the best available science and provides information required by NMFS to satisfy section 4(f) of the ESA. It contains the following elements:

1. A description of recovery goals and objectives.
2. Measureable criteria that identify the biological and physical performance conditions that, when met, will result in a determination that the species be removed from the threatened and endangered species list.

3. An assessment of the current extinction risk for the ESU based on four key viable salmonid population (VSP) parameters ─ abundance, productivity, population spatial structure, and diversity ─ and the distance that needs to be covered to meet the delisting criteria.
4. Several recovery scenarios that allow flexibility in which populations are targeted for a particular recovery level to achieve a viable ESU.
5. A discussion of the threats to the species throughout its life cycle, and an evaluation of the effects of these threats and associated limiting factors (which are related to the ESA section 4(a)(1) listing factors) on species survival and viability.
6. Recovery strategies and actions that will improve the ESU's evolutionary and ecological functionality by addressing these threats and limiting factors, and that have a high potential for bringing the ESU to a state where it can be delisted.
7. Direction for monitoring and evaluation and adaptive management to fine-tune the course towards recovery.
8. Estimates of the time required and costs to carry out the actions to achieve recovery.

The Plan includes several appendices that provide additional detailed information:

- Appendix A ─ Current ESU Viability Assessment;
- Appendix B ─ Research, Monitoring & Evaluation for Adaptive Management; and
- Appendix C ─ Temperature in the Lower Snake River during Fall Chinook Salmon Egg Incubation, Fry Emergence, Shoreline Rearing and Early Seaward Migration.

The Plan also includes four modules as appendices. NMFS developed these modules (discussed in Section 1.4) to support recovery planning. The modules provide detailed information that applies to all Snake River ESA-listed salmon and steelhead species.

1.2 ESA Requirements

The ESA requires NMFS to develop and implement plans for the conservation and survival of species listed as endangered or threatened under the ESA. Section 4(f) of the ESA refers to these plans for conservation and survival as recovery plans.

ESA section 4(a)(1) lists five factors for determining whether a species is an endangered or a threatened species. Elimination of these factors must 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 its continued existence.

These listing factors, or threats, need to be addressed to the point that the removal of the species from a listed status is not likely to result in their re-emergence.

ESA section 4(f)(1)(B) directs that the Secretary of Commerce (i.e. NMFS), to the extent practicable, incorporate in each recovery plan:

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, in accordance with the provisions of this section, that the species be removed from the list; and
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.

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

1.3 Recovery Domains and Technical Recovery Teams

The Snake River fall Chinook salmon ESU is not the only salmonid species in the Pacific Northwest that needs help. Currently, 19 evolutionarily significant units (ESUs) and distinct population segments (DPSs) of Pacific salmon and steelhead in the Pacific Northwest are listed under the ESA as endangered or threatened[2]. For the purpose of recovery planning for these species, NMFS designated five geographically based "recovery domains": Interior Columbia; Willamette-Lower Columbia; Puget Sound and Washington Coast; the Oregon Coast; and the Southern Oregon/Northern California Coast (Figure 1-2). The range of the Snake River fall Chinook salmon ESU is in the Snake River sub-domain of the Interior Columbia domain. Three other ESA-listed species also spawn and rear in the Snake River basin: the Snake River spring-summer Chinook salmon ESU, the Snake River steelhead DPS, and the Snake River sockeye salmon ESU.

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[2] An ESU of Pacific salmon (Waples 1991; NMFS 1991) and a DPS of steelhead (NMFS 2006a) are considered to be "species" as the word is defined in section 3 of the ESA.

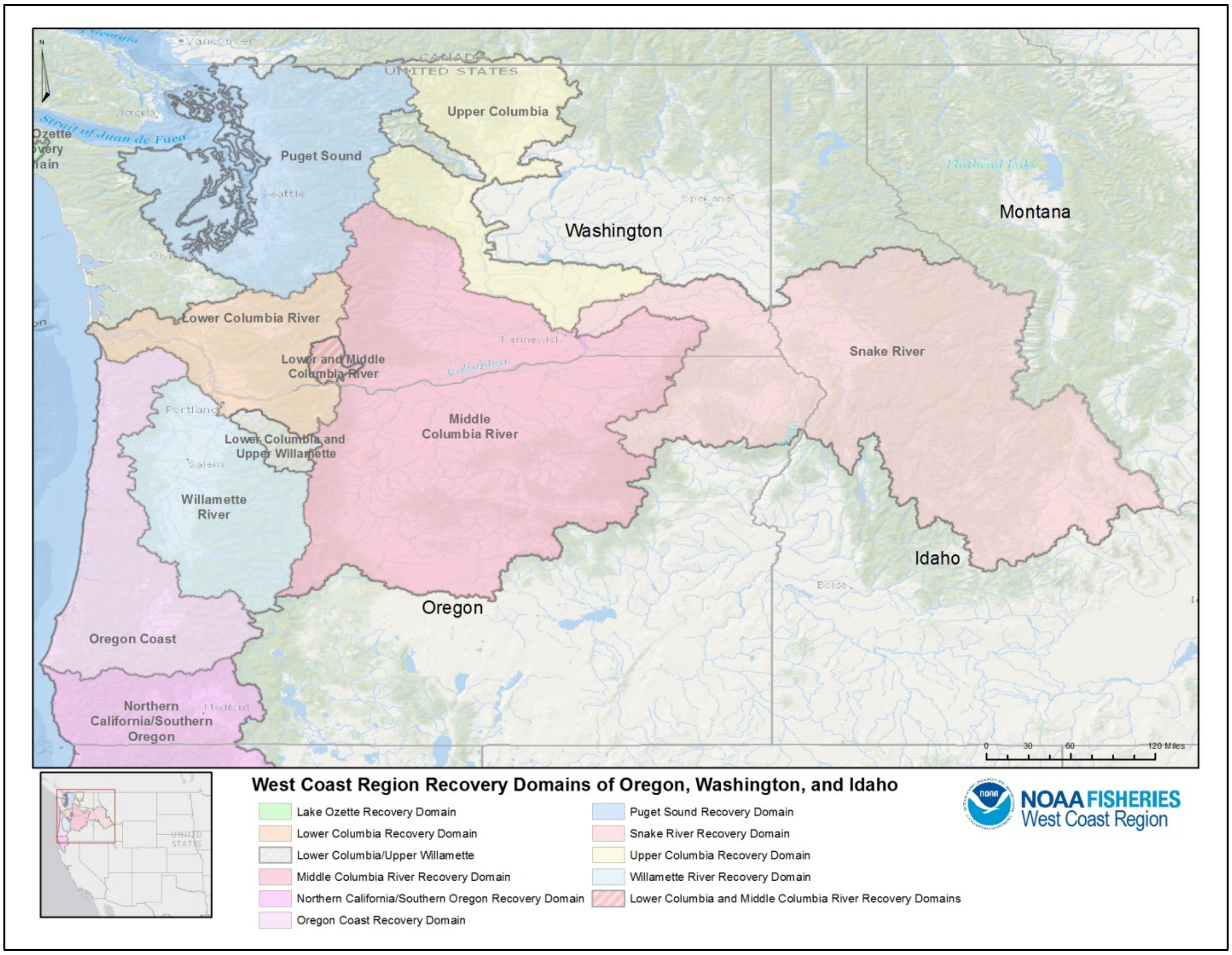

Figure 1-2. Columbia Basin Recovery Domains for NMFS West Coast Region.

For each domain, NMFS appointed teams of scientists, called technical recovery teams, to provide a solid scientific foundation for recovery plans. These scientists were nominated for their geographic, species, and/or topical expertise. The Interior Columbia Technical Recovery Team (ICTRT) included biologists from NMFS, states, tribes, entities, and academic institutions.[3] NMFS directed each technical recovery team to define species structures; develop recommendations on biological viability criteria for each species and its component populations; provide scientific support to local and regional recovery efforts; and provide scientific evaluations of proposed recovery plans. The ICTRT addressed the four listed Snake River species.

All the technical recovery teams used a common set of biological principles in developing their recommendations for species and population viability criteria. The biological principles are

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[3] ICTRT members were Thomas Cooney (NMFS Northwest Fisheries Science Center) (co-chair), Michelle McClure, (NMFS Northwest Fisheries Science Center) (co-chair), Casey Baldwin (Washington Department of Fish and Wildlife), Richard Carmichael (Oregon Department of Fish and Wildlife),Peter Hassemer (Idaho Department of Fish and Game), Phil Howell (U. S. Forest Service), Howard Schaller (U.S Fish and Wildlife Service), Paul Spruell (University of Montana), Charles Petrosky (Idaho Department of Fish and Game), Dale McCullough (Columbia River Inter-tribal Fish Commission) and Fred Utter (University of Washington).

described in NMFS' technical memorandum, "Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units" (McElhany et al. 2000). Viable salmonid populations (VSP) are defined in terms of four population parameters: abundance, population productivity or growth rate, population spatial structure, and diversity. Each technical recovery team made recommendations using the VSP framework. Their recommendations were also based on data availability, the unique biological characteristics of the species and habitats in the domain, and the members' collective experience and expertise. NMFS encouraged the technical recovery teams to develop species-specific approaches to evaluating viability, while using the common VSP scientific foundation.

1.4 Recovery Planning Modules

NMFS developed several modules to assist in recovery planning for ESA-listed Columbia Basin salmon and steelhead species. These modules provide consistent information that is applicable to multiple species. They are referenced and incorporated into specific recovery plans as appropriate. NMFS will update the modules periodically to reflect new data. This plan incorporates four modules as appendices.: (1) Appendix D ─ *Module for the Ocean Environment* (*hereafter* Ocean Module) (Fresh et al. 2014), (2) Appendix E ─ *Supplemental Recovery Plan Module for Snake River Salmon and Steelhead Mainstem Columbia River Hydropower Projects* (*hereafter* Hydro Module) (NMFS 2008a, 2014a), (3) Appendix F ─ *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (*hereafter* Estuary Module) (NMFS 2011b), and 4) Appendix G ─ *Snake River Harvest Module* (*hereafter* Harvest Module) (NMFS 2014b). These modules provide information that applies to Snake River fall Chinook salmon, as well as to other Snake or Columbia River Basin ESA-listed salmon and steelhead.

The Ocean Module (Fresh et al. 2014) (Appendix D) uses the latest science to (a) synthesize what is known about how each of the four listed Snake River species uses ocean ecosystems, (b) identify major uncertainties regarding their use of the ocean environment, and (c) define the role of the ocean in recovery planning and implementation for each species. The module is available on the NMFS West Coast Region web site: http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/interior_columbia/snake/ocean_module.pdf.

The Hydro Module (NMFS 2014a) (Appendix E) was completed in June 2014 and supplements the 2008 Hydro Module for Snake River anadromous fish species listed under the ESA: Snake River steelhead, Snake River spring/summer Chinook salmon, Snake River fall Chinook salmon and Snake River Sockeye Salmon (NMFS 2008a). The 2008 Hydro Module overviews limiting factors, summarizes current recovery strategies, and provides survival rates associated with the Federal Columbia River Power System (FCRPS). The FCRPS consists of 14 Columbia and Snake River hydropower and water storage projects that are operated as a coordinated system for power production and flood control. The 2014 Hydro Module provides new information relevant to the Snake River species, including the most recent survival estimates and discussion of latent

and delayed mortality. The Hydro Module is available on the NMFS West Coast Region web site:
http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/interior_columbia/snake/hydro_supplemental_recovery_plan_module_063014.pdf.

The Estuary Module (NMFS 2011b, Appendix F) discusses limiting factors and threats that affect all the salmonid populations in the mainstem Columbia River estuary and plume, and presents actions to address these factors. The Estuary Module was prepared for NMFS by the Lower Columbia River Estuary Partnership (contractor) and PC Trask & Associates, Inc. (subcontractor). It provides the basis of estuary recovery actions for ESA-listed salmon and steelhead in the Columbia River basin. This module is available on the NMFS West Coast Region web site:
http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/estuary-mod.pdf.
This plan summarizes actions identified in the Estuary Module to address threats to Snake River fall Chinook salmon. The Estuary Module discusses these actions in more detail.

The 2014 Harvest Module (NMFS 2014b) (Appendix G) describes fishery policies, programs, and actions affecting the ESA-listed Snake River fish species, including Snake River fall Chinook salmon. The Harvest Module is available on the NMFS West Coast Region web site:
http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/interior_columbia/snake/harvest_module_062514.pdf.

1.5 Tribal Trust and Treaty Responsibilities

The salmon and steelhead that were once abundant in the watersheds throughout the Snake River Basin were critically important to Native Americans throughout the region. Pacific Northwest Indian tribes today retain strong economic, cultural, educational, and spiritual ties to salmon and steelhead, based on thousands of years of use for tribal subsistence, religious and/cultural ceremonies, and commerce. Many Northwest Indian tribes have treaties reserving their right to fish in usual and accustomed fishing places, including the geographic areas covered by this recovery plan.

Much of the management related to the treaty-reserved fishing rights for the Confederated Tribes of the Umatilla Indian Reservation, the Confederated Tribes and Bands of the Yakama Nation, Nez Perce Tribe, and the Confederated Tribes of the Warm Springs Reservation of Oregon in the Columbia River basin is under the continuing jurisdiction of the U.S. District Court for the District of Oregon in the case of *United States v. Oregon*, No. 68-513 (U.S. District Court 1968). In *U.S. v. Oregon*, the Court affirmed that language in the “Stevens treaties,” e.g., “… the right of taking fish at all usual and accustomed places, in common the citizens of the Territory …”, (Article III, Treaty with the Yakama, 1855; 12 Stat., 951) reserved for these tribes up to 50 percent of the harvestable surplus of fish passing through their usual and accustomed fishing areas. The language in the Treaty with the Eastern Band of Shoshoni and Bannock (1868) (15

Stat., 673), addressing the Shoshone Bannock tribes' rights is different. The Shoshone Bannock tribes have a reserved right under the treaty to, " … hunt on the unoccupied lands of the United States so long as game may be found thereon …." (Article 4).

Additionally, four Washington coastal tribes, the Makah, Quileute, Quinault, and Hoh, have treaty rights to ocean salmon harvest that may include some fall Chinook salmon destined for the Snake River basin. 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 tribes in the Columbia River Basin, whose reservations were created by Executive Order, do not have reserved treaty rights but do have a trust relationship with the federal government and an interest in salmon and steelhead management, including harvest and hatchery production. Tribes occupying the Upper and Middle Snake River reaches include the Burns Paiute Tribe, Shoshone Paiute Tribes of the Duck Valley Reservation, and the Fort McDermitt Paiute-Shoshone Tribe, which are Executive Order Tribes. These tribes, along with the Shoshone-Bannock Tribes of the Fort Hall Reservation, have common vested interests to protect rights reserved through the United States Constitution, federal unratified treaties (e.g. Fort Boise treaty of 1864 and Bruneau treaty of 1866), executive orders, inherent rights, and aboriginal title to the land, which has never been extinguished by these tribes. These rights, resources, cultural properties, and practices are not limited solely to hunting, fishing, gathering, and subsistence uses.

Restoring and sustaining a sufficient abundance of salmon and steelhead for harvest while achieving viable escapements is important in fulfilling tribal fishing needs. It is NMFS' policy to promote restoration of salmon and steelhead runs sufficient for tribal harvest. NMFS believes 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 Treaty reserved rights and tribal harvest goals and to include strategies that support those goals in a manner that is consistent with recovery of naturally spawning populations. NMFS believes that our relationship with the Pacific Northwest tribes is critically important to the region's future success in recovery of listed Pacific salmon.

1.5 Use of This Recovery Plan

The ESA clearly envisions recovery plans as the central organizing tool for guiding each species' recovery process. Accordingly, NMFS intends to use this recovery plan to organize and coordinate recovery of Snake River Fall Chinook salmon in partnership with state, tribal, and federal resource managers. Recovery plans are not regulatory documents, however, and 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). Recovery plans provide the following guidance:

- A context for regulatory decisions;
- A guide for decision making by federal, state, tribal, and local jurisdictions;
- A basis for species status reporting and delisting decisions;
- A structure to organize, prioritize, and sequence recovery actions;
- A structure to organize, prioritize, and sequence RM&E actions; and
- A framework for the use of adaptive management.

NMFS encourages federal agencies and non-federal jurisdictions to use recovery plans as they make decisions to allocate resources. For example:

- Actions carried out by federal agencies to meet ESA section 7(a)(1) obligations to use their programs in furtherance of the purposes of the ESA and to carry out programs for the conservation of threatened and endangered species;
- Actions that are subject to ESA sections 4(d), 7(a)(2), or 10;
- Hatchery and Genetic Management Plans and permit requests;
- Harvest plans and permits;
- Selection and prioritization of habitat protection and restoration actions;
- Development of RM&E programs;
- Revision of land use and resource management plans; and
- Other natural resource decisions at the federal, state, tribal, and local levels.

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

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

In implementing these programs, recovery plans are used as a reference for best available science and a source of context for evaluating the effects of actions on listed species. Recovery plans and recovery plan actions do not pre-determine the outcomes of any regulatory reviews or actions.

2. Background

Geographic setting, patterns of life history, recent history, and current distribution provide context for understanding the issues associated with recovery of Snake River fall Chinook salmon. This section provides this context. It also describes the critical habitat designation, recent programs and processes that have been initiated to improve the species since listing of Snake River fall Chinook salmon, and the relationship of this plan to those programs.

2.1 Geographic Setting

Snake River fall Chinook salmon historically spawned throughout the 600-mile reach of the mainstem Snake River from its mouth upstream to Shoshone Falls, a 212-foot high natural barrier near Twin Falls, Idaho (RM 614.7) (Figure 2-1). Much of the river reach flows along the southern portion of the Snake River plain, a broad, basaltic plateau formed from successive layers of sediment and lava flows.

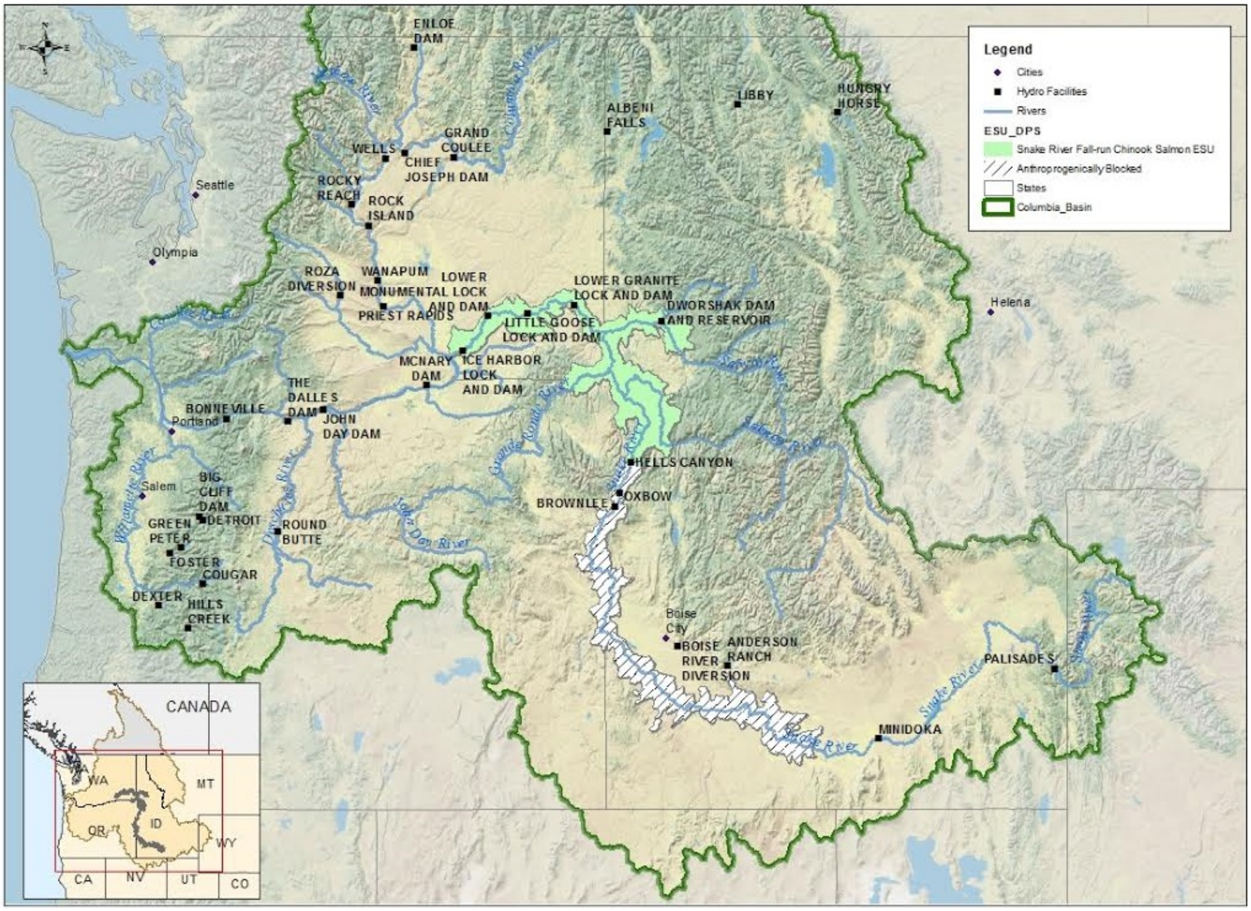

Figure 2-1. Snake River hydropower facilities from the historical limit of fall Chinook salmon access to the confluence with the Columbia River.

The geological formation creates a unique hydrological feature, an extensive spring complex from the Eastern Snake Plain Aquifer that contributed about 4,000 cubic feet per second of flow at an average temperature of approximately 15.5 °C (60 °F) to the Middle Snake River (Stearns 1936; Connor et al. 2015). The spring releases stretched from Shoshone Falls to Bancroft Springs (RM 552.8) and influenced water temperatures in the mainstem Snake River over a distance of approximately 86 miles, diminishing between the mouths of the Boise and Burnt Rivers. A large spring complex, known as Thousand Springs, was a major contributor of spring water to the river reach (Figure 2-2). The area influenced by the aquifer historically provided prime spawning conditions for fall Chinook salmon.

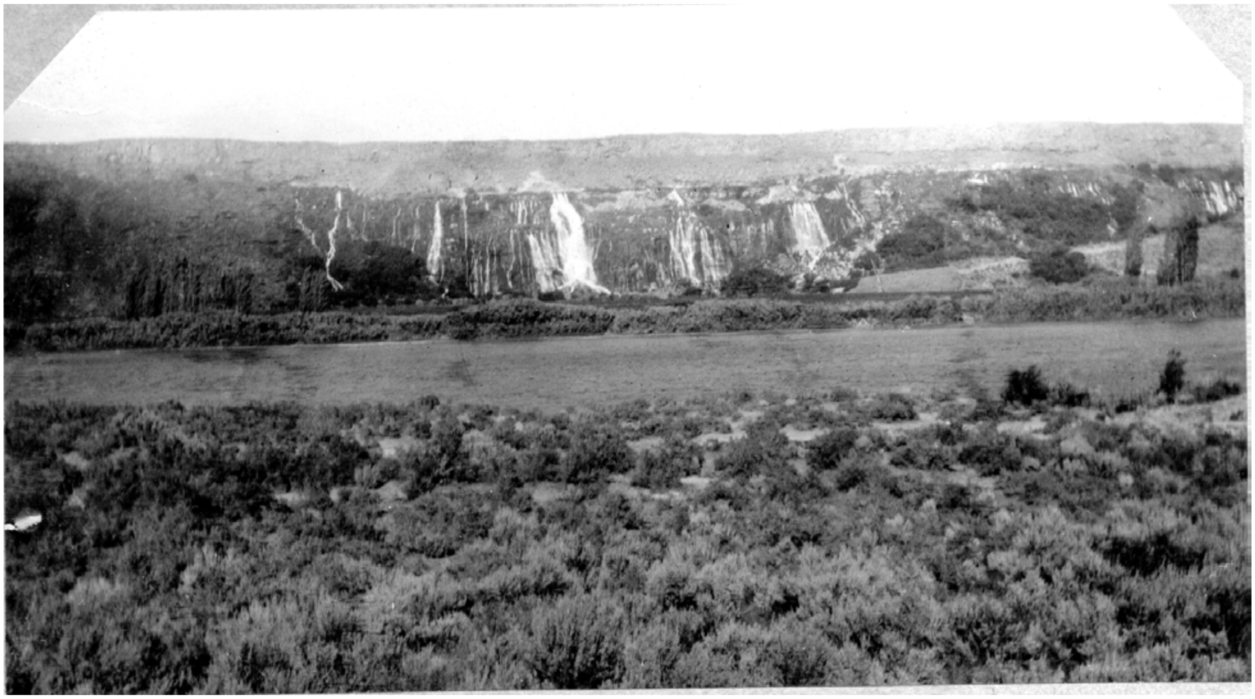

Figure 2-2. The area known as Thousand Springs (RM 584) contributes spring water from the Eastern Snake Plain Aquifer to the Middle Snake River (I.C. Russell, United States Geological Survey, 1902).

Nine major tributaries join this reach of the Middle Snake River: Salmon Falls Creek and the Owyhee and Bruneau Rivers originating in northern Nevada; the Boise, Payette, and Weiser Rivers originating in the central mountains of Idaho; and the Malheur, Burnt, and Powder Rivers originating in eastern Oregon.

Downstream of the mouth of the Powder River, the Snake River turns north and flows into Hells Canyon. Hells Canyon, carved by the Snake River at the far western end of the Snake River plain, is the deepest river canyon in North America, reaching nearly 8,000 feet deep and 10 miles wide. Its terraces are repetitive layers of weathered basalt alternating with sedimentary soils. The Seven Devils Mountains to the east and the Wallowa Mountains to the west form the upper reaches of the canyon walls and create a series of jagged peaks reaching nearly 10,000 feet (Brown 2003). In the free-flowing reach through Hells Canyon, the Snake River is steep and swift (1.8 meters/kilometer [m/km]), with numerous large rapids, shallow riffles, and deep pools, surrounded at the upstream end by nearly vertical cliff faces. The canyon becomes somewhat wider near Johnson Bar (RM 230), with moderate to steep topography continuing to the northern boundary of the Hells Canyon National Recreation Area (at RM 176) (IPC 1999). Hells Canyon is accessible only on foot or by boat. No roads cross it, and the few roads that reach the Snake River between Hells Canyon Dam and the Oregon–Washington state boundary are rough or close to impassable.

The climate in Hells Canyon is hot and dry in the summer, with relatively mild winters. Seasonal temperatures range from about minus 5 °C in January to about 35 °C in July. At elevations above 3,280 feet (1,000 m), mean temperatures range from 0 °C in January to between 28 °C and 33 °C in July (Johnson and Simon 1987). Precipitation is bimodal, with intense, short duration summer storms and milder, longer duration winter storms (Abramovich et al. 1998). The average annual precipitation for the Brownlee Dam and Lewiston, Idaho weather stations ranges from about 12 to 18 inches (Miller et al. 2003).

The Snake River Hells Canyon reach flows through the states of Idaho, Oregon, and Washington. Its southern end forms the border between Oregon and Idaho; at the tri-state convergence point it continues north for about 30 miles, separating Idaho and Washington, before turning west through Washington to join the Columbia River (Figure 2-1). The Snake River enters the Columbia River approximately 319 miles from the Pacific Ocean. Several tributaries join the lower Snake River, including the Grande Ronde, Imnaha, Salmon, Clearwater, and Tucannon Rivers. The river also courses through a mosaic of state, local, tribal, and federal jurisdictions. The Bureau of Land Management (BLM) and U.S. Forest Service (USFS) manage most of the public land in Hells Canyon, including parts of the Wallowa-Whitman National Forest in Oregon and the Payette and Nez Perce National Forests in Idaho. Other state and federal government agencies with natural resource jurisdiction in the area include the Idaho Department of Lands, National Marine Fisheries Service, Bureau of Indian Affairs, and U.S. Fish and Wildlife Service. Several special management areas also exist in the Hells Canyon area and are directly administered by the USFS. These include the Eagle Cap Wilderness in Oregon, the Hells Canyon Wilderness in Idaho and Oregon, the Hells Canyon National Recreation Area in Idaho and Oregon, the Wild and Scenic Imnaha River in Oregon, the Seven Devils Scenic Area in Idaho, and the Wild and Scenic Snake River in Idaho and Oregon (Brown 2003).

2.2 Historical Context

Before development of the impassable dams that form the Hells Canyon Complex, the majority of fall Chinook salmon adults in the Snake River basin returned to areas upstream of Hells Canyon (NMFS 2006b) along the Middle Snake River. This upstream area historically supported the bulk of fall Chinook salmon production. Snake River fall Chinook salmon spawned and reared in a large section of the Middle Snake River, stretching from Auger Falls (rkm 976.3) downstream to near the Burnt River mouth at the present site of Huntington, Idaho (rkm 527.6).

The Middle Snake River downstream of Shoshone Falls was largely characterized as low gradient, relatively shallow with abundant potential spawning and rearing habitat. According to Dauble et al. 2003, "historic spawning areas for fall Chinook salmon occurred primarily within wide alluvial floodplains, which were once common in the mainstem Columbia and Snake Rivers. These areas possessed more unconsolidated sediment and more bars and islands, and had lower water surface slopes than did less extensively used areas." In comparison, only limited spawning activity occurred downstream of RM 273, about one mile below the present location of Oxbow Dam (Waples et al. 1991) and where the majority of the species' spawning now occurs.

The major tributaries to the Middle Snake River — Salmon Falls Creek and the Owyhee, Bruneau, Boise, Payette, Weiser, Malheur, Burnt, and Powder Rivers — were accessible to fall Chinook salmon and other anadromous fishes; however the tributaries likely were less importance to the ESU than the mainstem Snake River spawning areas. The Middle Snake River transitioned into the Lower Snake River near the present location of Hells Canyon Dam, 248 miles upstream from the confluence with the Columbia River. Historical accounts describe fall Chinook salmon in the lower 169 miles (272 kms) of the Lower Snake River and in the Tucannon, Clearwater, Selway, Grande Ronde, and Imnaha Rivers (Van Dusen 1903; Chapman 1940; Schoning 1947; Parkhurst 1950; Fulton 1968). Schoning (1947) reported that no fall Chinook salmon were ever found in the Salmon River or its tributaries, but that account was later challenged by Burns (1992) who had compiled anecdotal evidence for fall Chinook salmon spawning in the lower most portion of the South Fork Salmon River during 1895-1990, the 1930s, and as recent as 1982.

Fall Chinook salmon were extirpated from the Clearwater Basin after the construction in 1927 of Lewiston Dam on the mainstem Clearwater River, six miles upstream from the river's mouth. Lewiston Dam resulted in the extirpation of Chinook salmon because its fish ladder was dry after the spring runoff as a result of routing all water through the powerhouse. This problem was remedied in 1939 (Chapman 1940) but the fall Chinook salmon population associated with the Clearwater River had already become extinct. Later, in 1973, Lewiston Dam was removed, allowing recovery of Chinook salmon in the Clearwater Basin, with the exception of the North Fork Clearwater River where anadromous fish were extirpated following construction of Dworshak Dam on this river, 1.9 miles from its confluence with the mainstem Clearwater River.

European-American Settlement and Influences

In the late 1800s, approximately 408,500 to 536,180 fall Chinook salmon are believed to have returned annually to the Snake River (Connor et al. 2015). The fish were extremely abundant and were distributed throughout the mainstem Snake River and likely the lower reaches of many of its major tributaries, from its confluence with the Columbia River upstream more than 600 miles to Shoshone Falls, Idaho (Waples et al. 1991). As discussed earlier, the great majority of these fish spawned upstream of the present site of Hells Canyon Dam.

The number of fall Chinook salmon returning to the Snake River began to drop toward the end of the 19th century. At this time European-American commercial harvest of Columbia River salmon turned to fall Chinook salmon as catches of spring and summer Chinook salmon declined. Annual catches of fall Chinook salmon at the time ranged from 3 million to nearly 9 million kilograms (kg.) (Fulton 1968, as cited in Waples et al. 1991). Chapman and Chandler (2003) estimated a peak commercial harvest of 80 percent of the returning adults. This rate of harvest resulted in a steady decline in adult abundance.

During this same period, development of the Snake River basin for mining, timber harvest, agriculture, livestock production, and other human uses altered mainstem and tributary habitats. Tributaries were dredged and dammed, reducing access to spawning and rearing areas and contributing sediment to the streams. Construction and operation of irrigation systems reduced instream flows, increased stream temperatures, increased fine sediment inputs into aquatic habitats, and created partial or complete migration barriers (Chandler et al. 2003). Livestock grazing reduced riparian vegetation, increased stream temperatures, and altered stream banks and channels. As summarized by Murray (1964), “[F]rom tributary headwaters to the confluence of the Salmon River, every drainage has been changed or influenced by domestic livestock, farming, timber cutting, fire and controlled burning, dam building and water diversion.”

Construction of Swan Falls Dam in 1901 to generate electricity for mines in the Owyhee Mountains further reduced fall Chinook salmon access to historical habitat:

> *[The dam]. . . became the upstream terminus for salmon in the Snake River. [It] blocked approximately 157 miles of mainstem Snake River, or approximately 25 percent of the entire anadromous section of the mainstem Snake River. In addition, the dam blocked fish access to Salmon Falls and Rock Creeks, which were the uppermost basins to support spring/summer chinook in the Snake River basin. Also, many smaller tributaries were blocked with construction of Swan Falls Dam (*Chandler et al. 2003).

Returns of Snake River fall Chinook salmon continued to diminish in the early 20th century. Settlers fishing in the lower portions of the Columbia River, where harvest was regulated, had moved upstream to Celilo Falls in 1904 and installed mechanized fish wheels in the vicinity of the falls that markedly increased catch. Concern over this unregulated fishery was expressed by H.G. Van Dusen, Master Fish Warden for the state of Oregon Department of Fisheries in 1907. In 1908, after several years of lobbying by Van Dusen, the state of Oregon passed a law that banned fish wheels in the portion of the Columbia River that included Celilo Falls and limited fishing near the falls to hook and line after August 25 (McAllister 1909). Thereafter, use of fish wheels declined over time and was eventually outlawed by the states of Oregon and Washington in 1928 and 1935, respectively (Oregon Historical Society 2003). The parties also agreed to the restricted fall fishing season and to the construction of hatcheries below all power plants and obstructions in the lower and mid-Columbia River (McAllister 1909). Nevertheless, Irving and Bjornn (1981) estimated that the mean number of fall Chinook salmon returning to the Snake

River declined from an annual return high of 47,600 in the period between 1938 and 1947 to 29,000 during the 1950s.

The construction of hydropower dams on the Middle Snake River below Shoshone Falls began in 1901 with the construction of Swan Falls Dam (RM 458). Following construction of this dam, additional dams were constructed upstream of Swan Falls beginning with Lower Salmon Falls, Upper Salmon Falls, Bliss, and CJ Strike Dams (Table 2-1). These projects inundated much of the fall Chinook salmon spawning habitat in the Middle Snake River. Later, beginning in the mid-1950s, the Federal Power Commission (the predecessor agency to the current Federal Energy Regulatory Commission (FERC) issued a license to Idaho Power Company (IPC) for the construction of Brownlee Dam. IPC completed Brownlee Dam in 1958 and then Oxbow Dam, 12 miles downstream of Brownlee Dam, in 1961, and Hells Canyon Dam, 26 miles downstream from Oxbow Dam, in 1967 (referred to collectively as the Hells Canyon Complex). Brownlee Dam ultimately would become a barrier to all migration of anadromous fish after initial passage efforts failed. Adult fish were successfully passed around Brownlee Dam using trap and haul methods, but juvenile fish passage collection at a large net barrier at Brownlee Dam failed. The large slack water of the river reduced the ability of the young fish to migrate through the reservoir in a timely manner before summer water temperatures and low dissolved oxygen levels established in the summer months (Graban 1964; Haas 1965). Efforts to pass fish ceased in 1964, which led to the extirpation of the remaining fall Chinook salmon in the Middle Snake River, along with spring/summer Chinook salmon and steelhead. The primary spawning habitat for fall Chinook salmon between Swan Falls and Brownlee Dam, often referred to as the Marsing Reach, extended from immediately below Swan Falls Dam to the town of Marsing, Idaho, where approximately 95 percent of the spawning in the Middle Snake River occurred after construction of Swan Falls Dam. The remaining 5 percent occurred generally between Marsing and the confluence of the Boise/Owhyee Rivers with the Snake River. Very little spawning occurred downstream of this area in the Middle Snake River.[4] Table 2-1 lists the eight dams on the mainstem Snake River from below Shoshone Falls to Hells Canyon.

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[4] A more complete overview of the events leading to this extirpation is available at the Northwest Power and Conservation Council’s website: http://www.nwcouncil.org/history/HellsCanyon.

Table 2-1. Mainstem Snake River dams operated by Idaho Power Company.

River Mile (RM)	Idaho Power Company Project	Type of Project
580.8	Upper Salmon Falls Dam	Run-of-the-river
575.3	Lower Salmon Falls Dam	
560.3	Bliss Dam	Run-of-the-river
494	C.J. Strike Dam	Storage, hydro
457.7	Swan Falls Dam	Run-of-the-river
284.6	Brownlee Dam	Storage, flood control, hydro
272.5	Oxbow Dam	Storage, flood control, hydro
247.6	Hells Canyon Dam	Storage, flood control, hydro

Construction of four federal dams on the lower Snake River in the 1960s and early 1970s (Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams) further restricted fall Chinook salmon production. The lower Snake River dams inundated 135 miles (217.3 km) of the lower mainstem habitat formerly used by Snake River fall Chinook salmon. By 1975, the total loss in Snake River mainstem habitat, based on river miles, was approximately 83 percent. Although the four lower Snake River dams had fish passage facilities, returns of adult fall Chinook salmon to the Snake River declined to very small numbers: an average of 12,720 from 1964 through 1968; 3,416 from 1969 through 1974; and 610 from 1975 through 1980 (Waples et al. 1991). Only about 78 natural-origin adults (Lavoy and Mendel 1996) returned to the Snake River in 1990, which precipitated the ESA-listing of the species.

Today, Snake River fall Chinook salmon spawn in the mainstem Snake River downstream of Hells Canyon Dam, including in the tailraces (areas downstream of the dams where the water exits and is often turbulent) of the lower Snake River dams (Dauble et al. 1999). The upper end (tailrace) of the Lower Granite Dam reservoir is now the downstream limit of the ESU’s spawning habitat and the reservoir is the downstream end of early (pre-smolt) rearing habitat. Figure 2-1 shows the dams on the length of the Snake River from the current accessible habitat to the historical extent of the fall Chinook salmon.

2.3 Life History

Snake River basin fall Chinook salmon spend one to four years in the Pacific Ocean, depending on gender and age at the time of ocean entry (Connor et al. 2005). They return to the Columbia River in August and September, and pass Bonneville Dam from mid-August to the end of September, with a median passage date of mid-September. The adults enter the Snake River between early September and mid-October (DART 2013).

Spawning

Once they reach the Snake River, fall Chinook salmon generally travel to one of five major spawning areas: the upper mainstem Snake River reach from Hells Canyon Dam to the mouth of the Salmon River (upper reach), lower mainstem reach from the mouth of the Salmon River to the upper end of Lower Granite reservoir (lower reach), lower Grande Ronde River, lower Clearwater River, and lower Tucannon River (described in Section 2.4 below). In recent years, adults in the two mainstem Snake River reaches and the Grande Ronde, and Tucannon Rivers have spawned from late October through early December and spawning peaked about the first week in November (Connor et al. 2011). Adults spawn about a week or two earlier in the lower Clearwater River compared to the adults in the other four major spawning areas (Connor et al. 2011).

Egg Incubation, Emergence, and Early Rearing

Egg incubation and emergence timing, as well as other early life history stages of Snake River fall Chinook salmon are significantly influenced by water temperature regime. Historically, juvenile Snake River fall Chinook salmon exhibited different early life history timing and growth in different reaches of riverine habitat depending on water temperature and growth opportunity. Taylor (1990) found that relatively warm streams produced juvenile Chinook salmon that migrated seaward as subyearlings, whereas relatively cool streams produced juvenile Chinook salmon that migrated seaward as yearlings. This growth opportunity paradigm can be used to depict early life history timing and growth of juvenile fall Chinook salmon prior to habitat changes caused by settlers in the 19th century, and to help understand variation in early life history among fish of the five major contemporary spawning areas.

Historically, as described in Sections 2.1 and 2.2, the core population of fall Chinook salmon spawned along the Middle Snake River in relatively warm spring water areas. A secondary population of fall Chinook salmon spawned along the Lower Snake River from the Grande Ronde River mouth to the Snake River mouth, and in several larger tributaries along that stretch of river. The different reaches of historical habitat that supported fall Chinook salmon fostered phenotypic diversity in spawn timing, rearing, and seaward migration as temperature varied among the rivers (Connor et al. 2015). The progression through the life stages that preceded downstream dispersal from natal riverine habitat can be assessed based on historical, predevelopment emergence timing estimates made from reconstructed temperature regimes (e.g, Connor et al. 2015). Fall Chinook salmon would have emerged earliest in the spawning areas directly influenced by discharges from the Snake River Plains Aquifer. The 15.5 °C water from this aquifer mixed with the cooler Middle Snake River water near Auger Falls (i.e., the upstream boundary of spawning) resulting in temperatures that averaged 9.5 °C during incubation and an estimated fry emergence date in mid-February. The estimated fry emergence date was early April for the portion of the Middle Snake River population that spawned near Swan Falls and points downstream where the influence of the aquifer was relatively weak (mean incubation temperatures of 6.2 °C to 7.0 °C). For example, the Marsing reach in the lower Middle Snake River had an estimated emergence date of April 10. Further downstream, any spawning that occurred in the Weiser area of the Middle Snake River had an estimated emergence date of April 19. Water temperature during incubation at the Oxbow site on the Middle Snake River (prior to construction of the Hells Canyon Complex) was relatively cold during the incubation period with an estimated emergence date of May 23rd (Connor et al. 2015).

Subpopulations of the Lower Mainstem Snake River population occupied spawning areas located well beyond the warming influence of the aquifer and likely produced late emerging fry over a wide range of dates. For example, based on estimates, the population's Upper Mainstem Snake River major spawning area (MaSA) (see Section 2.4) was one of the warmest spawning areas (mean incubation temperature ≈ 5.5 °C) with an estimated emergence date in mid-May compared to the Selway River that was the coolest spawning area (mean incubation temperature ≈ 4.5 °C) with an estimated emergence date in late June. Fall Chinook salmon in the lower elevation areas of the mainstem Snake River, as well as in the Grande Ronde and Tucannon Rivers, likely emerged later than fall Chinook salmon from the aquifer-fed reaches in the Middle Snake Reach above Hells Canyon, but earlier than fall Chinook salmon from the Hells Canyon reach of the Lower Snake River. Conditions in the Clearwater River fostered the latest emergence timing; Connor (2001) reported an estimated emergence date for the lower Clearwater River of June 17.

The warmer winter and early spring habitat conditions in the Middle Snake River that fostered early emergence also supported a faster progression in preparing for outmigration. Early-emerging juveniles could feed, rear and grow in their natal areas before outmigrating when summer water temperatures rose to potentially lethal levels (Connor et al. 2015). In comparison, later-emerging fall Chinook salmon produced from cold habitats, such as in the Clearwater River and Hells Canyon reach of the Snake River, did not have much time to rear and grow in natal habitats. The fish would have needed to outmigrate to avoid rising high summer water temperatures, which rose above 20 °C for a month or more each summer in the lower portion of the middle Snake River, and the lower Snake River and its tributaries. Thus, juveniles of subpopulations that were locally adapted to the relatively cool habitats in the Clearwater River drainage likely progressed through juvenile stages latest, grew the slowest, and depended on localized traits, such as rapid outmigration at a smaller size, to help compensate for the cooler incubation temperatures (Connor et al. 2015). Further, once downstream dispersal began, the seaward migrants had unrestricted access to pristine, abundant, and diverse habitats along the Columbia River and estuary. The juveniles also had the opportunity to either enter the Pacific Ocean as subyearlings, or overwinter in fresh or brackish water and enter the ocean as yearlings.

Today, water temperature and growth opportunity during egg incubation and early rearing continue to create variations in early life history among fish in the five major contemporary spawning areas. The lower Tucannon River is the warmest of the five major spawning areas during egg incubation (e.g., mean incubation temperatures, 6.4, 6.7, and 6.6 °C). The Snake River upper reach between the Salmon River and Hells Canyon Dam is also warm during egg incubation, with water temperatures more conducive to egg incubation than existed historically due to releases from the Hells Canyon Complex (e.g., mean incubation temperatures 6.0, 5.9, and 6.4 °C). The lower Clearwater River remains the coolest (e.g., mean incubation temperatures

5.0, 5.1, and 5.0 ^{o}C; brood year1992–1994 from Connor et al. 2003a). The developmental timing of juveniles in the Tucannon River and Snake River mainstem upper reach reflects the warm temperature regimes, and is similar to what was observed historically in the Middle Snake River (Connor et al. 2002, 2003a). In comparison, the hypoliminetic releases from Dworshak Reservoir have warmed the winter thermal regime in the lower Clearwater River and accelerated egg incubation compared to historical conditions in that river; however, fish from this area still emerge later than from other areas. Emergence timing estimates for brood years 1992–1994 ranged from April 8 to April 18 for the Tucannon River, April 16 to April 27 for the Snake River (Salmon River to Hells Canyon Dam), and May 28 to June 2 for the lower Clearwater River (Connor et al. 2003a).

Most young fall Chinook salmon move to shoreline riverine habitat after emerging from the gravel (e.g., Connor et al. 2002; but see Tiffan and Connor 2011). Temperature during shoreline rearing continues to influence growth opportunity, and the timing of dispersal from riverine habitat into downstream reservoirs. For example in spring 1995, the Snake River upper reach averaged 11.8 ^{o}C and fall Chinook salmon parr rearing along the shorelines grew an average (± SD) of 1.2 ± 0.3 mm/d compared to parr rearing along the mainstem Snake River lower reach that experienced a mean spring temperature of 10.9 ^{o}C and grew an average of 1.0 ± 0.3 mm/d (Connor and Burge 2003). The dates of peak dispersal from the Snake River upper and lower reaches into Lower Granite Reservoir were May 28 and June 4 in 1995, respectively (Connor et al. 2002). In contrast, fall Chinook salmon parr in the lower Clearwater River grow more slowly (e.g., 1995, 0.8 ± 0.5 mm/d; Connor et al. 2015) and linger in riverine habitat longer (e.g., 1995 date of peak dispersal July 2; Connor et al. 2002) than do parr in the Snake River reaches. Juveniles that incubate and rear in the relatively cool Clearwater River are most likely to exhibit the overwintering life history strategy.

The behavior of parr after the initiation of downstream dispersal from riverine habitat has not been fully investigated in the Tucannon and Grande Ronde Rivers, but this behavior has been a large topic of research in the two Snake River reaches and the lower Clearwater River. Connor et al. (2013) evaluated factors contributing to timing of dispersal downstream in the mainstem Snake River. The data suggested that competition for food and space was a stronger factor for dispersal timing into Lower Granite reservoir from the two reaches compared to the factors flow and temperature (Appendix C). The migrating juveniles forage along nearshore habitats, feeding and growing, as they make their way downstream to the reservoir. In comparison, the behavior of natural-origin parr after the initiation of downstream dispersal from riverine habitat of the lower Clearwater River is heavily dependent on when the parr begin to move downstream. Those parr that begin downstream dispersal in about June likely move downstream rapidly until they are delayed in lower 6 km of the lower Clearwater River where the river transitions and forms the east arm of Lower Granite Reservoir (Tiffan et al. 2009a). These early dispersing fish have the opportunity to enter Lower Granite Reservoir, grow, and then become actively migrating smolts along with their Snake River counterparts. However, the average parr in the lower Clearwater River does not begin downstream dispersal before a partial thermal barrier forms in July when the warm Snake River water from the south arm of Lower Granite Reservoir meets the cool lower Clearwater River water from the east arm of the reservoir (Cook et al. 2006). The parr can be delayed in the east arm until the thermal barrier dissipates in September (B. Arnsberg, unpublished data). While the delayed fish continue to grow (e.g., 103 mm fork length in August), it is unlikely that many resume active migration as subyearlings because their late schedule of development coincides with environmental conditions that do not favor smoltification (e.g., declining photoperiod and temperature).

Lower Granite Dam, Juvenile Rearing, and Passage

Time of passage at Lower Granite Dam is closely associated with growth and juvenile development in Lower Granite Reservoir, which in turn are dependent on many factors including juvenile abundance in the reservoir. Juveniles from the Snake River upper and lower reaches share a common temperature environment in the reservoir that is regulated by summer flow augmentation, thus growth differences between fish from the two reaches diminish in the reservoir (Connor and Burge 2003). Tiffan et al. (2009b) found that young fall Chinook salmon move up and down in the water column of the reservoir to maintain an optimum body temperature for growth.

As a result of the expanding improvements in flow augmentation, combined with increased hatchery production, estimated abundance of fall Chinook salmon (natural- and hatchery-origin combined) at Lower Granite Dam increased from an average ± SE (minimum; maximum) of 195,349 ± 93,983 (13,672 in 1992; 708,732 in 1999) during the time period 1992 to 1999, to 2,103,788 ± 115,120 (1,109,662 in 2007; 2,727,434 in 2012) during the time period 1999 to 2014 (Tiffan and Connor 2015). The 1999 and 2000 cutoff dates of those two time periods were established to divide the years into “low” and “high” abundance periods. Growth of natural-origin subyearling smolts from the Snake River that took place mostly in Lower Granite Reservoir averaged 0.6 ± 0.4 g/d during the low abundance period compared to 0.2 ± 0.3 g/d for fish during the 2000 to 2011 portion of the high abundance period (Connor et al. 2013). Smolt fork length fell from an average of 137 ± 8 mm during the low abundance period to an average of 94 mm ± 0.7 mm during the high abundance period. The inter-annual mean of the median days of passage at Lower Granite Dam for Snake River smolts was 14 days later during the low abundance period (July 14 ± 10 d) than during the high abundance period (June 30 ± 6 d).

A similar response in smolt growth and passage timing has not been documented for fish from the lower Clearwater River. Juveniles fall Chinook salmon from the Clearwater River do not experience high levels of smolt abundance for two reasons: 1) the increase in abundance of subyearling smolts is highly correlated with the number of subyearling hatchery smolts released (r^2 = 0.67; Connor et al. 2015); and 2) the large majority of hatchery smolts pass Lower Granite Dam before natural-origin parr from the lower Clearwater River enter the reservoir (e.g., Connor et al. 2012). Across the major spawning areas, juveniles from the Clearwater River pass Lower Granite Dam the latest. For example in 2011, the median dates of passage for fish from the Snake River upper reach, Snake River lower reach, and lower Clearwater River were June 16, July 12, and September 28, respectively (Connor et al. 2012).

Accounts of fall Chinook salmon smolt migration before dam development on the lower Snake River indicate that the fish once exhibited an earlier migration timing. Mains and Smith (1964) examined smolt migration timing through the lower Snake River. They sampled juvenile anadromous salmonids 41 km downstream from the present location of Lower Granite Dam (constructed in 1973) in 1954 and 1955 after the locally adapted Clearwater River subpopulation had been driven to extinction (Rich 1940), but when brood year 1953 and 1954 natural-origin fall Chinook salmon juveniles from the middle and lower Snake River were migrating seaward. Based on daily catch data, passage of the entire Chinook salmon smolt run was complete by the end of June (Mains and Smith 1964). During the low abundance period, only 25 percent of the smolts from the Snake River reaches had passed Lower Granite Dam by the end of June compared to 50 percent during the high abundance period. Since it is unlikely that the construction of the Hells Canyon Complex caused a net reduction in cumulative temperature units between spawning and downstream dispersal from natal riverine habitat, the protracted nature of passage through Lower Granite Reservoir presently observed must be the result of impoundment. Migrants pass much faster through free-flowing stretches of river than through reservoirs (e.g., means ± SDs for subyearling smolts, 107 ± 6 km/d versus 19 ± 3 km/d; Tiffan et al. 2009a).

Juvenile Migration through Snake and Columbia Rivers ─ Subyearlings and Yearlings

Today, some fall Chinook salmon smolts from the five major spawning areas sustain active migration after passing Lower Granite Dam and enter the ocean as subyearlings, whereas some delay seaward migration and enter the ocean as yearlings (Connor et al. 2005; McMichael et al. 2008; Fresh et al. 2014). Those fish that discontinue active seaward migration continue to move downstream slowly throughout winter while growing to fork lengths above 170 mm before increasing their rate of downstream movement and entering saltwater in spring (Connor et al. 2005; Tiffan et al. 2012c). This alternative pathway to the ocean was first observed in Brownlee Reservoir in 1958 (Durkin et al. 1970), and is referred to as the “reservoir-type” juvenile life history or tactic (Connor et al. 2005).

Although the proportion of the natural-origin juvenile population that exhibits the reservoir-type tactic is not known, its importance to adult returns has been widely discussed and documented. Haas (1965) speculated that the fish that survived in Brownlee Reservoir to become yearling migrants were sustaining production in the Middle Snake River that was historically sustained by subyearling migrants. Connor et al. (2005) reported that an overall average of 41 percent of the natural-origin adults they collected at Lower Granite Dam during 1998–2003 had entered the ocean as yearlings. Hegg et al. (2013) conducted otolith microchemistry on a sample of adults collected at Lower Granite Dam presumed to be of natural-origin during 2006–2008. Of the adults sampled, 16 were determined to be from the Snake River upper reach, 58 were from the Snake River lower reach, 2 were from the Grande Ronde River, and 44 were from the Clearwater or Salmon Rivers (water chemistry signals did not vary between these rivers). The percentage of the returning adults estimated to have entered the ocean as yearlings was 13 percent for fish from the Snake River upper reach, 62 percent for fish from the Snake River lower reach, 50 percent for fish from the Grande Ronde River, and 77 percent for fish from the Clearwater-Salmon River grouping. Of these adults, it was estimated that 97 percent had inhabited the lower Snake River reservoirs during winter.

Juvenile fall Chinook salmon also rear in the lower Columbia River and estuary (Waples et al. 1991). Migration timing to the estuary is critical as there is a finite window of opportunity during which juveniles are physiologically able to survive the transition from fresh water to salt water (Tiffan et al. 1997). The yearling and subyearling components of the ESU have different estuary and ocean life history patterns. Yearling Snake River fall Chinook salmon migrate downstream rapidly (averaging 24.6 km/day) and typically use main channels and other large flow distributaries during their migration (Weitkamp et al., In Review). There is little evidence of extended rearing (weeks to months) by Snake River fall Chinook salmon yearlings in the estuary (Fresh et al. 2014). Yearlings generally move through the reach in about a week, similar to yearling Snake River spring/summer Chinook salmon. In contrast, Snake River fall Chinook salmon subyearlings exhibit a diversity of migration behaviors. Some subyearlings use shallow nearshore and off-channel areas below Bonneville Dam for rearing and migration (Fresh et al. 2005). Snake River fall Chinook salmon can be present in the estuary as juveniles in winter, as fry from March to May, and as fingerlings throughout the summer and fall (Weitkamp et al., In review; Fresh et al. 2005; Roegner et al. 2012; Teel et al. 2014).

Ocean Dispersal and Rearing

Once in the Northern California Current, dispersal patterns differ for yearlings and subyearlings. Subyearlings migrate more slowly, are found closer to shore in shallower water, and do not disperse as far north as yearlings (Trudel et al. 2009, Tucker et al. 2011, Sharma and Quinn 2012, Fisher et al. 2014; Fresh et al. 2014). By the beginning of their second year at sea, yearling fall Chinook salmon have moved off the shelf and into the Gulf of Alaska. Subyearlings first appear in ocean research trawls in June, primarily north of the Columbia River mouth, and some reach the west coast of Vancouver Island by June (Trudel et al. 2009). By September, trawl catches show that subyearling Snake River fall Chinook salmon are widely dispersed in the Northern California Current from central Oregon to the west coast of Vancouver Island and by the end of their first year in the ocean, these fish have not dispersed much farther north (Tucker et al. 2011).

Snake River basin fall Chinook salmon spend one to four years in the Pacific Ocean, depending on gender and age at the time of ocean entry (Connor et al. 2005). Natural-origin females that enter the ocean as subyearlings typically spend three years in saltwater (80 percent of the 1998–2003 returns), whereas females that enter the ocean as yearlings typically spend three to four years in saltwater (1998–2008 returns; 44 percent returned after three years and 54 percent returned after four years). Natural-origin males that enter the ocean as subyearlings largely return to freshwater after three years in saltwater (47 percent of the 1998–2003 returns), while males that enter saltwater as yearlings have a relatively even ocean-age class distribution (1998–2008 returns; 29 percent after two years, 31 percent after three years, 24 percent after four years). A small number of maturing males (referred to as jacks) return to the river after one year or less in the ocean. Adult fall-run Chinook salmon, including Snake River fall Chinook salmon, return to the lower Columbia in August and September.

2.4 Distribution

The Snake River fall-run Chinook salmon ESU is one of three fall Chinook salmon ESUs that spawn and rear in the Interior Columbia basin (Figure 2-3) (NMFS 1999a, 64 FR 50394). The other two are the Upper Columbia River summer- and fall-run Chinook salmon ESU and the Deschutes River summer-and fall-run Chinook salmon ESU.

- The Snake River fall-run Chinook salmon ESU contains a single major population group with two populations: the Lower Mainstem Snake River and the Middle Snake River. At present, only the Lower Mainstem Snake River population (including tributaries below Hells Canyon Dam) is extant.
- The Upper Columbia summer/ fall-run Chinook salmon ESU spawns in the Hanford Reach of the Columbia River and in the lower reaches of major tributaries to the Middle Columbia. It is considered viable and self-sustaining and therefore is not ESA-listed. It is considered to have the closest affinity to the Snake River fall Chinook salmon ESU, but genetic differences also indicate “significant, long-term reproductive isolation of the two groups” (Waples et al. 1991; NMFS 1999a).
- The Deschutes River summer/ fall-run Chinook salmon ESU is considered a single population and is also not ESA-listed. Genetic and life history data for the population indicate a closer affinity to fall Chinook salmon in the Snake River than to those in the Columbia River (Myers et al. 1998).

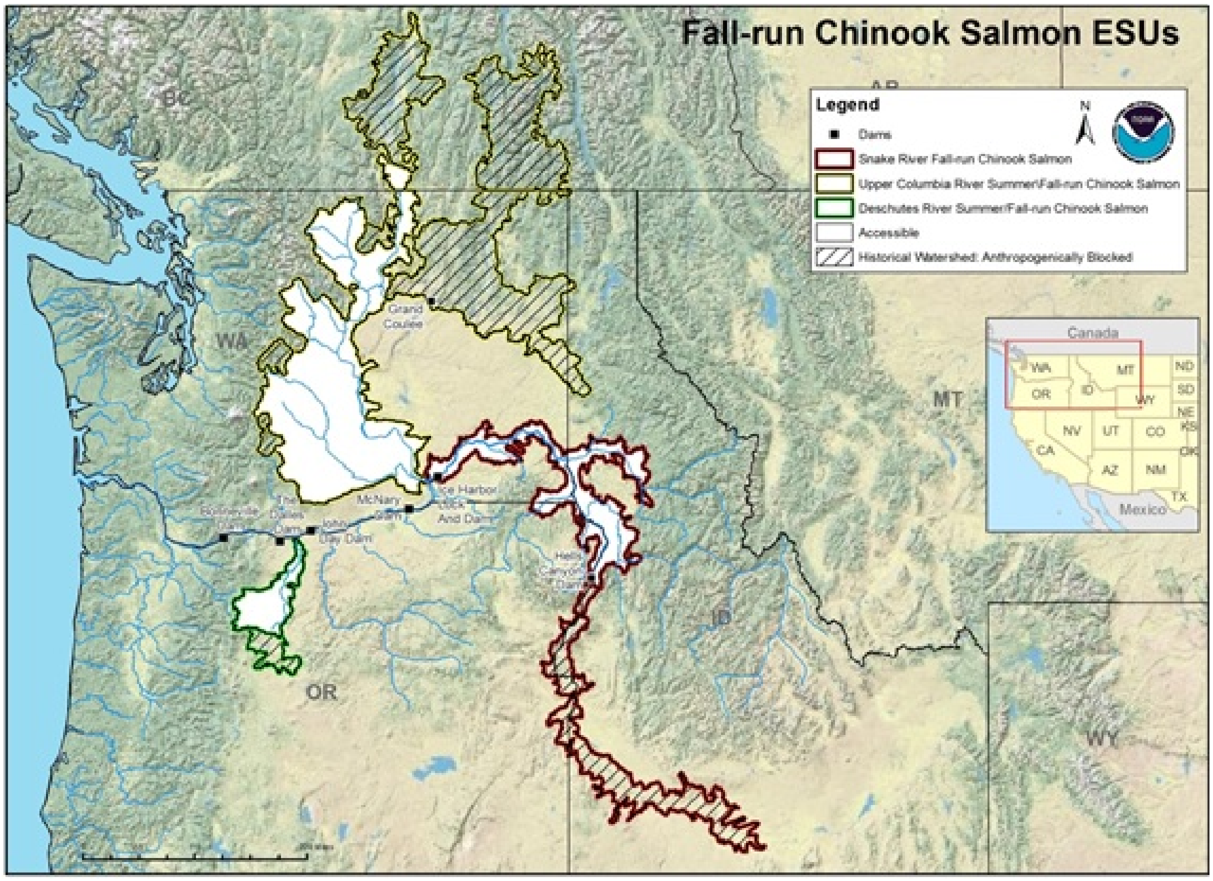

Figure 2-3. Distribution of Interior Columbia River fall Chinook salmon ESUs.

The historical Snake River fall Chinook salmon ESU included the core mainstem Snake River populations as well as several functionally dependent or locally adapted subpopulations that spawned in numerous locations including the Grande Ronde, Clearwater, and Selway Rivers. The great majority of Snake River fall Chinook salmon historically spawned in the Middle Snake River area above the current location of Hells Canyon Dam. The primary (largest and most productive) Middle Snake River subpopulation likely spawned within the area of direct aquifer influence, which extended about 34 miles downstream from Auger Falls to Lower Salmon Falls, with production centered on Millet Island. Temperature conditions during spawning and incubation were strongly influenced by water inputs from the aquifer, allowing for earlier emergence timing and growth especially in the reaches upstream of the current Swan Falls Dam site. The area extending approximately 2.18.5 miles upstream from the mouth of the Burnt River was likely a secondary spawning area (Connor et al. 2015). The subpopulation above Swan Falls was extirpated by construction of the Swan Falls Dam in 1901. After construction of Swan Falls Dam blocked passage to upstream areas, the remaining reaches of the Middle Snake River where water temperatures were influenced by the aquifer likely became the primary spawning and rearing area for Snake River fall Chinook salmon (Haas 1965; Irving and Bjornn 1981). The Middle Snake River areas supported approximately 60 percent of all production in the ESU before the Hells Canyon Complex and lower Snake River dams were completed (Chandler et al. 2001; Dauble et al. 2003).

Today, the only extant Snake River fall Chinook salmon population, the Lower Mainstem Snake River population, spawns in 100 miles of the mainstem Snake River from the Hells Canyon Dam downstream to the upper end of the Lower Granite Dam pool (near Lewiston, Idaho) plus the lower reaches of major tributaries (ICTRT 2010). This area — which provides the only habitat remaining after the inundation of the lower Snake River spawning areas by federal and private hydropower development — includes remaining spawning habitat in the Hells Canyon Reach that has been estimated at 20 percent of the spawning area historically available (Chandler et al. 2001; Dauble et al. 2003).

Historically, the primary subpopulation of the Lower Snake River population probably spawned along the stretch of the Snake River between the Grande Ronde River mouth and the confluence with the Columbia River. While most of the information on this historical lower Snake River population is anecdotal, there is compelling evidence for the existence of secondary functionally dependent, or locally adapted, subpopulations in the Tucannon, Selway, Clearwater, Grande Ronde, and Imnaha Rivers, as well as in the lower portion of the South Fork Salmon River (see Section 2.2) (Connor et al. 2015).

The Lower Mainstem Snake River area was historically substantially less productive than the areas that supported the extirpate population in the ESU for two reasons. First, the area was not influenced by the Snake River Plains Aquifer. Second, the geomorphology of the Lower Snake River was less suitable for fall Chinook salmon production compared to the geomorphology of the areas in the Middle Snake River (Dauble et al. 2003). The extant Lower Mainstem Snake River population has multiple major and minor spawning areas in diverse tributary habitats, however, that support diversity and potential resilience for recovery under today's ecological conditions.

For the extant Lower Mainstem Snake River population, the ICTRT (ICTRT 2007) identified five major spawning areas (MaSAs), the locations of which are identified in Figure 2-4. The five MaSAs include:

1. Upper Mainstem Snake River MaSA ─ The stretch of the Lower Snake River from Hells Canyon Dam downstream to the mouth of the Salmon River, and including the lower mainstems of the Imnaha and Salmon Rivers;
2. Lower Mainstem Snake River MaSA ─ The stretch of the Lower Snake River from the mouth of the Salmon River downstream to the upper end of Lower Granite Reservoir;
3. Grande Ronde River MaSA;
4. Clearwater River MaSA; and
5. Tucannon River MaSA (and contiguous mainstem Snake River habitat).

The historic distribution of spawning was linear and included mainstem Snake River reaches from Hells Canyon downstream to the mouth of the Snake River along with the lower portions of three relatively large tributaries: the Clearwater, Grande Ronde, and Tucannon Rivers (Connor et al. 2005). In addition, the lower mainstem reaches of the Salmon and Imnaha Rivers were likely minor spawning areas. There is some anecdotal information that the Clearwater River historically may have supported substantial numbers of Chinook salmon with adult timing similar to the current fall Chinook salmon run. September entries in the journals of Lewis and Clark describe the mainstem Clearwater River reach downstream of the North Fork Clearwater River as "200 yards wide and abounding in salmon of excellent quality." Newspaper reports from October 1927 describe large numbers of salmon at the Lewiston Dam site trying to ascend upstream.

Historically, some level of fall Chinook salmon spawning may have occurred in the lower Snake River in the reach currently inundated by the Ice Harbor Dam pool (Dauble et al. 2003). Spawners using the lowest potential spawning reaches in the Snake River, currently inundated by Ice Harbor Dam, could have been associated with either the Lower Snake River population or a population centered on mainstem Columbia River spawning areas currently inundated by John Day and McNary Dams.

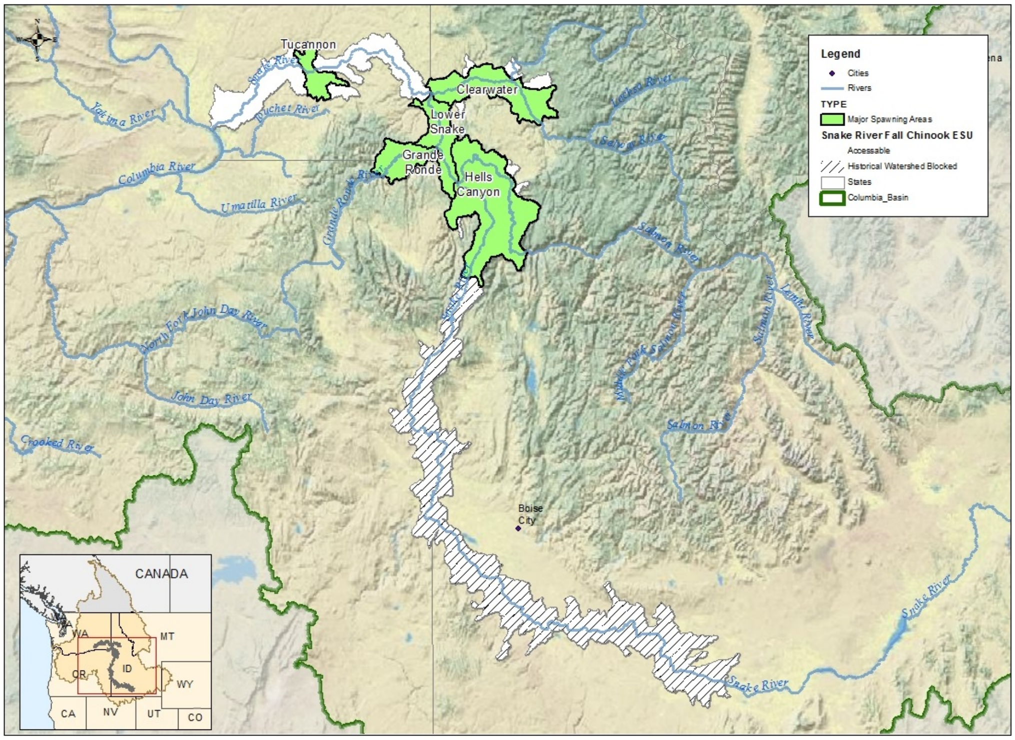

Figure 2-4. Current Snake River fall Chinook salmon Major Spawning Areas (MaSAs). Note: Designation of MaSAs for this population were based on consistent spatial patterns in annual redd counts and USGS spawning habitat modeling specific to mainstem spawning Chinook salmon. Snake River fall Chinook salmon MaSAs reflect geographic separation in spawning habitat patches, current spawning densities and unique habitat conditions in adjoining lower tributary reaches (Source: ICTRT 2010).

Redd (spawning nest) survey effort increased after the Snake River fall Chinook salmon ESU was petitioned and listed under the Endangered Species Act. Redd counts provide a general depiction of the spatial distribution of spawning in the wild. Since 1991 the majority of the redds have been counted in the Snake River upper reach (mean ± SE, 30 ± 2%) followed closely by the lower Clearwater River (24 ± 2%) and Snake River lower reach (23 ± 2%), and the Tucannon (11 ± 2%) and Grande Ronde (7 ± 1%) Rivers (Figure 2-5).

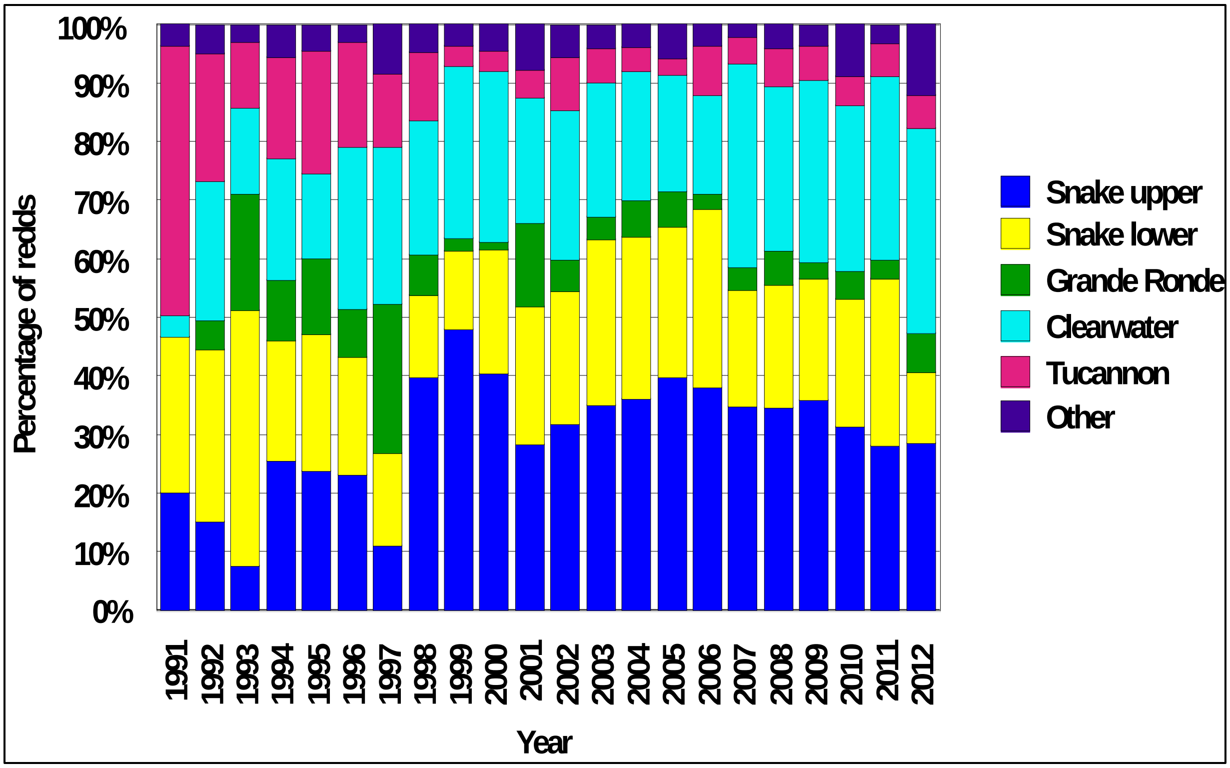

Figure 2-5. Percent of Snake River basin fall Chinook salmon redds counted in the five major spawning areas and in other adjacent areas surveyed since the population was petitioned for listing in 1991 (data from the Idaho Power Company, Nez Perce Tribe, U.S. Fish and Wildlife Service, and Washington Department of Fish and Wildlife).

2.5 Critical Habitat

The ESA, section 3(5), requires NMFS to designate critical habitat for any species it lists under the ESA. The Act defines critical habitat as areas that contain physical or biological features that are essential for the conservation of the species, and that may require special management considerations or protection. Critical habitat designations must be based on the best scientific information available, in an open public process, within specific time frames. Under section 4(b)(2) of the ESA, NMFS may exclude areas 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. Before designating critical habitat, NMFS must carefully consider economic, national security, and other relevant impacts of the designation.

A critical habitat designation does not set up a preserve or refuge, and does not affect activities on private land unless federal permitting, funding, or direct action is 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.

NMFS defines essential salmon habitat as consisting of four components: (1) spawning and juvenile rearing areas; (2) juvenile migration corridors; (3) areas for growth and development to adulthood; and (4) adult migration corridors. Essential features of spawning and rearing areas include adequate spawning gravel, water quality, water quantity, water temperature, food, riparian vegetation, and access. Essential features of juvenile migration corridors include adequate substrate, water quality, water quantity, water temperature, water velocity, cover/shelter, food, riparian vegetation, space, and safe passage conditions. The adult migration corridors are the same areas as juvenile migration corridors, and the essential features are the same, with the exception of adequate food (since adults do not eat on their return migration to natal streams) (NMFS 1993, 58 FR 68543). Because Pacific Ocean areas used by listed salmon for growth and development to adulthood are not well understood, NMFS has not defined essential features of these areas or designated critical habitats in the ocean and nearshore (NMFS 1993, 58 FR 68543; NMFS 2005b, 70 FR 52640).[5]

NMFS designated critical habitat for Snake River fall Chinook salmon on December 28, 1993 (NMFS 1993, 58 FR 68543). The designation consists of all Columbia River estuarine areas,[6] as well as river reaches upstream to the confluence of the Columbia and Snake Rivers, and all Snake River reaches from the confluence of the Columbia River upstream to Hells Canyon Dam. It also includes the Palouse River from its confluence with the Snake River upstream to Palouse Falls, the Clearwater River from its confluence with the Snake River upstream to its confluence with Lolo Creek, and the North Fork Clearwater River from its confluence with the Clearwater River upstream to Dworshak Dam. Critical habitat also includes river reaches presently or historically accessible (except reaches above impassable natural falls, and Dworshak and Hells Canyon Dams) to Snake River fall chinook salmon in the following hydrologic units: Clearwater, Hells Canyon, Imnaha, Lower Grande Ronde, Lower North Fork Clearwater, Lower Salmon, Lower Snake, Lower Snake-Asotin, Lower Snake-Tucannon, and Palouse. Designated areas consist of the water, waterway bottom, and the adjacent riparian zone (defined as an area 300 feet from the normal high water line on each side of the river channel) (NMFS 1993, 58 FR 68543).

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[5] However, recent data and analyses are beginning to provide new information on ocean use. This information is summarized for the plume and nearshore ocean in the Ocean Module (Appendix D).

[6] From a straight line connecting the west end of the Clatsop jetty (south jetty, Oregon side) and the west end of the Peacock jetty (north jetty, Washington side) (NMFS 1993 [58 FR 68543])

2.6 Recent History and Programs since Listing

The drastic declines in Snake River fall Chinook salmon runs in the late 1980s through early 1990s[7] prompted harvest managers to implement significant harvest reductions and hatchery managers to undertake egg bank programs to conserve the gene pool. Since NMFS listed Snake River fall Chinook salmon under the ESA in 1992, ESA protections have also contributed substantially to conserving the species. For example, the ESA prohibits the take of listed species with some exemptions for activities pursuant to ESA section 4, section 7, and section 10. Regulations that apply to Snake River fall Chinook salmon today include NMFS' December 28, 1993, ESA section 4(b)(2) critical habitat designation (NMFS 1993, 58 FR 68543) and the July 10, 2000, 4(d) rule (NMFS 2000, 65 FR 42422), which contains regulations deemed necessary and advisable for the conservation of the species. The 4(d) rule addresses habitat, harvest, hatchery, and research and monitoring activities.

Furthermore, upon listing, all federal activities authorized, funded, or carried out by federal agencies that may affect the species require ESA section 7 consultations to ensure that they do not jeopardize the continued existence of the species nor adversely modify its critical habitat. Section 10(a) mandates regulatory reviews and permits for any take for scientific purposes or to enhance the propagation of the species. The objective of all ESA regulatory actions is to conserve the listed species and its ecosystems. Thus, even though a recovery plan has not been in place to provide context, many changes have collectively led to substantially improved survival. The following sections summarize the recent history of programs and processes that have influenced Snake River fall Chinook salmon survival since listing.

2.6.1 Federal Columbia River Power System

The Federal Columbia River Power System (FCRPS) is managed as a collaboration among three federal agencies - the Bonneville Power Administration (BPA), the U.S. Army Corps of Engineers (Corps), and the Bureau of Reclamation (USBR) (hereinafter the FCRPS agencies). Collectively, the FCRPS agencies maximize the use of the Columbia River by generating power, protecting fish and wildlife, controlling floods, providing irrigation and navigation, and sustaining cultural resources. The 31 federally owned multipurpose dams on the Columbia and its tributaries that comprise the FCRPS provide about 60 percent of the region's hydroelectric generating capacity. The FCRPS supplies irrigation water to more than a million acres of land in Washington, Oregon, Idaho and Montana. As a major river navigation route, the Columbia-Snake Inland Waterway provides shipping access from the Pacific Ocean to Lewiston, Idaho, 465 miles inland. Water storage at all projects on the major tributaries and mainstem of the Columbia totals 55.3 million acre-feet, much of which enhances flood control.

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[7] As described in Section 2.2 adult returns averaged 12,720 from 1964 through 1968; 3,416 from 1969 through 1974; and 610 from 1975 through 1980 (Waples et al. 1991). Only about 78 natural-origin adults (Lavoy and Mendel 1996) returned to the Snake River in 1990, which precipitated the ESA-listing of the species.

Snake River fall Chinook salmon must navigate eight FCRPS dams as both out-migrating juveniles and returning adults. In 1993, NMFS and the FCRPS agencies completed their first ESA section 7 consultation on the FCRPS and NMFS issued a biological opinion. NMFS and the FCRPS agencies were sued on that biological opinion. Judge Marsh, the presiding judge declared, “The situation literally cries out for a major overhaul” (Marsh 1994). Two decades of ESA consultations ensued, biological opinions, and ongoing litigation involving multiple diverse plaintiffs - including environmental organizations, river users, states, and tribes. NMFS issued a FCRPS biological opinion (FCRPS BiOp) in 2008; supplemental biological opinions in 2010 and 2014 updated the 2008 biological opinion (NMFS 2008b; NMFS 2010; NMFS 2014c).[8]

2.6.1.1 Structural and Operational Improvements

Since 1994, the FCRPS agencies have made significant changes to improve salmon survival, including improvements and additions to fish passage facilities, operational changes in flow and spill, implementation of a juvenile transportation program, and predator control. Primarily through the Corps’ Columbia River Fish Mitigation Project, structural improvements have been added to improve fish passage at all eight dams that Snake River fall Chinook salmon navigate. Over $1 billion has been invested since the mid-1990s in baseline research, development, and testing of prototype improvements, and construction of new facilities and upgrades. The Hydro Module (NMFS 2014a, Appendix E) summarizes the structural and operational changes to the FCRPS since 1994.

The configuration and operational improvements at the mainstem dams, along with improved flow management programs and temperature control operations at Dworshak Dam - in concert with other measures described in this section - have substantially increased both juvenile survival rates (see Figure 2-9 below) and the number of returning adults. The Hydro Module discusses recent improvements in salmon and steelhead passage rates as adult passage facilities have become more effective. In addition, the FCRPS agencies provide annual updates in their Endangered Species Act Federal Columbia River Power System Annual Progress Reports (Annual Progress Reports) that detail the implementation and progress of the 2008 Biological Opinion actions (USACE et al. 2009; USACE et al. 2010; USACE et al. 2011; USACE et al. 2012; USACE et al. 2013).

Current configurations and operations at the dams are designed to achieve the 2008 FCRPS BiOp’s hydro dam passage performance standard of 93 percent survival at each project for summer migrating fish (NMFS 2008b). The current estimates of average adult Snake River fall Chinook salmon survival (conversion rate estimate using known-origin fish after adjusting for reported harvest and natural rates of straying) between Bonneville and Lower Granite Dams is 90.5 percent. Passage rates for the fish from 2008 to 2012 averaged 93.5 percent from Bonneville to McNary Dam, and 96.9 percent from McNary to Lower Granite Dam (NMFS 2014c).

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[8] It is the state of Oregon’s position that additional or alternative actions to the FCRPS BiOp 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’ FCRPS BiOp. At this time, Oregon is a plaintiff in litigation against the FCRPS agencies and NMFS, challenging the adequacy of the measures contained in the current (2008 as supplemented in 2010 and 2014) FCRPS BiOps.

Juvenile Snake River fall Chinook salmon passage rates have also improved because of FCRPS changes, including provision of summer spill and the addition of surface spillway weirs. Survival studies show that with few exceptions, the fish passage improvement measures are performing as expected and are very close to achieving, or are already achieving, the juvenile dam passage survival objectives of 96 percent for yearling Chinook salmon and 93 percent for subyearling Chinook salmon (NMFS 2014c) (Figure 2-6).

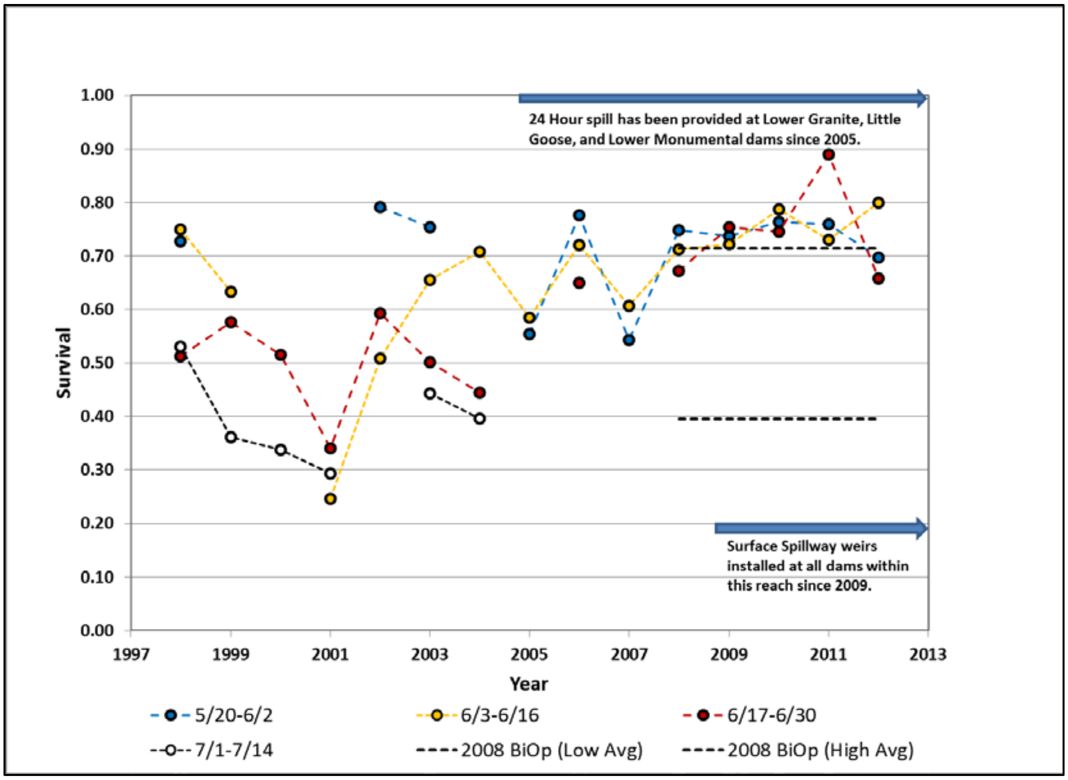

Figure 2-6. Estimated survival rates from two-week cohorts of juvenile subyearling SR fall Chinook salmon between Lower Granite and McNary Dams from 1998 to 2012. Black horizontal dashed lines denote Prospective minimum and maximum average survival rates estimated in the 2008 BiOp; blue arrows denote years in which Court Ordered summer spill occurred at the three Snake River transport projects (top) and years in which all dams in this reach were configured with surface passage routes (bottom) (NMFS 2014c).

2.6.1.2 Transportation Studies

Transporting juvenile fall Chinook salmon in barges or trucks past the lower Snake River dams has been a management action since the late 1970's. Juvenile fish are collected at the projects with transport capabilities (Lower Granite, Little Goose, Lower Monumental, and McNary Dams) and barged or trucked to release locations below Bonneville Dam. The objective is to increase survival of the fish by transporting them past known areas of high mortality. The survival of transported juveniles is about 98 percent, which is higher than survival estimated for in-river migrants. From 2008 to 2011, an average of 52.8 percent of subyearling Snake River fall Chinook salmon were transported (DeHart 2012).

The value of transportation as a strategy to improve juvenile survival is continuously evaluated. Transport of juveniles was considered an essential management measure when no voluntary spill was provided at the Snake River dams during the summer migration season. Beginning in 2005, spill was provided at the Snake River projects during the summer months and in 2007 a study was initiated to assess the benefit of transporting Snake River fall Chinook salmon juveniles. The design of the study was a collaborative effort between NMFS, U.S. Fish and Wildlife Service (USFWS), the Nez Perce Tribe, and the states of Idaho and Oregon. It involved marking over 500,000 fish annually for a five-year period. The results will be based on the difference in adult return rates between fish that were transported or migrated in-river as juveniles. The results of this study will inform future management decisions on transport actions. This study is addressed in more detail in the Hydro Module (NMFS 2014a, Appendix E).

2.6.1.3 Additional FCRPS agencies' offsite mitigation addressing habitat, predation, and hatchery reform

Since 2000, the FCRPS consultations have included actions to provide offsite mitigation for hydro impacts that remain after dam operations and structural improvements. Thus, the FCRPS agencies have been implementing and funding substantial tributary and estuary habitat programs, predator control for avian predators and northern pikeminnow, and hatchery reform actions. The FCRPS offsite mitigation program is summarized in the Annual Progress Reports (USACE et al. 2009; USACE et al. 2010; USACE et al. 2011; USACE et al. 2012; USACE et al. 2013).

2.6.2 Columbia Basin Fish Accords

Many of the 2008 FCRPS BiOp actions depend on cooperation with states and tribes. To promote regional collaboration and supplement the 2008 FCRPS BiOp , the FCRPS Agencies entered into the 2008 Columbia Basin Fish Accords with three States (Idaho, Montana, and Washington), five Tribes (Confederated Tribes of the Warm Springs Reservation of Oregon, the Confederated Tribes of the Umatilla Indian Reservation, the Confederated Tribes and Bands of the Yakama Nation, Confederated Tribes of the Colville Reservation, and the Shoshone-Bannock Tribes), and the Columbia River Inter-Tribal Fish Commission. The Accords provide firm commitments to hydropower performance standards and operations, habitat and hatchery actions, greater clarity regarding biological benefits and they secure funding. The Accords directly addressed long-standing issues between the tribes and the FCRPS agencies, including adequate spill regimes, which are particularly important for outmigrating Snake River fall Chinook salmon juveniles. A provision in the "2008 Columbia Basin Fish Memorandum of Agreement between the three Treaty Tribes and FCRPS Action Agencies," expresses that the tribes' willingness to accept the negotiated spill operations is directly related to their expectation that the Lyon's Ferry Snake River fall Chinook salmon production program remains stable and substantially unaltered as designed for the term of the Agreement (through 2018) (BPA et al. 2008). The Lyons Ferry fall Chinook salmon production program is overviewed in the Hatchery Program Section (2.6.8) below.

2.6.3 Columbia Basin Fish and Wildlife Program

The Northwest Power and Conservation Council (Council), an interstate compact agency of Idaho, Montana, Oregon, and Washington, was established under the authority of the Pacific Northwest Electric Power Planning and Conservation Act of 1980 (Northwest Power Act or Act). The Act directs the Council to develop a program to "protect, mitigate, and enhance fish and wildlife, including related spawning grounds and habitat, on the Columbia River and its tributaries … affected by the development, operation, and management of [hydroelectric projects] while assuring the Pacific Northwest an adequate, efficient, economical, and reliable power supply." The Act also directs the Council to ensure widespread public involvement in the formulation of regional power and fish and wildlife policies. As a planning, policy-making, and reviewing body, the Council develops its Fish and Wildlife Program, and then monitors its implementation by BPA, the U.S. Army Corps of Engineers, and the Federal Energy Regulatory Commission (FERC) and its licensees. The Council is presently implementing its 2014 Fish and Wildlife Program (NPCC 2014). The Council is required to update the Fish and Wildlife Program every five years.

The Council emphasizes implementation of fish and wildlife projects based on needs and actions described in the FCRPS BiOp, ESA recovery plans, and the 2008 Columbia Basin Fish Accords. The Council also sponsors independent science review of Columbia Basin Fish and Wildlife Program actions proposed for funding and follows up with science reviews of the actions from the Independent Science Review Panel. It also sponsors the Independent Science Advisory Board, which serves NMFS, Columbia River Indian Tribes, and the Council by providing independent scientific advice and recommendations regarding specific scientific issues.

2.6.4 Hells Canyon Project Federal Power Act Relicensing

The existing license for Idaho Power Company's Hells Canyon Complex (Hells Canyon, Oxbow, and Brownlee dams) expired in 2005. The Federal Energy Regulatory Commission (FERC), the federal agency responsible for the licensing non-federal hydropower projects, issued a Final Environmental Impact Statement for the project in 2007 (FERC 2007). Since 2005, FERC has issued annual licenses to allow the project to operate while remaining issues are resolved. The annual licenses for the Hells Canyon Project are identical to the original license which was issued in 1955. Upon expiration of the original license, FERC can issue annual licenses indefinitely. In the interim, Idaho Power Company continues to implement its fall Chinook salmon flow program, initiated in 1991. This Idaho Power Company program provides stable flows for spawning fall Chinook salmon and protective flow conditions for incubating, and rearing fall Chinook salmon downstream of Hells Canyon Dam.

As part of the relicensing process, Idaho Power Company must obtain Clean Water Act 401 water quality certifications from the Oregon and Idaho Departments of Environmental Quality, and FERC must complete ESA Section 7(a)(2) consultations with the U.S. Fish and Wildlife Service (for listed bull trout) and NMFS. Currently, representatives of federal and state agencies are working with one another, as well as with Idaho Power Company and affected tribes, to resolve remaining water quality, fish passage, and ESA concerns. FERC will decide whether to issue a new license once these concerns are addressed; however, it is not clear when this process will be completed.

2.6.5 Additional Mainstem and Estuary Activities

In addition to the FCRPS consultation, many section 7 consultations have addressed the effects of federal actions on mainstem and estuary habitats in the Snake River fall Chinook's salmon migration and estuary rearing areas. Individually, these consultations have resulted in actions that avoided jeopardy to the species and adverse modification of its critical habitat within the individual action areas. Collectively, these consultations have protected mainstem and estuary habitats from getting worse and in many cases have improved the habitat. Examples include dredging for navigation, docks and other overwater structures, port development, Clean Water Act permits for National Pollution Discharge Elimination Systems (NPDES permits), Clean Water Act 401 water quality certifications, pilings, dikes, and other urban and agricultural activities.

Many voluntary and regulatory actions other than those prompted by the ESA have also protected and improved habitats, particularly in the estuary. These actions are overviewed in the ESA Recovery Plan Estuary Module for Salmon and Steelhead (NMFS 2011b) (Appendix F) and in the Lower Columbia River Estuary Partnership's Years in Review, since 1999.

2.6.6 Tributary Habitat Activities

While Snake River fall Chinook salmon are predominantly mainstem spawners, they also spawn in the lower reaches of the Salmon, Grande Ronde, Tucannon, Imnaha, and Clearwater Rivers. Furthermore, tributary habitat conditions contribute to mainstem habitat parameters such as sediment and gravel recruitment, water quality and water quantity and also provide cold water refugia that are important for Snake River fall Chinook salmon. Since the listings, NMFS has reviewed hundreds of federal actions through section 7 consultations and also issued section 10 permits on non-federal activities in the tributaries. These consultations and permits have reduced threats of further impacts associated with mining, dredging, agriculture, grazing, forestry, and industry, and in many cases, contributed to healing ecosystem functions in the tributaries. Furthermore, numerous voluntary activities on private lands have improved riparian management, water management and water quality, all of which have influenced, at least indirectly, Snake River fall Chinook salmon spawning and rearing habitat quality.

2.6.7 Harvest Management

Due to their patterns of ocean distribution (Good et al. 2005; Fresh et al. 2014) and the timing of their spawning run up the Columbia River, Snake River fall Chinook salmon are subject to incidental harvest in a wide range of fisheries. They are harvested by both ocean and in-river fisheries. Coastal fisheries in California, Oregon, Washington, British Columbia, and southeast Alaska have reported recoveries of tagged fish from the Snake River. Snake River fall Chinook salmon are caught incidentally in fisheries that target harvestable hatchery and non-listed natural-origin fish. Historically, incidentally caught Snake River fall Chinook salmon were subject to total exploitation rates approaching 80 percent. Since ESA listing, harvest impacts in both ocean and inriver fisheries have been substantially reduced. The harvest rate has been relatively stable at 40 to 50 percent since the mid-1990s (Figure 5-6) (Ford et al. 2011). More detail on harvest rates is provided in Section 5. The fisheries are managed by multiple jurisdictions interacting through several institutional processes:

- Ocean fisheries in Southeast Alaska, British Columbia, and off the coasts of Washington and most of Oregon are managed pursuant to the provisions of the Pacific Salmon Treaty (PST) between the U.S. and Canada. The Pacific Salmon Commission (PSC) negotiates, facilitates, and monitors implementation of fishing regimes. The PSC does not regulate; regimes are implemented by the Parties' domestic management entities. In the U.S., the Pacific Fishery Management Council (PFMC) regulates fisheries on the West Coast south of the Canadian border. The North Pacific Fisheries Management Council (NPFMC) has jurisdiction for ocean fisheries off Alaska, although the NPFMC has delegated management authority to the state of Alaska. The PSC reached agreement on new fishing regimes in May of 2008. Pursuant to the procedural terms of the Treaty, the Commission recommended that the Parties (Canada and the United States) adopt and implement these new regimes through their respective domestic management authorities (Koenings and Sprout 2008). In December 2008 the Parties approved the new regimes that came into effect on January 1, 2009 and will continue through 2018. NMFS completed an ESA biological opinion on these regimes on December 22, 2008 (NMFS 2008b).

- Fisheries in the Pacific south of the U.S./Canada border and between three and 200 miles from the coast are managed subject to the provisions of the Magnuson-Stevens Fishery Conservation and Management Act of 1976 (revised and reauthorized in 2006) (Magnuson-Stevens Act), through the PFMC process. The PFMC is one of eight fishery management councils established by the Magnuson-Stevens Act. NMFS has considered the effect of PFMC fisheries on ESA-listed species through a series of biological opinions as species were first listed and subsequently as new information became available. NMFS consulted on the effect of ocean fisheries on Snake River fall Chinook salmon in a March 8, 1996 biological opinion and subsequently in an opinion on the 1999 Pacific Salmon Treaty Agreement dated November 11, 1999 (NMFS 1999c). These opinions set the standards regarding harvest impact for Snake River fall Chinook salmon that continue to apply to the combined effect of all ocean fisheries. NMFS requires that the Southeast Alaskan, Canadian, and PFMC fisheries, in combination, achieve a 30.0 percent reduction in the age-3 and age-4 adult equivalent total exploitation rate relative to the 1988-1993 base period.

- Ocean fisheries between Cape Falcon (on the north Oregon coast) and the Canadian border are coordinated with fisheries in the Columbia River, Puget Sound, and coastal rivers through the North of Falcon (NOF) process. This process was established by the states and the member tribes of the Northwest Indian Fisheries Commission; it occurs largely coincident with the PFMC process. In the NOF process, the co-managers develop preseason fishing plans that are coordinated between ocean and river fisheries to ensure that conservation and various allocation objectives are met. Allocation objectives include treaty Indian/non-treaty allocations and allocations between various non-treaty user groups, such as commercial and recreational fisheries.

- Fisheries in the Columbia Basin, particularly in the mainstem of the Columbia River, are managed pursuant to harvest plans developed by the parties to *U.S. v. Oregon*, under the continuing jurisdiction of the federal district court. Parties to this process include the federal government, the states of Oregon, Washington, and Idaho, and the four Columbia River Treaty Tribes and the Shoshone-Bannock Tribes. A negotiated long-term Management Agreement for 2008–2017 (U.S. District Court 2008) includes management provisions for fall fisheries that affect Snake River fall Chinook salmon. NMFS provided ESA compliance in a biological opinion dated May 5, 2008 (NMFS 2008b).

- Regulations for recreational fisheries in the tributaries of the Columbia and Snake Rivers are developed by Idaho, Washington, and Oregon for their respective waters. Each Tribe regulates tributary fisheries under their respective jurisdictions. NMFS has reviewed various terminal area state and tribal fisheries through provisions of ESA section 4(d), 7 or 10, depending on the action being proposed. Management provisions of the *U.S. v. Oregon* Agreement apply to state and tribal fisheries that affect Snake River fall Chinook salmon in the mainstem Columbia and Snake Rivers up to Lower Granite Dam. Additional harvest impacts to Snake River fall Chinook salmon occur in fisheries in the mainstem Snake River above Lower Granite Dam and in lower reaches of the associated tributaries, but these are limited primarily to incidental catches that occur in fisheries directed at steelhead.

The Harvest Module (Appendix G) provides a more detailed summary of harvest that affects Snake River fall Chinook salmon.

2.6.8 Hatchery Programs

The Snake River fall Chinook salmon ESU includes four hatchery interrelated programs: the Lyons Ferry Hatchery, Fall Chinook Acclimation Ponds Program, Nez Perce Tribal Hatchery, and Idaho Power Company Hatchery Program (NMFS 2005a, 70 FR 37160). The relationship between fish from these programs and listing and delisting decisions is described in Section 3.[9]

Fall Chinook salmon hatcheries have a long history in the Snake River. Gilbert and Everman (1895) first visited the middle Snake River to look for sites to construct a hatchery. The first experimental station was constructed at Swan Falls Dam in 1901 (Van Dusen 1903). The first full-scale hatchery was constructed in 1902 and operated until 1909. Oxbow Hatchery was operated from 1962 until 1973.

The large-scale hatchery effort that exists today began in 1976 when Congress authorized the Lower Snake River Compensation Plan (LSRCP) to compensate for fish and wildlife losses caused by the construction and operation of the four Lower Snake dams. The LSRCP called for a large fall Chinook salmon production program at a new hatchery - Lyons Ferry Hatchery - to be constructed. At the time, the Snake River fall Chinook salmon run was so small that an egg-bank program was considered necessary to prevent extinction before the new hatchery could be completed. To implement the egg-bank program, adult fish were collected at Ice Harbor Dam and juveniles were released in the lower Columbia and the Snake Rivers. As egg-bank fish returned to the lower Columbia River, they were also used as broodstock along with the fish from Ice Harbor Dam. This program ceased in the fall of 1984 when Lyons Ferry Hatchery (managed by WDFW) became operational.

In the early years of the Lyons Ferry Hatchery program, fall Chinook salmon were collected by trapping for broodstock at lower Snake River dams (Bugert and Hopley 1989). It is likely that some level of non-ESU strays were incorporated into the Lyons Ferry Hatchery program and posed risks to ESU diversity (Good et al. 2005). Straying of out-of-ESU hatchery fall Chinook salmon from outside the Snake River Basin was a major risk factor in the late 1980s to mid-1990s when the extant Snake River fall Chinook salmon population was down to approximately one hundred natural adult returns (Waples et al. 1991). Out-of-ESU hatchery strays have since been much reduced due to the removal of hatchery strays at downstream dams and a reduction in the number of hatchery fish released into the Umatilla River, where the majority of out-of-ESU strays originated. Furthermore, the potential effects of any lingering out-of-ESU hatchery strays is reduced given the significant rebound in the naturally spawning population of the Snake River fall Chinook salmon ESU.

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[9] As stated in NMFS Hatchery Listing Policy (NMFS 2005a), a key feature of the ESU concept is the recognition of genetic resources that represent the ecological and genetic diversity of the species. These genetic resources can reside in a fish spawned in a hatchery (hatchery fish) as well as in a fish spawned in the wild (natural fish). Hatchery stocks with a level of genetic divergence relative to the local natural population(s) that is no more than what occurs within the ESU are considered part of the ESU. In assessing the status of an ESU, NMFS applies the hatchery listing policy in support of the conservation of naturally spawning salmon and the ecosystems upon which they depend. Hatchery fish will be included in assessing an ESU's status in the context of their contributions to conserving natural self-sustaining populations. The effects of hatchery fish on the status of an ESU will depend on which of the four key attributes are currently limiting the ESU, and how the hatchery fish within the ESU affect each of the attributes.

The hatchery effort has grown in size and complexity. When the initial focus of Snake River fall Chinook salmon hatchery operations was to provide fish for harvest as mitigation for the losses caused by the construction and operation of the four lower Snake River dams, fish were released only at Lyons Ferry Hatchery, which is well below most of the area available for natural spawning. Over time, the hatchery effort has focused more on supplementation, with an increasing proportion of fish released above Lower Granite Dam. A major change in this direction was the 1995 implementation of the Fall Chinook Acclimation Program (FCAP), which involves releases at sites on the Snake and the Clearwater Rivers at facilities operated by the Nez Perce Tribe. Acclimated releases increase the likelihood through imprinting that the juveniles will return as adults to spawn in the areas where they acclimated, reducing straying rates.

In 2002, the Nez Perce Tribal Hatchery began culture of fall Chinook salmon to supplement the Clearwater River, with releases at four locations, and a direct (non-acclimated) stream release by WDFW near Couse Creek on the Snake River began. Direct releases of fall Chinook salmon into the Grande Ronde River began in 2005 as an effort to boost returns to that area. Coincident with these supplementation releases, added mitigation releases have also occurred.

The Idaho Power Company Hatchery Program, which releases approximately 1 million fish near Hells Canyon Dam, began in 2000. Oxbow Hatchery, operated by Idaho Department of Fish and Game, has reared up to 200,000 of the 1 million fish in some past years, with the remainder of the fish reared at either Umatilla Hatchery or Irrigon Hatchery under contract with the Oregon Department of Fish and Wildlife. Currently, the full 1 million fish are reared at Irrigon Hatchery. All fish are transported by Idaho Power Company to Hells Canyon Dam for release.

Together, the four Snake River fall Chinook salmon hatchery programs release up to 5.5 million fish at full program capacity. Approximately 88 percent of the fish are released above Lower Granite Dam (where the majority of accessible natural production habitat remains), and of these, 75 percent are acclimated before release. Production goals, release sizes, release locations, release priorities, life stage and marking of released fish for all four Snake River fall Chinook salmon hatchery programs are all established through the *U.S. v. Oregon* management process. Figure 2-7 shows the location of the facilities used for Snake River fall Chinook salmon culture.

In October 2012, NMFS issued a biological opinion that provides ESA compliance through 2018 for the Snake River fall Chinook salmon hatchery programs described here (Hatchery BiOp) (NMFS 2012a). The Hatchery BiOp includes a detailed RM&E program to address key knowledge needs and gaps that are described in Sections 6 and 7 of this recovery plan.

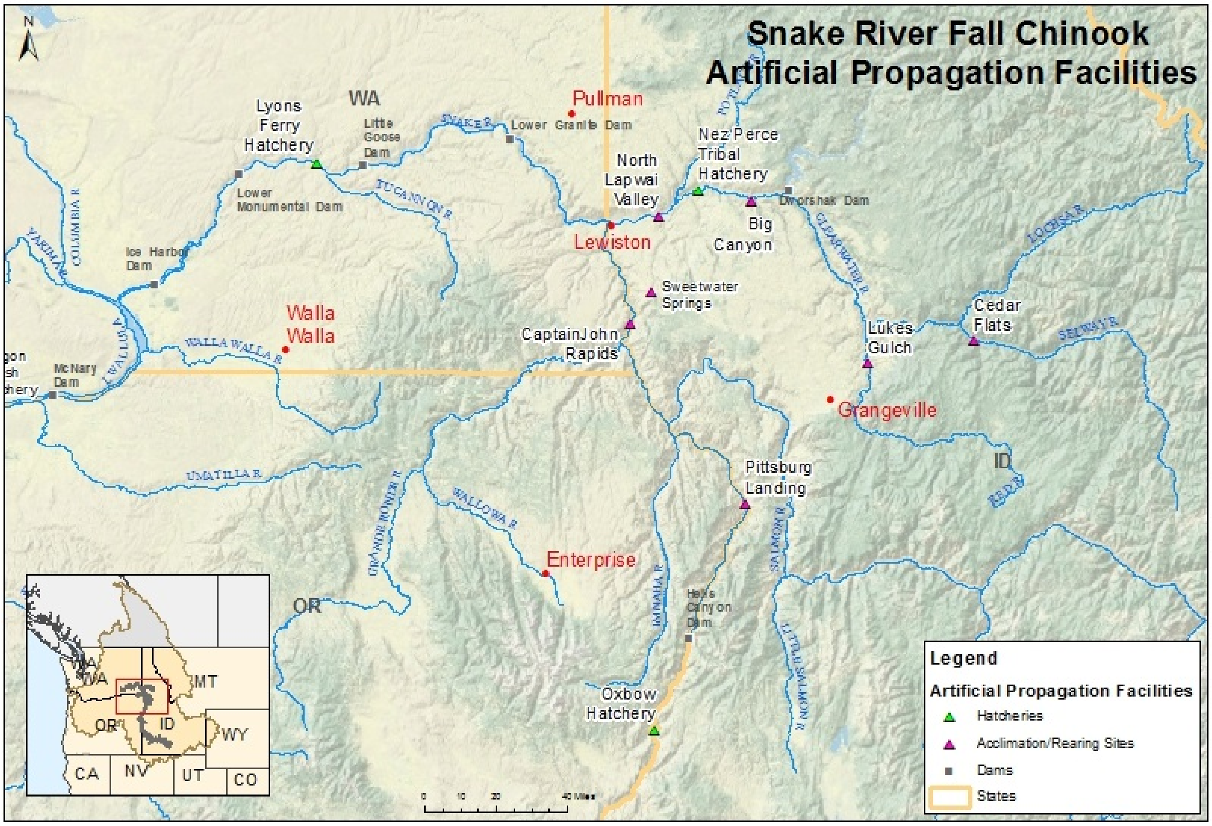

Figure 2-7. Snake River fall Chinook salmon hatcheries and acclimation facilities.

2.7 Relationship of Existing Programs to Recovery Plan

While the recovery plan is not intended to be regulatory or binding, it does incorporate existing programs described above that have undergone ESA section 7 consultation or section 10 permit review or that NMFS has otherwise formally agreed to. This is because those programs play a significant role in conserving the species. The recovery plan also describes the actions that go beyond existing programs in order to achieve the plan's goals. More details about specific actions that are incorporated into this recovery plan are described in Section 6 (Recovery Strategy and Site-Specific Actions).

3. Recovery Goals, Objectives, and Delisting Criteria

This section of the recovery plan for Snake River fall Chinook salmon defines the ESA recovery goal. It also describes ESA recovery objectives, which are statements about the necessary conditions for meeting the ESA recovery goal¸ and ESA recovery, or delisting, criteria that provide values for determining that ESA objectives have been reached.

In addition to the ESA recovery goal, this section identifies broad sense goals that acknowledge additional social, cultural, and economic values regarding this species. Broad sense goals are typically provided by stakeholders and NMFS includes them in recovery plans to provide additional direction about the management for the species after delisting occurs.

3.1 Snake River fall Chinook Salmon Recovery Goals

3.1.1 ESA Recovery Goal and Objectives

ESA Recovery Goal

ESA recovery goals should support conservation of natural fish and the ecosystems upon which they depend. Thus, the ESA recovery goal for Snake River fall Chinook salmon is that:

- *The ecosystems upon which Snake River fall Chinook salmon depend are conserved such that the ESU is self-sustaining in the wild and no longer needs ESA protection.*

A self-sustaining viable ESU depends on the status of its populations and the ecosystems (e.g. habitats) that support them. A self-sustaining viable population has a negligible risk of extinction due to reasonably foreseeable changes in circumstances affecting its abundance, productivity, spatial structure, and diversity characteristics over a 100- year time frame and achieves these characteristics without dependence upon artificial propagation. Artificial propagation may be used to benefit threatened and endangered species and a self-sustaining population may include artificially propagated fish, but a self-sustaining population must not be dependent upon propagation measures to achieve its viable characteristics. Artificial propagation may contribute to, but is not a substitute for, addressing the underlying factors (threats) causing or contributing to a species' decline.

ESA Recovery Objectives

The ESA recovery objectives define the conditions necessary to meet the ESA recovery goal.

Abundance and productivity: Population-level persistence in the face of year-to-year variations in environmental influences.

- ESU- and population-level combination of abundance and productivity sufficient to maintain genetic, life history, and spatial diversity and sufficient to exhibit demographic resilience to environmental perturbations.

Spatial Structure: Resilience to the potential impact of catastrophic events.

- Spatial structure of populations and spawning aggregations distributed in a manner that insulates against loss from a local catastrophic event and provides for recolonization of a population or aggregations that is affected by such an event.

Diversity: Long-term evolutionary potential.

- Patterns of phenotypic, genotypic, and life history diversity that sustain natural production across a range of conditions, allowing for adaptation to changing environmental conditions.

Threats: The underlying causes of decline have been addressed.

- The primary threats to the species have been ameliorated and regulatory mechanisms are in place that should help prevent a recurring need to re-list Snake River fall Chinook salmon as threatened or endangered.

3.1.2 Broad Sense Goals

This plan for Snake River fall Chinook salmon is founded on a premise that citizens throughout the region value and enjoy the substantial ecological, cultural, social, and economic benefits that are derived from having healthy, diverse salmon populations. NMFS believes that while the plan’s primary goal is to delist the species, it is important to achieve ESA recovery in a manner that is consistent with other federal legal obligations, mitigation goals, and other broad sense goals to provide social, cultural or economic values, including:

- Subbasin visions for healthy ecosystems with abundant, productive and diverse species and habitats that also support the social, cultural and economic well-being.
- Treaty and trust obligations to the Columbia Basin tribes with treaty-reserved rights to take salmon at their usual and accustomed fishing places and to implement Secretarial Order # 3206, American Indian Tribal Rights, Federal-Tribal Trust Responsibilities, and the Endangered Species Act.
- Federally authorized objectives for Snake River fall Chinook salmon to mitigate for losses due to Snake River hydropower development. These help maintain fisheries and contribute to conservation of existing wild stocks.

- Support reintroduction of fall Chinook salmon passage and populations above Hells Canyon Dam.

Although the broad sense scope exceeds the definition of delisting provided by the ESA, broad sense goals incorporate many of the traditional uses, as well as rural and Sovereign Tribes values, that are important in the Pacific Northwest. They also provide for other legislative mandates or social, economic, and ecological values. These broad sense recovery goals allow development of recovery plans that support these larger objectives.

Broad Sense Goal to Support Subbasin Visions

During the Northwest Power and Conservation Council's subbasin planning process for Columbia River salmon and steelhead runs, groups of local stakeholders in the different subbasins that support spawning and rearing Snake River fall Chinook salmon - the lower Snake River, Snake River Hells Canyon, Tucannon, Grande Ronde, Imnaha, and Clearwater River subbasins - developed vision statements describing desired future conditions for their individual subbasins. These vision statements reflect the thoughts of local citizens and were developed through collaborative and public processes that included state, tribal, federal, and community representatives. The vision statements developed for the different subbasin plans paint similar visions of desired future conditions for the subbasins. They provided important direction for the subbasin plans, which were adopted by the Northwest Power and Conservation Council in 2004 as amendments to the Council's Fish and Wildlife Program (NPCC 2004). These vision statements are summarized together here as a subbasin-level broad sense goal.

- To support and maintain healthy ecosystems with abundant, productive, and diverse populations of aquatic and terrestrial species and habitats, which also provide for the social, cultural, and economic well-being of local communities and the Pacific Northwest.

Broad Sense Goals to Mitigate for Columbia and Snake River Hydropower Development

The Nez Perce Tribe, Washington Department of Fish and Wildlife, Oregon Department of Fish and Wildlife, and Idaho Department of Fish and Game included goals in the Lyons Ferry Hatchery, Fall Chinook Acclimation Program, and Idaho Power Company Hatchery and Genetic Management Plan (HGMP) (WDFW et al. 2011) and Nez Perce Tribal Hatchery HGMP (NPT 2011). These goals address both natural-origin and hatchery-origin returns. The hatchery-return goals are derived from authorizations for hatchery programs developed as mitigation for Columbia and Snake River hydropower development. Chief among these authorizations is the Lower Snake River Compensation Plan (LSRCP) (USACE 1975), established in the mid-1970s, in collaboration with NMFS. The purpose of the LSRCP is to, "replace adult salmon, steelhead and rainbow trout lost by construction and operation of four hydroelectric dams on the lower Snake River in Washington…. and to … "provide the number of salmon and steelhead trout needed in the Snake River system to help maintain commercial and sport fisheries for anadromous species on a sustaining basis in the Columbia River system and Pacific Ocean (NMFS and USFWS 1972)," The LSRCP and the goals it established preceded the ESA listing by several years. The base period for calculating the goals, as described in WDFW et al., 2011, included production above the Hells Canyon Complex, thus, the goals, are for a much bigger habitat area than is presently available. It is important to continue evaluating habitat potential of existing natural production areas while addressing opportunities to improve that capacity and to expand capacity back up above the Hells Canyon Complex.

While NMFS' goal for this recovery plan is to delist Snake River fall Chinook salmon, we also believe it is important to simultaneously plan to achieve mitigation goals and other broad sense goals. Accordingly, we will work with the tribes, states, and other federal agencies to achieve these goals in a manner that does not impede recovery of natural-origin Snake River fall Chinook salmon.

The following broad sense goals support mitigation of Snake River hydropower development and include both natural-origin and hatchery-origin goals.

- To provide the number of Snake River fall Chinook salmon, closely aligned to locations where these fish were present historically, needed in the Snake River system to help maintain tribal, commercial, and recreational fisheries for anadromous species on a sustaining basis in the Columbia River system and Pacific Ocean; and
- To protect, maintain, or enhance biological diversity of existing wild stocks, as described in the HGMPs for Lyons Ferry and Nez Perce Tribal Hatcheries (WDOE at al. 2000a and NPT 2011).

  Natural-Origin Return Goals
    - Achieve ESA delisting (see ESA recovery objectives and criteria, in Section 3.2 below).[10]
    - Interim[11] goal of 7,500 natural-origin fall Chinook salmon (adults and jacks) above Lower Monumental Dam.
    - Long-term goal of 14,360 natural-origin fall Chinook salmon (adults and jacks) above Lower Monumental Dam.

  Hatchery-Origin Return Goals
    - The interim total return target based on current production levels and survival is 15,484 hatchery-origin fish above Lower Monumental Dam.
    - The long-term total return goal is 24,750 hatchery-origin fish above Lower Monumental Dam.

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[10] The ESA goal provided in the HGMPs and accompanying NMFS biological opinion is for 3,000 adult returns based on ICTRT 2007 recommendations. The relationship between that goal and the ESA viability criteria in this recovery plan is explained in section 3.3

[11] The interim goal is a stepping stone target and once reached, shifts focus to long-term goals. Meeting the interim goal is a signal that conservation efforts are working and should be continued and added to for achieving long-term targets.

Broad Sense Goals for Reintroduction above Hells Canyon Dam

As described in Section 3.2.2, it may be possible to achieve ESU viability and ESA delisting by improving the status of the single extant Lower Mainstem Snake River fall Chinook salmon population and without restoring the extirpated population above the Hells Canyon Complex. This potential opportunity exists because the extant population is spatially complex, and because water temperatures in the Lower Mainstem Snake River are now more conducive to fall Chinook salmon production than they were historically. Nevertheless, this recovery plan includes several potential scenarios for achieving ESU viability - including a scenario that aims to restore the extirpated population in the Middle Snake River reach above the Hells Canyon Complex to viable status - because we cannot predict with certainty that future ecological conditions and ESU characteristics will support recovery (see Section 3.2.2). In the event that we can achieve ESU recovery and ESA delisting with the extant Lower Mainstem Snake River population, NMFS will continue to support efforts to establish a second population above the Hells Canyon Complex as an important broad sense goal. Restoring this population would provide an extinction-risk buffer, greater resilience, and a potential longer-term ESA recovery option, in case the single population does not achieve and/or sustain ESU-level viability. Furthermore, reintroduction of Snake River fall Chinook salmon above Hells Canyon will restore lost fishing opportunities for Upper Snake River tribes. The following broad sense goals support passage and reintroductions above Hells Canyon Dam.

- Restore effective upstream and downstream fall Chinook salmon passage through the Hells Canyon Hydropower Complex.
- Restore extirpated fall Chinook salmon population above Hells Canyon Dam to sustainable and harvestable levels.
- Restore meaningful, sustainable fisheries in areas upstream of Hells Canyon Dam.

3.2 Snake River Fall Chinook Salmon ESA Recovery Criteria

The ESA requires that recovery plans; "…to the maximum extent practicable, incorporate objective, measurable criteria which, when met, would result in a determination in accordance with the provisions of the ESA that the species be removed from the Federal List of Endangered and Threatened Wildlife and Plants (50 CFR 17.11 and 17.12)…." NMFS applies two kinds of recovery, or delisting, criteria: biological viability criteria, which deal with population or demographic parameters, and "threats" criteria, which relate to the five listing factors detailed in the ESA section 4(a)(1). The threats criteria define the conditions under which the listing factors, or threats, can be considered to be addressed or mitigated. Together, the viability criteria and threats criteria make up the "objective, measurable criteria" [hereinafter referred to as delisting criteria] required under section 4(f)(1)(B)(ii) for the delisting decision.

The delisting criteria are based on the best available scientific information and incorporate the most current understanding of the ESU and the threats it faces. As this recovery plan is implemented, additional information will become available that can increase certainty about whether the threats have been ameliorated, whether improvements in population and ESU status have occurred, and whether linkages between threats and changes in salmon status are understood. These criteria will be reviewed periodically, as appropriate new information becomes available.

3.2.1 Snake River fall Chinook Salmon ESA Viability Criteria

To remove the Snake River fall Chinook salmon ESU from the list of threatened and endangered species, NMFS must determine that the ESU has met criteria for low risk or viable status. This means that the ESU would be likely to meet the first three ESA recovery objectives provided in Section 3.1.1. The fourth ESA recovery objective needs to be met through threats criteria as described in Section 3.3 and is addressed there.

As described in Section 1, NMFS convened the Interior Columbia Technical Recovery Team (ICTRT) and requested that they recommend biological viability criteria specifically adapted for listed Interior Columbia salmon and steelhead. The ICTRT developed its recommended viability criteria based on a set of general guidelines set out in McElhany et al. (2000), expressed in terms of population level abundance, productivity, spatial structure, and diversity. Collectively, abundance, productivity, spatial structure and diversity make up viable salmonid population (VSP) parameters (McElhany et al 2000; ICTRT 2007). The ICTRT criteria represent a consistent framework with examples of metrics that they intended to be evaluated and adapted to fit the specific characteristics and conditions of a particular ESU (ICTRT 2007). The ICTRT criteria are hierarchical, with ESU- level objectives expressed in terms of the VSP status of individual populations considered in aggregate major population groupings (MPGs). Background on the general ICTRT VSP criteria is provided here as context for the Snake River fall Chinook salmon viability criteria which follow. The biological status of Snake River fall Chinook salmon relative to the viability criteria is evaluated in Section 4.

Abundance and Productivity

Abundance is expressed in terms of natural-origin spawners (adults on the spawning ground), measured over a time series, i.e. some number of years. The ICTRT used a recent 10- geometric mean of natural-origin spawners as a measure of current abundance. Productivity (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:spawner ratios (returns per spawner or recruits per spawner) (or 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, typically subject to a high degree of annual variability and sampling induced uncertainties. Viable populations should demonstrate sufficient productivity to support a net replacement rate of 1:1 or higher at abundance levels established as long-term targets. In addition, productivity rates from parent spawning levels below minimum abundance targets should, on average, be sufficiently greater than 1.0 to allow the population to rapidly return to abundance target levels (ICTRT 2005b). The ICTRT provided a simple method for estimating current intrinsic productivity using spawner-to-spawner return pairs from low to moderate escapements over a recent 20-year period (ICTRT 2007). The ICTRT recognized that alternative metrics could be employed to estimate productivity, especially in circumstances where the simple average method would be based on relatively few annual return-per-spawner estimates.

Abundance and productivity are linked, as populations with low productivity can still persist if they are sufficiently large, and small populations can persist if they are sufficiently productive. A viable population needs sufficient abundance to maintain genetic health and to respond to normal environmental variation, and sufficient productivity to enable the population to quickly rebound from periods of poor ocean conditions or freshwater perturbations. The ICTRT developed viability curves that provide quantitative metrics for evaluating the abundance and productivity of a population. A viability curve describes those combinations of abundance and productivity that yield a particular risk or extinction level at a given level of variation. Viability curves are generated using a population viability analysis. The ICTRT developed curves corresponding to a range of extinction risk levels of 1 percent, 5 percent, and 25 percent (Figure 3-1).

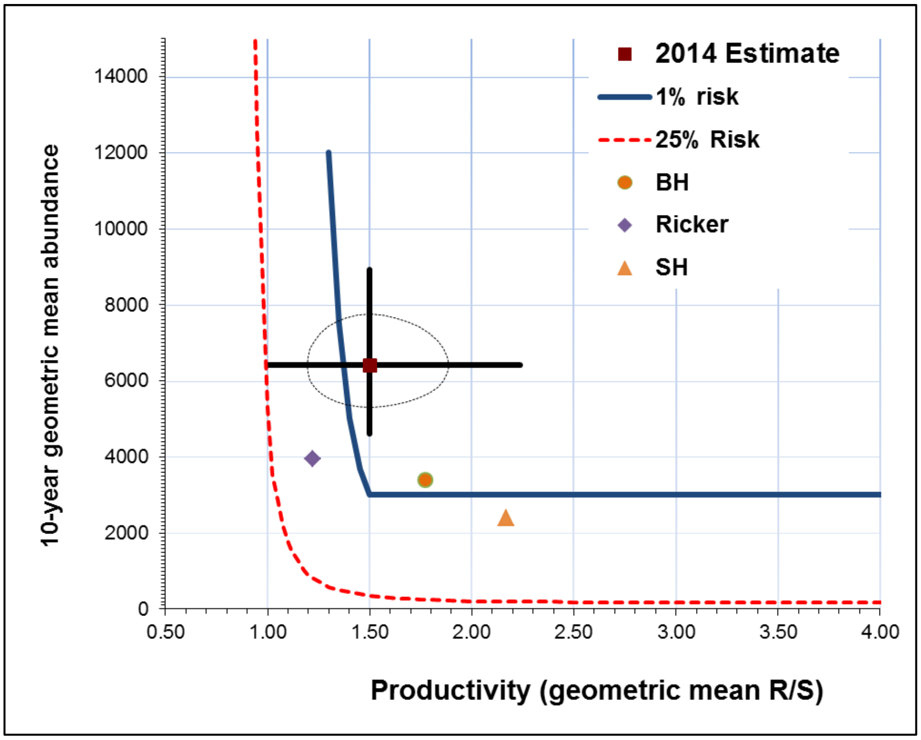

Figure 3-1. Viability curve for the Lower Mainstem Snake River fall Chinook salmon population based on 1991 through 2013 data series (1991 to 2010 brood years). The oval represents 1 standard error assuming bivariate normal distribution. Lines represent 90% confidence limits. Point estimate for standard (empirical) ICTRT method. The 1% and 5% viability curves were generated based on Hanford Reach Fall Chinook Salmon data series (ICTRT 2007).

Spatial Structure and Diversity

A population's spatial structure is made up of both the geographic distribution of individuals in the population and the processes that generate that distribution (McElhany et al. 2000). Diversity refers to the distribution of 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 (ibid). Spatial structure and diversity considerations are combined in the evaluation of a salmonid population's status because they are so interrelated. The ICTRT 2007 developed a framework for integrating multiple spatial structure and diversity metrics and determining a population's composite risk level. We use this framework, adapting evaluations of the individual components to characteristics of the population and information currently available, in the biological status review summarized in Section 4.

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 or toxic spill, 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. Some of the factors and metrics identified by the ICTRT (2007) for evaluating spatial structure include: number and spatial arrangement of spawning areas; spatial extent or range of the population; and changes in gaps and continuities between spawning areas.

Population-level diversity is similarly important for long-term persistence. 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. Some of the factors and metrics identified by the ICTRT for evaluating diversity include: life history strategies; phenotypic variation; genetic variation; spawner composition; distribution of the population across habitat types; and selective changes in natural processes or impacts.

3.2.2 Potential ESA Viability Scenarios for Snake River fall Chinook Salmon

As described in Section 2, the historical Snake River fall Chinook salmon ESU consisted of a single MPG made up of two populations, with the population above the Hells Canyon Complex currently extirpated. The only extant population is the Lower Mainstem Snake River population. In general, an ESU with a single historical MPG would be inherently at greater extinction risk than other salmon species with several MPGs (ICTRT 2007). Further, an ESU with a single historical MPG consisting of a single remaining population would be at greater extinction risk than other salmon species with one MPG and more than one extant population. These are key considerations for potential Snake River fall Chinook salmon viability scenarios.

As with most ESUs, there is more than one scenario for achieving viability. As the ICTRT recognized, "…different scenarios of ESU recovery may reflect alternative combinations of viable populations and specific policy choices regarding acceptable levels of risk…." (ICTRT 2007). The ICTRT basic application of technical recovery team criteria (ICTRT 2007) recommended two populations that meet criteria for high viability for the Snake River fall Chinook salmon ESU to be low risk. The ICTRT recognized that there "…are significant difficulties in re-establishing fall Chinook salmon populations above the Hells Canyon Complex, and suggest that initial effort be placed on recovery for the extant population, concurrently with scoping efforts for re-introduction…" As recovery efforts progress, the risk and feasibility associated with opening this area to fall Chinook salmon can be re-assessed...." Thus, the ICTRT's basic recommendation was for the Lower Mainstem Snake River population to be highly viable and for the currently extirpated Middle Snake River population to also be highly viable.

As recovery efforts affecting Snake River fall Chinook salmon have progressed since the ICTRT's 2007 recommendations, it is apparent that there are opportunities to consider alternative combinations of viable populations and policy choices for delisting. Those alternative quantitative criteria are each consistent with the basic set of viability objectives used by the ICTRT and provided in Section 3.1.1. The extant Lower Mainstem Snake population is presently well distributed across a large area that provides for complex spatial structure and opportunities for within population diversity. The population has maintained the historically predominant subyearling life history strategy along with demonstrating an additional yearling life history strategy adaptation. Furthermore, the abundance of this population has grown substantially.

The set of objectives provided in Section 3.1.1 provide a basic framework for tailoring ESU and population-level viability criteria to specific biological and environmental settings. The following scenarios, including a placeholder for additional scenarios, for ESU recovery are based on the guidance provided in ICTRT (2007) and McElhany et al. (2000) for meeting those objectives. The scenarios provide a range of potential population characteristics that, if achieved, would indicate that the ESU has met the ESU-level objectives. Each scenario includes viability criteria and potential metrics for measuring viability characteristics. We cannot predict with certainty future ecological conditions and ESU characteristics. Thus, the viability scenarios are illustrations of potential conditions, which if met, in combination with meeting threats criteria (described in Section 3.3.2 below) would result in a delisting decision. These scenarios are based on current information and there are likely other scenarios that also could achieve ESA viability and delisting. The potential metrics are based on our present state of knowledge. They illustrate example metrics and do not represent absolute standards. We expect, over time, that some of these potential metrics will evolve and change as RM&E results emerge, new technologies emerge, and our scientific understanding improves.

Below we present for consideration two scenarios (A and B) and a placeholder for developing additional scenarios that would achieve the ESA objectives in Section 3.1.1 and represent conditions where, after considering the status of threats, we would make a delisting determination.

Scenario A focuses on achieving viability for multiple populations and is the same as the ICTRT's basic application of its criteria. In contrast, Scenario B applies an alternative variation of ICTRT metrics to address the basic viability objectives and to achieve ESU viability with the single extant population. Increased risks associated with a single population ESU are mitigated if the Lower Mainstem Snake River fall Chinook salmon population achieves Highly Viable status with a high degree of certainty. Given this spatial structure, it is possible to recover this ESU with just one population, because while the Lower Mainstem Snake River population historically had substantially less spawning and rearing habitat compared to the other historical population, it is also spatially complex, successfully spawning and rearing across a diverse set of habitats, with five major spawning areas (MaSAs). This characteristic provides opportunities for achieving the ICTRT viability objectives (Section 3.1.1) because it provides for resilience to environmental perturbations and localized catastrophic events and a greater degree of within-population adaptation to environmental variation when compared to populations with simpler habitat structure. To the degree this potential is realized, it would be possible for this single population to meet ESU-level objectives. However, even with the potential that ESU-level ESA recovery can be achieved with one population, it is still important for this ESU to continue exploration and work towards establishing a second population above Hells Canyon Dam. This second population would provide a buffer, greater resilience, and a potential longer-term ESA recovery option, in case the single population does not achieve and/or sustain ESU-level viability.

Scenario A - Multiple Populations

This relatively simple scenario represents a basic application of the general MPG-level guidelines provided by the ICTRT. Scenario A would achieve ESU viability by focusing on two populations: the Lower Mainstem Snake River population and the presently extirpated Middle Snake population above the Hells Canyon Complex.

Scenario B – Single Population Measured in the Aggregate

Scenario B illustrates a single-population pathway to ESU viability with VSP objectives evaluated in the aggregate (population-wide), based on all natural-origin adult spawners. This Scenario is an alternative to the ICTRT's basic application of criteria which required two populations. The scenario focuses on the Lower Mainstem Snake River population.

Potential Additional Scenarios – Natural Production Emphasis Areas

Another variation on the single-population scenario would be scenarios where VSP objectives are evaluated based on natural-origin production coming from one or two of the five MaSAs that are Natural Production Emphasis Areas with a low percentage of hatchery-origin spawners. These one or two MaSAs would produce a significant level of natural-origin adult spawners. The other MaSAs would have higher acceptable levels of hatchery-origin spawners.

Scenario A. Multiple Populations: Two populations; one highly viable the other viable.

Viability Criteria

1.
    a. Lower Mainstem Snake River population has a combination of natural-origin abundance and productivity with a 50 percent probability of exceeding the viability curve for a 1 percent risk of extinction over 100 years; and,
    b. Middle Snake River population has a combination of natural-origin abundance and productivity with a 50 percent probability of exceeding the viability curve for a 5 percent risk of extinction over 100 years;
2. Two populations exhibiting robust spatial distribution of spawning aggregations.
3. All major habitat types occupied within a population;
4. Patterns of genetic and life history diversity reflect historically dominant patterns;
5. Any difference(s) from historical diversity patterns represent positive natural adaptations to prevailing environmental conditions; and,
6. Evolutionary trajectory of population is dominated by natural-selective processes.

Potential Metrics

1. Lower Mainstem Snake population has most recent 10-year geometric mean > 3,000 natural-origin spawners and 20-year geometric mean productivity ≥ 1.5,[12] and
2. Middle Snake River population has a most recent 10-year geometric mean > 3,000 natural-origin spawners and 20-year geometric mean productivity ≥ 1.27;
3. Hatchery influence on spawning ground is low (e.g., pHOS is < 30%) for at least one population and hatchery program is operated to limit genetic risk (e.g., the proportionate natural influence (PNI) > 67%.[13]);
4. 4 of 5 MaSAs occupied in Lower Mainstem Snake population and one or more spawning areas occupied for Middle Snake population;
5. Historically dominant subyearling life-history pattern stable or increasing;
6. Adult and juvenile run timing patterns stable;
7. Indicators of genetic substructure trending towards patterns for natural-origin dominated population.

Scenario B: Single Population Measured in the Aggregate: One population that is highly viable with high certainty and naturally produced fish well distributed and measured in the aggregate across multiple MaSAs.

Viability Criteria

1. Combination of natural-origin abundance and productivity exhibits an 80 percent or higher probability of exceeding the viability curve for a 1 percent risk of extinction over 100 years.
2. Criteria 3 through 6 from Scenario A.

Potential Metrics:

1. Most recent 10-year geometric mean > 4,200 natural-origin spawners;
2. Most recent 20-year geometric mean productivity ≥ 1.7;
3. Four of five Lower Mainstem Snake MaSAs occupied; and
4. Recent (2 or more brood cycles) hatchery influence on spawning ground is low (e.g. pHOS is < 30%) for the population as a whole and hatchery program is operated to limit genetic risk (e.g., the proportionate natural influence (PNI) > 67%).

Placeholder for Natural Production Emphasis Area Scenarios

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[12] Productivity is a measure of a population's ability to sustain itself. It can be measured as spawner:spawner ratios, annual population growth rate, or trends in abundance. Population specific estimates of abundance and productivity are derived from time series of annual estimates, which are typically subject to a high degree of annual variability and sampling uncertainty. Appropriate metrics for productivity differ at low and high abundance levels. Particularly at high abundance, there is a potential that high proportions of hatchery fish may mask the intrinsic productivity of natural origin fish. Appropriate metrics for measuring productivity at high abundance may need to be developed.

[13] Based on our knowledge at this time, pHOS and PNI are useful metrics for genetic fitness risks, and pHOS is also a useful metric for competition risk. Alternative or more specific metrics may become available in the future, but pHOS and PNI provide a good starting point.

There is potential for alternative single population scenarios that could lead to ESA viability in a much shorter time frame than Scenario A and that would have the potential to retain present hatchery-origin return mitigation objectives, which would not be possible with either Scenarios A or B.

Components of Natural Production Emphasis Area Scenarios would include:

- The single population meets the ESU VSP objectives in 3.1.1 and would be highly viable in order for the ESU to be viable.
- Achievement of VSP objectives is based on population performance in one or more Natural Production Emphasis Areas (NPEAs). NPEAs are major spawning areas, (MaSAs) that produce a substantial level of the ESU's natural-origin adult spawners with a low proportion of hatchery-origin spawners.
- Given the historical dominance of the mainstem Snake River above the Salmon River confluence, the MaSA in this area is emphasized for natural production along with possibly one other MaSA.
- The remaining MaSAs that are not NPEAs should also produce natural-origin returns; however, they could have higher acceptable levels of hatchery-origin spawners, within the range of those presently observed.
- Appropriate criteria to measure VSP performance of the MaSAs would be needed.
  - Metrics for productivity based on population trends that are stable or increasing and also metrics for evaluating diversity based on natural influence in the NPEAs.
  - Direct estimation of relative contributions of hatchery vs. natural-origin returns to specific MaSAs is difficult to measure. New indices should include estimates of fidelity and dispersal from hatchery release sites and genetic based assessments of the relative proportions of hatchery parentage at the major spawning area level based on sampling of juvenile production.
- Viability metrics would need to explicitly address two key uncertainties associated with evaluating intrinsic productivity and diversity with the relatively high proportion of hatchery spawners: the masking effect on determining if population productivity is sufficient to sustain the population in the absence of hatchery supplementation, and the impact of chronically high hatchery fractions on the ability of the population to adapt to future variations in natural conditions.
- Specific RM&E is underway that should inform, by 2018, whether we can establish most of these additional indices, however additional RM&E may be needed.
- Conservation mechanisms should be in place across the hydropower and habitat, harvest, and hatchery sectors to ensure that adequate regulatory mechanisms are in place to conserve the species in the event of an ESA delisting. This component is also implicitly part of Scenarios A and B, which would require meeting Threats Criteria for evaluating the adequacy of regulatory mechanisms. (See Section 3.3 Threats Criteria.)

NMFS generally finalizes recovery plans within twelve months of issuing the Proposed Plan. If the fishery co-managers, in coordination with NMFS, develop scenarios within that timeframe that are consistent with the components of the placeholder language, and that NMFS agrees would meet ESA viability criteria, then NMFS will include those scenarios in the final recovery plan. If specific new scenarios are not included in the final plan, fishery co-managers may continue collaborative efforts to develop alternative scenarios after the final plan is published.

3.3. Snake River Fall Chinook Salmon ESA Threats Criteria

In order for Snake River fall Chinook salmon to be delisted, the ESA recovery objectives identified in Section 3.1.1 should be met. This section provides criteria for addressing the threats objective that the underlying causes of decline have been addressed.

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

These factors are not equally important in securing the continuing recovery of Snake River fall Chinook salmon. The species faces its own unique set of threats across its life cycle. 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 the species. Likewise, it is possible that threats that are emerging (like climate change) or that are poorly understood (like toxic pollutants and exotic species) may become more significant.

NMFS will use the listing factor (threats) criteria below to help determine whether Snake River fall Chinook salmon 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

To determine that the ESU/DPS is recovered, threats to habitat should be addressed as outlined below:

1. Flow conditions that support adequate, spawning, rearing, and migration for maintaining viability are achieved through management of mainstem hydropower and flood control operations.
2. Passage conditions through mainstem hydropower systems, including dams, reservoirs and transportation, consistently meet or exceed performance standards from associated biological opinions and (a) accurately account for total mortality (i.e., juvenile passage and adult passage mortalities) and constrain mortality rates to levels that are consistent with recovery; and (b) are implemented in such a way as to avoid deleterious effects on populations or negative effects on the distribution of populations.
3. The feasibility of restoring fish passage and spawning and rearing habitat above the Hells Canyon Complex has been evaluated and steps are underway to address re-introduction of populations above Hells Canyon accordingly.
4. Water quality, including temperature, dissolved oxygen, total dissolved gas, and turbidity parameters, is adequate to support spawning, rearing, and migration consistent with maintaining viability.
5. Channel maintenance and dredging activities in the Snake and Columbia Rivers are conducted in a manner that protects shallow-water habitat and that does not promote the creation of predatory bird colonies.
6. Shallow-water habitat in the Columbia River estuary is protected and restored to provide adequate feeding, growth, and refuge from predators during the smolts’ transition to salt water.
7. Routine construction and maintenance practices are managed to reduce or eliminate mortality of listed species.
8. Forest management practices that protect watershed and stream functions are implemented on federal, state, tribal, and private lands.
9. Agricultural practices, including grazing, are managed in a manner that protects and restores riparian areas, floodplains, and stream channels, and protects water quality from sediment, pesticide, herbicide, and fertilizer runoff.
10. The effects of toxic contaminants on salmonid fitness and survival are understood and are sufficiently limited so as not to affect viability.
11. Channel function, including vegetated riparian areas, canopy cover, stream-bank stability, off-channel and side-channel habitats, natural substrate and sediment processes, and channel complexity are restored to provide adequate rearing and spawning habitat.
12. Floodplain function and the availability of floodplain habitats are restored to a degree sufficient to support a viable ESU. This restoration should include connectivity between river and floodplain and the restoration of impaired sediment delivery processes.

B. Over-utilization for commercial, recreational, scientific, or educational purposes

To determine that the ESU/DPS is recovered, any utilization for commercial, recreational, scientific, or educational purposes should be managed as outlined below:

1. Fishery management plans are in place that (a) accurately account for total fishery mortality (i.e., both landed catch and non-landed mortalities) and constrain mortality rates to levels that are consistent with recovery; and (b) are implemented in such a way as to avoid deleterious genetic effects on populations or negative effects on the distribution of populations.
2. Federal, tribal and state rules and regulations are effectively enforced.
3. Technical tools accurately assess the effects of the harvest regimes so that harvest objectives are met but not exceeded.
4. Handling of fish is minimized to reduce indirect mortalities associated with educational or scientific programs, while recognizing that monitoring, research, and education are key actions for conservation of the species.

C. Disease or predation

To determine that the ESU/DPS is recovered, any disease or predation that threatens its continued existence should be addressed as outlined below:

1. Hatchery operations do not subject targeted populations to deleterious diseases and parasites and do not result in increased predation rates of wild fish that are inconsistent with recovery.
2. Predation by avian predators is managed in a way that allows for recovery of the ESU.
3. The northern pikeminnow and other fish predators are managed to reduce predation on the ESU.
4. Populations of introduced exotic predators such as smallmouth bass, walleye, and catfish are managed such that competition or predation does not impede recovery.
5. Predation below Bonneville Dam by marine mammals does not impede achieving recovery.
6. Physiological stress and physical injury that may cause disease or increase susceptibility to pathogens during rearing or migration is reduced during critical low flow periods (e.g. low water years) or poor passage conditions (e.g. at diversion dams, bypasses, or ladders).

D. The inadequacy of existing regulatory mechanisms

To determine that the ESU/DPS is recovered, any inadequacy of existing regulatory mechanisms that threatens its continued existence should be addressed as outlined below:

1. Adequate resources, priorities, regulatory frameworks, plans, binding agreements, and coordination mechanisms are established and/or maintained for effective[14] enforcement of:
    - Hydropower system operations;
    - Flood control and other water use systems;
    - Land and water use systems for forestry, agriculture, mining, and other land uses;
    - Effective management of fisheries; and,
    - Hatchery operations.
2. Habitat conditions and watershed functions are protected through land use planning that guides human population growth and development.
3. Habitat conditions and watershed function are protected through regulations, land use plans, and binding agreements that govern resource extraction.
4. Regulatory, control, and education measures to prevent additional exotic plant and animal species invasions are in place.

E. Other natural or human-made factors affecting [the species'] continued existence

To determine that the ESU is recovered, other natural and manmade threats to its continued existence should be addressed as outlined below:

Hatcheries:

1. Snake River fall Chinook salmon hatchery mitigation programs are being operated in a manner that is consistent with maintaining viability of the ESU, including control of genetic and ecological risks of hatchery operations, impacts of water withdrawal and discharge, and fish health.
2. Monitoring and evaluation plans are implemented to measure population status, hatchery effectiveness, and ecological, genetic, and demographic risk containment measures.

Climate Change:

1. The potential effects of climate change have been evaluated and incorporated into management programs for hydropower, flood control, instream flows, water quality, fishery management, hatchery management, and reduction and elimination of exotic plant and animal species invasions.

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[14] "Effective" means that the system is adequate for conserving and maintaining the viability of the species.

3.4. Delisting Decision

The biological viability criteria and listing factor (threats) criteria provided in Sections 3.2 and 3.3 define conditions that, when met, would result in a determination that Snake River fall Chinook salmon is not likely to become endangered in the foreseeable future throughout all or a significant portion of its range. There may be other conditions in the future that were not anticipated in these criteria, but would meet conditions necessary for delisting. NMFS will update the criteria in Sections 3.2 and 3.3, as appropriate, if new information becomes available.

In accordance with its responsibilities under section 4(c)(2) of the ESA, NMFS will conduct reviews of Snake River fall Chinook salmon at least every five years to evaluate the status of the species and gauge progress toward delisting. Status reviews could be conducted in less than five years, if conditions warrant. Status reviews will take into account the following:

- The biological recovery (viability) criteria and listing factor (threats) criteria described above.
- The management programs in place to address the threats.
- Best available information on population and ESU status and new advances in metrics and risk evaluation methodologies.

4. Current ESU Biological Status Assessment

This section provides a general summary of the current biological status of the Snake River fall Chinook salmon ESU. Appendix A discusses the ESU's current biological status in more detail. Snake River fall Chinook salmon spawn predominately in the mainstem of the Snake River and some of its major tributaries[15]. Historically, the Snake River fall Chinook salmon ESU likely consisted of two large populations: the extant Lower Mainstem Snake River population, and a second (currently extirpated) population associated with the Middle Snake River above the current Hells Canyon Dam site.[16] The present biological status assessment focuses exclusively on the Lower Mainstem Snake River fall Chinook salmon population.

The ICTRT developed viability criteria for the Lower Mainstem Snake River fall Chinook salmon population that are tailored to the population's specific life history characteristics but follow the same basic principles applied to the other Interior Basin listed Chinook salmon ESUs. The ICTRT described these principles in its report, Viability Criteria for Application to Interior Columbia Basin Salmonid ESUs (ICTRT 2007). NMFS' evaluation of the current status of the Lower Mainstem Snake River population follows the framework recommended by the ICTRT for integrating information across 12 individual criteria using a matrix framework, as described in Section 3. The ICTRT criteria are organized into two separate groupings: 1) natural-origin abundance and productivity, and 2) spatial structure and diversity. Overall biological status at the population level is determined by the specific combination of ratings for those two groupings. The ICTRT provided one set of quantitative metrics for evaluating status vs. the individual viability criteria. It also provided examples of corresponding relative risk rating categories (very low, low, moderate and high). The ICTRT recognized that there could be other metrics for evaluating risks for particular viability criteria and provided some guidance for considering alternatives.

In the current ESU biological status assessment (Appendix A), NMFS adapted the ICTRT decision framework to assess the status of the Snake River fall Chinook salmon ESU that specifically incorporates alternative ESU viability criteria scenarios presented in Section 3. The alternative ESU viability scenarios described in Section 3 include both multiple population and single population versions. Given that at present there is only one extant population, we focus primarily on evaluating the current status vs. criteria for the single population's scenarios. However, the basic measures evaluated in the assessment would also apply to the multiple population scenario, which involves reintroduction of the ESU to areas above the Hells Canyon Complex.

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[15] On February 6, 2015, NMFS initiated a 5-year status review for 32 species of salmon and steelhead, including Snake River Fall-Run Chinook salmon. To ensure that this Proposed Plan was based on best available information, we incorporated material from the ongoing 5-year status review as Appendix A in this document.

[16] The ICTRT (2005) update identified two historical populations above the current Hells Canyon dam site. Based on information summarized in Connor et al. 2015 and the basic distance/dispersal approach used by the ICTRT to define population boundaries, it is likely that the two relatively continuous spawning aggregations were part of a single population.

4.1 Current Viability Rating

The detailed biological status assessment of the Lower Mainstem Snake River fall Chinook salmon population in Appendix A is based on information available in the spring of 2015. The primary focus is on status relative to the metrics and criteria thresholds for Viability Scenario B (single population aggregate metrics) described in Section 3, although we include brief summaries under specific VSP components of the findings or the additional information that would be required under variations that would be based on incorporating natural production emphasis areas that include one or more major spawning areas.

4.1.1 Abundance and Productivity

Prior to the early 1980s, returns of Snake River fall Chinook salmon were likely predominately of natural-origin (Bugert et al. 1990). Natural-origin return levels declined substantially following the completion of the three-dam Hells Canyon Complex (1959-1967), which completely blocked access to major production areas above Hells Canyon Dam, and the construction of the lower Snake River dams (1962-1975). Based on extrapolations from sampling at Ice Harbor Dam (1977-1990), the Lyons Ferry Hatchery (1987-present) and at Lower Granite Dam (1990-present), hatchery strays made up an increasing proportion of returns at the uppermost Snake River mainstem dam through the 1980s (Bugert et al. 1990; Bugert and Hopley 1989). Strays from out-planting Priest Rapids hatchery-origin fall Chinook salmon (and out-of-ESU stock from the mid-Columbia) and Snake River fall Chinook salmon from the Lyons Ferry Hatchery program (on-station releases initiated in the mid-1980s) were the dominant contributors. Estimated natural-origin returns reached a low of less than 100 fish in 1990.

In recent years, naturally spawning fall Chinook salmon in the lower Snake River have included both returns originating from naturally spawning parents and from returning hatchery releases. Hatchery-origin fall Chinook salmon escaping upstream above Lower Granite Dam to spawn naturally are now predominantly returns from supplementation program juvenile releases in reaches above Lower Granite Dam and from releases at Lyons Ferry Hatchery that have dispersed upstream. These fish are considered to be part of the listed ESU.

The geometric mean natural-origin adult abundance for the most recent 10 years of annual spawner escapement estimates (2005-2014) is 6,418, with a standard error of 0.19 (Tables 4-1 and 4-2). Natural-origin spawner abundance has increased relative to the levels reported in the most recent NWFSC status review (Ford et al. 2011), driven largely by relatively high escapements in the most recent three years (Figures 4-1 and 4-2).

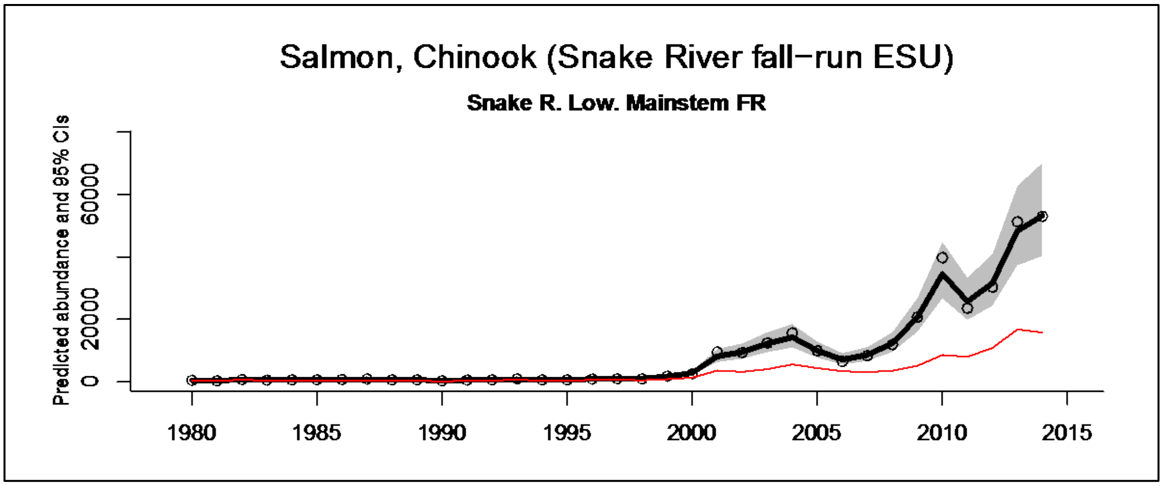


Figure 4-1. Smoothed trend in estimated total (thick black line) and natural (thin red line) population spawning abundance. Points show the annual raw spawning abundance estimates.

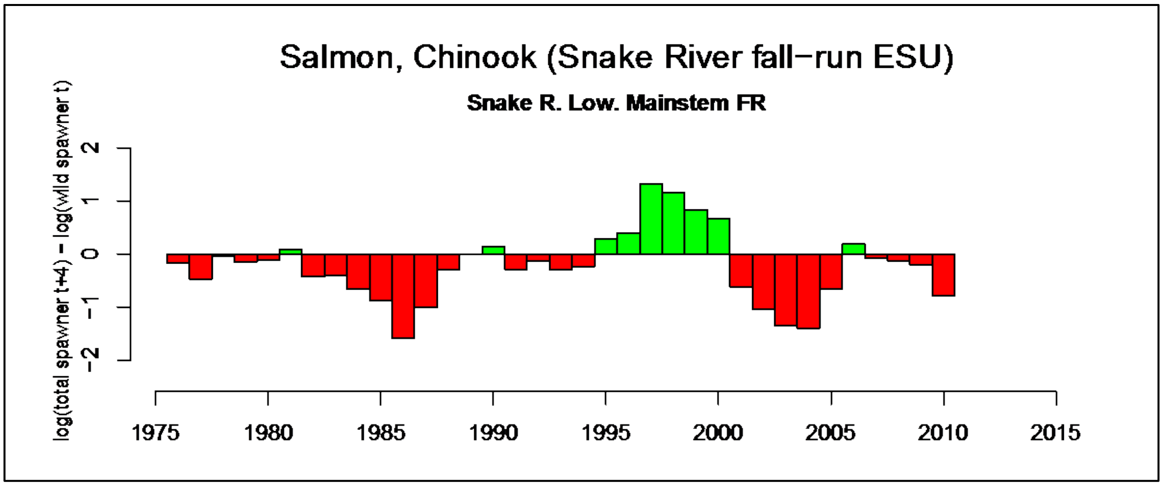


Figure 4-2. Trends in population productivity, estimated as the log of the smoothed natural spawning abundance in year *t* - smoothed natural spawning abundance in year (t – 4).

Table 4-1. Five-year geometric mean of raw wild spawner counts. This is the raw total spawner count times the fraction wild estimate, if available. In parentheses, 5-year geometric mean of raw total spawner counts is shown. A value only in parentheses means that a total spawner count was available but no or only one estimate of wild spawners available. The geometric mean was computed as the product of counts raised to the power 1 over the number of counts available (2 to 5). A minimum of 2 values were used to compute the geometric mean. Percent change between the most recent two 5-year periods is shown on the far right.

Population	MPG	1990-1994	1995-1999	2000-2004	2005-2009	2010-2014	% Change
Snake R. Low. Mainstem FR	Snake R.	333 (581)	548 (980)	3049 (8496)	3662 (10581)	11254 (37812)	207 (257)

Table 4-2. Fifteen-year trends in log wild spawner abundance computed from a linear regression applied to the smoothed wild spawner log abundance estimate. Only populations with at least 4 wild spawner estimates from 1980 to 2014 are shown and with at least 2 data points in the first 5 years and last 5 years of the 15-year period.

Population	MPG	1990-2005	1999-2014
Snake R. Low. Mainstem FR	Snake R.	0.22 (0.17, 0.26)	0.15 (0.1, 0.19)

Snake River fall Chinook have a very broad ocean distribution and have been taken in ocean salmon fisheries from central California through southeast Alaska. They are also harvested in-river in tribal and non-tribal fisheries. Historically they were subject to total exploitation rates on the order of 80 percent. Since they were originally listed in 1992, fishery impacts have been reduced in both ocean and river fisheries (Figure 4-3). Total exploitation rate has been relatively stable in the range of 40 to 50 percent since the mid-1990s.

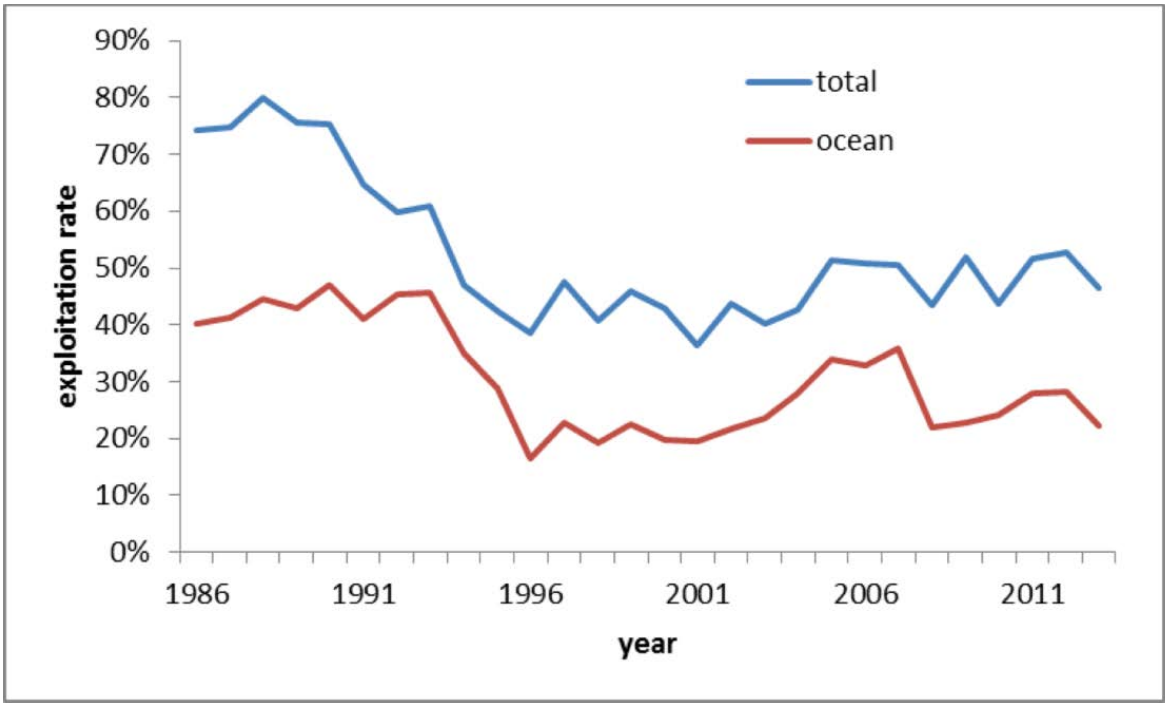


Figure 4-3. Total exploitation rate for Snake River fall Chinook salmon. Data for marine exploitation rates from the Chinook Technical Committee model (Calibration 1503) and for in-river harvest rates from the Columbia River Technical Advisory Committee (TAC 2014; Robin Ehlke, WDFW, personal communication).

Productivity, defined in the ICTRT viability criteria as the expected replacement rate at low to moderate abundance relative to a population's minimum abundance threshold, is a key measure of the potential resilience of a natural population to annual environmentally driven fluctuations in survival. The ICTRT Viability Report (ICTRT 2007) provided a simple method for estimating population productivity based on return-per-spawner (R/S) estimates for the most recent 20 years. To assure that all sources of mortality are accounted for, the ICTRT recommended that productivities used in Interior Columbia River viability assessments be expressed in terms of returns-to-the-spawning-ground. Other management applications express productivities in terms of pre-harvest recruits. Pre-harvest recruit estimates are available for Snake River fall Chinook salmon.

The ICTRT Viability report (ICTRT 2007) also acknowledged that alternative means of assessing productivity at low to moderate spawning abundance may be appropriate or required, especially in cases where total (natural- plus hatchery-origin) spawning levels consistently are at or above the minimum threshold for a particular population. In particular, it anticipated that fitted stock-recruit models might provide a useful alternative for evaluating a population's abundance and productivity relative to specific recovery criteria. The ICTRT recommended that if such an approach was used the 'steepness' parameter (e.g., Hilborn and Walters 1992) of the stock-recruit model would be an appropriate index of productivity. Steepness is defined as the expected return-per-spawner at a parent-spawner level of 20 percent of the predicted equilibrium escapement for a data series. Steepness is derived algebraically from the more basic stock-recruit curve parameters (productivity at the origin and capacity). While the consistently high spawner escapements driven by a combination of natural and hatchery supplementation returns have complicated interpretation of results from the simple R/S method, the increased range in parent escapement estimates has increased the feasibility of using fitted stock-recruit relationships as an alternative approach for estimating production parameters.

Estimates of current productivity for this population were developed using both the simple average R/S method and by fitting stock-recruit functions using maximum likelihood statistical routines (nls routine in the R statistical package). Using the ICTRT simple 20-year R/S method, the current estimate of productivity for this population (1990-2009 brood years) is 1.53 with a standard error of 0.18. Findings using the simple R/S method indicate that there have been years when abundance was high but productivity (R/S) fell below the replacement level (Figure 4-4), indicating potential influence from density-dependence limitations, poor ocean conditions, or poor migration conditions. This estimate of productivity, however, may be problematic for two reasons: (1) the increasingly small number of years that actually contribute to the productivity estimate means that there is increasing statistical uncertainty surrounding that estimate, and (2) the years contributing to the estimate are now far in the past and may not accurately reflect the true productivity of the current population. Under the simple R/S method, all of the R/S estimates for years after 1999 are excluded from the average due to the total (hatchery plus wild) escapements in those years. Total escapements for brood years 2010 through 2014 are also well above the minimum threshold levels and will be excluded in calculating productivity using the simple ICTRT method in future assessments.

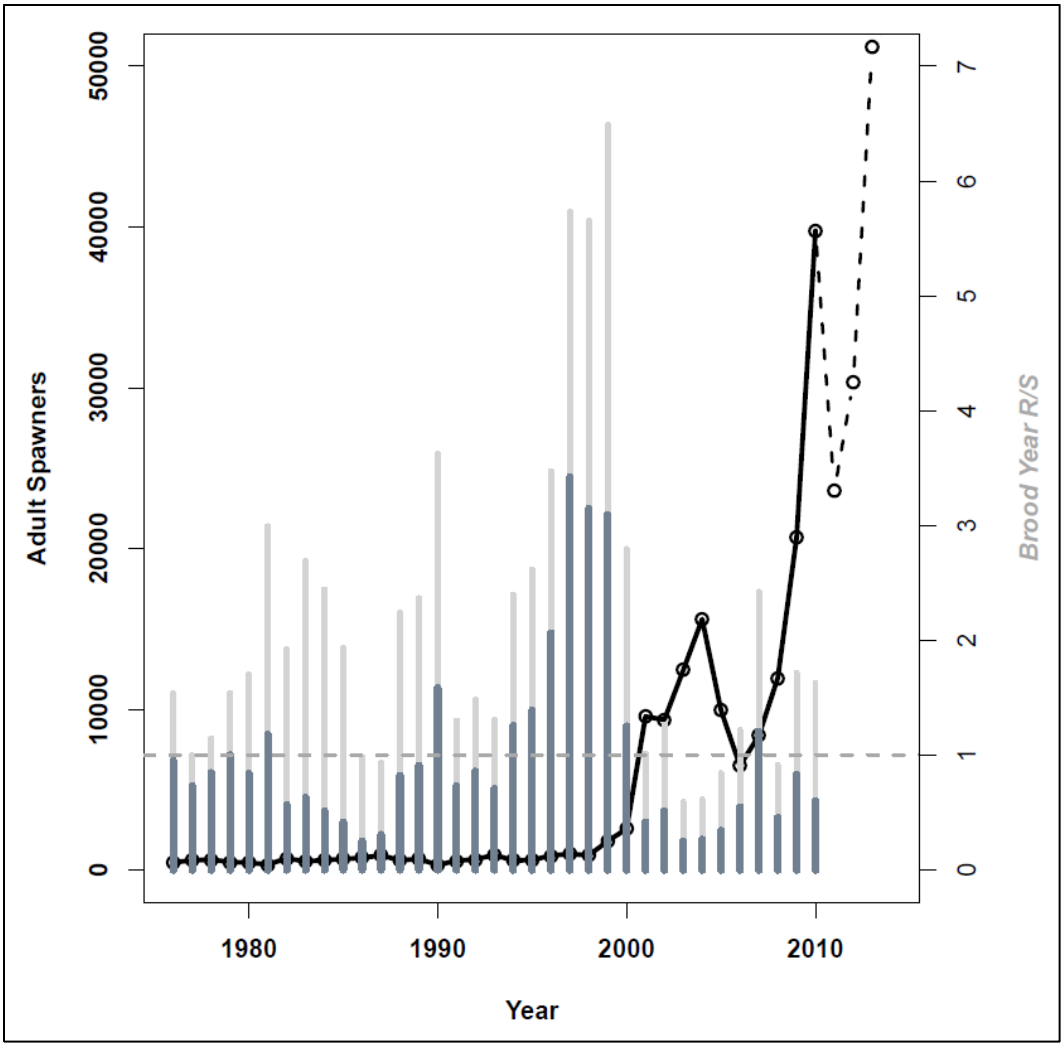


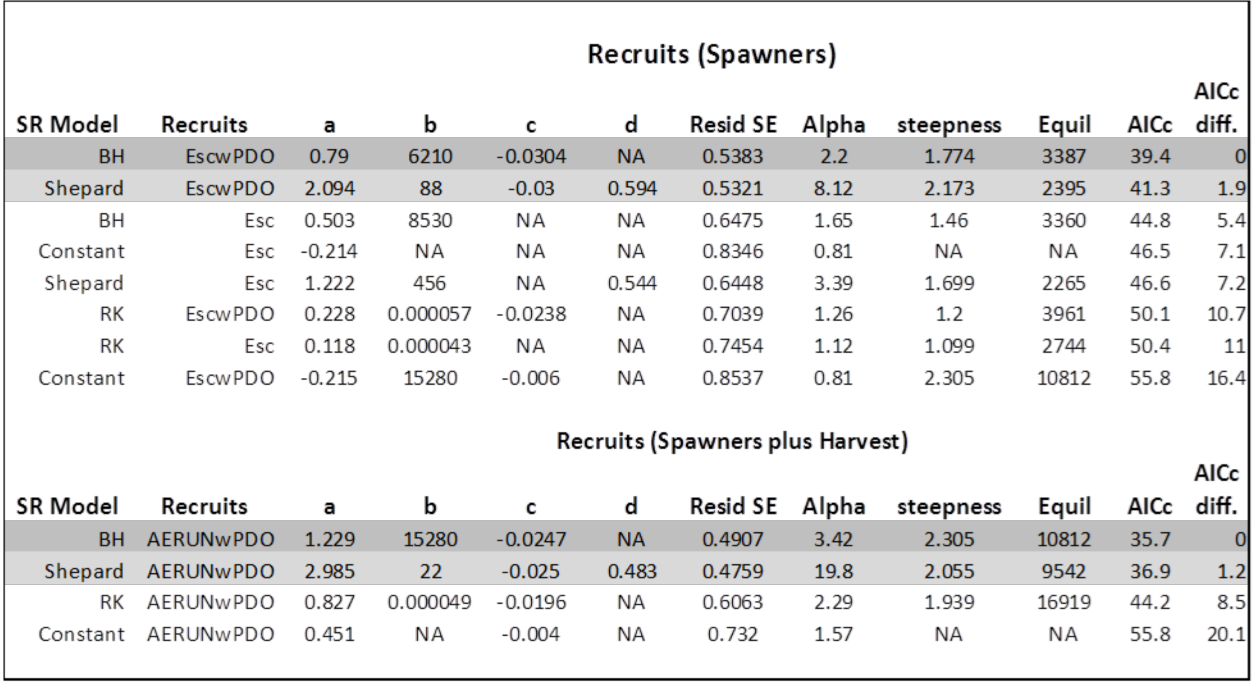
Figure 4-4. Brood year parent spawning levels (right side axis, hatchery plus natural-origin adults) and brood year return per spawner estimates (left side axis, red squares) vs. parent brood year. Light bars: recruits are adult escapement plus ocean (adult equivalent) and in-river harvest. Dark bars: recruits are escapement over Lower Granite Dam. Parent brood year escapements with incomplete return ages depicted with dashed line.

Expressing productivity as an expected average return-per-spawner from parent-spawner escapements below levels associated with strong density-dependent effects is a key feature of the ICTRT methods for assessing current population performance against viability curves. The ICTRT determined, based on preliminary sensitivity analyses, that estimated productivities derived by fitting stock-recruit relationships to current data series could be compared to a single set of viability curves if those estimates were expressed as steepness (ICTRT 2007).

NMFS fit four alternative stock-recruit models to the 1991-2010 brood-year spawner and return data set for the Lower Mainstem Snake River fall Chinook salmon population. The four models were: (1) a model that assumed a constant underlying R/S value that is invariant with respect to spawner density, (2) a Beverton-Holt R/S model, (3) a Ricker R/S model, and (4) the Shepard R/S model. The Shepard R/S model (Shepard 1982) is a form that includes a third fitted parameter corresponding to the general shape of the relationship. Each function was fit with and without an annual Pacific Decadal Oscillation (PDO) term to evaluate the potential contribution of year-to-year variations in ocean conditions. The nls routine in the R statistical package was then used to estimate the parameters of the three stock-recruit models (Table 4-3). The models were statistically compared using the AICc criteria (AICcmodavg package).

Regardless of whether recruits were measured as returns-to-the-spawning-grounds or as pre-harvest recruits, based on a comparison of AICc values the three models incorporating density-dependent terms (Beverton-Holt, Ricker and Shepard) fit the data significantly better than the constant R/S model (Table 4-3). The estimated equilibrium abundance estimates from the three density-dependent models were each below the recent 10-year geometric mean natural abundance estimate of 6,418. The Beverton Holt model had the lowest AICc score, followed by the Shepard function. The fitted relationships for natural log return-per-spawner vs. parent spawners and the results of bootstrapping to illustrate the potential influence of parameter uncertainty for the Beverton-Hold function are provided in Figure 4-5. The inset pie chart in the top panel summarizes the proportions of the bootstrap samples that fall into the four possible risk categories. Approximately 67 percent of the samples exceeded the viability curve for Very Low Risk, below the recovery plan requirement of 80 percent. The spawner/recruit plot includes the 1991-2014 recruit and parent spawner pairs, unadjusted and adjusted to reflect the fitted PDO relationship included in the analysis.

Table 4-3. Snake River Fall Chinook. Spawner=recruit function fits.



Recruits (Spawners)

SR Model	Recruits	a	b	c	d	Resid SE	Alpha	steepness	Equil	AICc	AICc diff.
BH	EscwPDO	0.79	6210	-0.0304	NA	0.5383	2.2	1.774	3387	39.4	0
Shepard	EscwPDO	2.094	88	-0.03	0.594	0.5321	8.12	2.173	2395	41.3	1.9
BH	Esc	0.503	8530	NA	NA	0.6475	1.65	1.46	3360	44.8	5.4
Constant	Esc	-0.214	NA	NA	NA	0.8346	0.81	NA	NA	46.5	7.1
Shepard	Esc	1.222	456	NA	0.544	0.6448	3.39	1.699	2265	46.6	7.2
RK	EscwPDO	0.228	0.000057	-0.0238	NA	0.7039	1.26	1.2	3961	50.1	10.7
RK	Esc	0.118	0.000043	NA	NA	0.7454	1.12	1.099	2744	50.4	11
Constant	EscwPDO	-0.215	15280	-0.006	NA	0.8537	0.81	2.305	10812	55.8	16.4

Recruits (Spawners plus Harvest)

SR Model	Recruits	a	b	c	d	Resid SE	Alpha	steepness	Equil	AICc	AICc diff.
BH	AERUNwPDO	1.229	15280	-0.0247	NA	0.4907	3.42	2.305	10812	35.7	0
Shepard	AERUNwPDO	2.985	22	-0.025	0.483	0.4759	19.8	2.055	9542	36.9	1.2
RK	AERUNwPDO	0.827	0.000049	-0.0196	NA	0.6063	2.29	1.939	16919	44.2	8.5
Constant	AERUNwPDO	0.451	NA	-0.004	NA	0.732	1.57	NA	NA	55.8	20.1

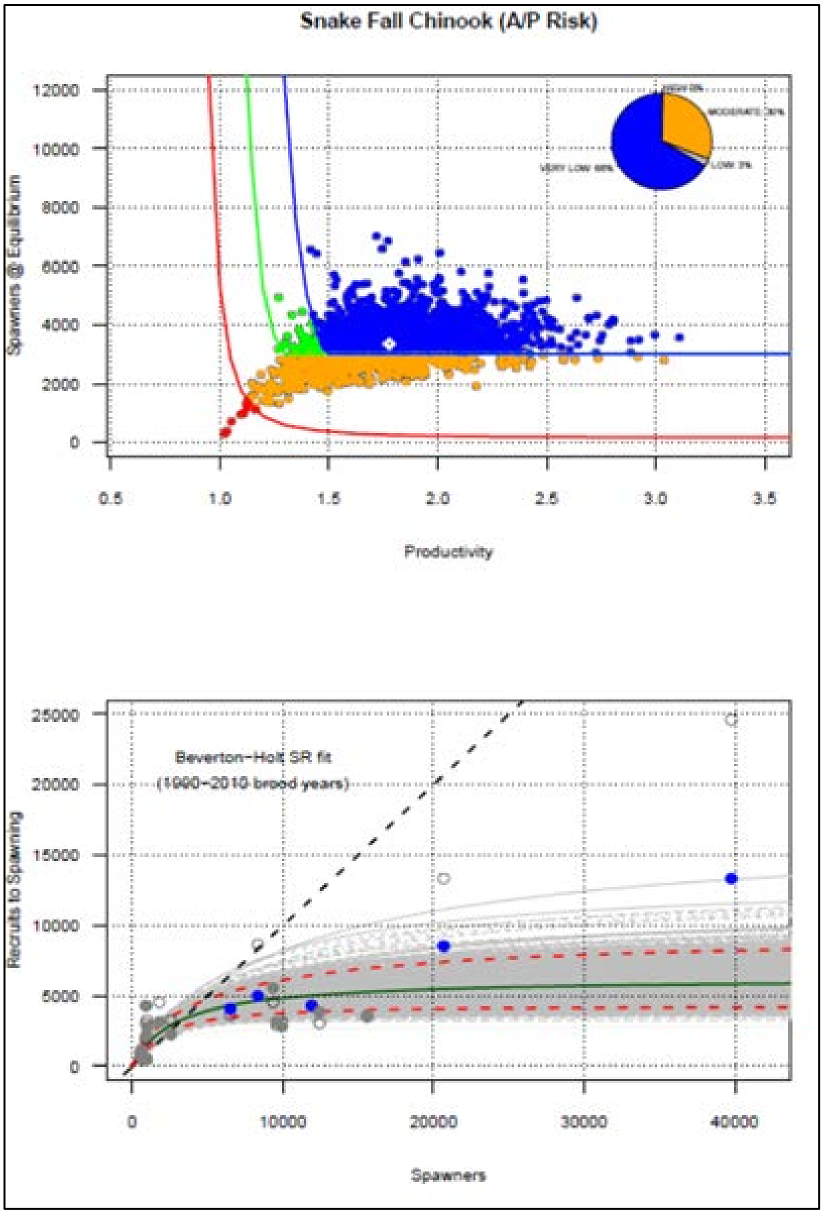


Figure 4-5. Beverton Holt stock recruit relationship fitted to broodyears 1991-2010 Snake River Fall Chinook adult escapement estimates. Includes parameter uncertainty generated using the nlsBoot routine for the R statistical package. Top panel: Summary of bootstrap results (2,000 iterations) plotted against Snake Fall Chinook viability curves. Pie chart in upper right corner summarizes the proportions of bootstrap runs vs. ICTRT viability curves (Hi, Moderate, Low and Very Low risk). Bottom panel: Data points (with and without average fitted PDO multiplier). Black dashed lline is 1:1 replacement.

Abundance and Productivity Summary

In conclusion, while the 10-year geometric mean natural-origin abundance level has been high, the abundance/productivity margin is insufficient to rate the population as Very Low Risk given the uncertainty-buffering requirement under the single population viability scenario. The current paired estimates from either the simple empirical method or the fitted stock production functions both indicate that the buffer requirements are not met. The potential that the ‘true’ underlying abundance and productivity being estimated from the samples falls above the 5 percent viability curve (with minimum abundance threshold) is greater than 80 percent. As a result, the Lower Mainstem Snake River fall Chinook salmon population is rated at Low Risk for abundance and productivity.

NMFS acknowledges that there could be alternative single population viability scenarios given the unique spatial complexity of the Lower Mainstem Snake River fall Chinook salmon population if major spawning areas supporting the bulk of natural returns are operating consistent with long-term diversity objectives. Under this variation, the requirements for a sufficient combination of natural abundance and productivity could be based on a combination of total population natural abundance and relatively high production from one or more major spawning areas with relatively low hatchery contributions to spawning. At present (escapements through 2014), given the widespread distribution of hatchery releases and the lack of direct sampling of reach-specific spawner compositions, there is no indication of a strong differential distribution of hatchery returns among major spawning areas.

4.1.2 Spatial Structure and Diversity

The ICTRT framework for evaluating population-level status in terms of spatial structure and diversity is hierarchical, organized around two major goals: maintaining natural patterns for spatially mediated processes and maintaining natural levels of variation (ICTRT 2007). The overall rating is driven by considerations for an explicit series of factors associated with each goal. Each of the factors has an associated set of metrics for evaluating its contribution to risk. The framework also incorporates a scoring system that weights more direct measures of current population performance over indirect indicators.

Goal 1: Maintain natural rates and levels of spatially mediated processes.

Metrics:

a. Number and distribution of spawning areas

b. Spatial extent and range of spawning areas relative to historical template

c. Changes in gaps between spawning areas

Goal 2: Maintain natural levels of variation.

Metrics:

a. Changes and loss of major life history strategies

b. Variation and loss of phenotypic traits, such as adult run and spawning timing, adult age structure and juvenile outmigrant size distributions

c. Genetic variation

d. Spawner composition, proportion and origin of natural spawning hatchery fish

e. Changes in use of major habitat types (ecoregions) within the population

f. Selective mortality factors: Hydrosystem, Hatcheries, Harvest, Habitat

The extant Lower Mainstem Snake River population occupies the 100-mile reach of the mainstem Snake River from the upper end of the Lower Granite Dam pool (near Lewiston, Idaho) to the Hells Canyon Dam, the 110-mile reach of the Clearwater River from the upper end of the Lower Granite Dam pool (near Lewiston, Idaho) to Selway Falls, plus the lower reaches of major tributaries (e.g., the Grande Ronde and Imnaha Rivers). Existing maps of geomorphic spawning habitat potential and of redd distributions were used as input for evaluating spatial structure and diversity elements of viability (ICTRT 2007).

The ICTRT identified five major spawning areas (MaSAs) for the Lower Mainstem Snake River fall Chinook salmon population (Figure 4-6):

1. *Upper Mainstem Snake River reach* - Hells Canyon Dam downstream to the mouth of the Salmon River and including the lower mainstem of the Imnaha and Salmon Rivers
2. *Lower Mainstem Snake River reach* - mouth of the Salmon River downstream to the upper end of Lower Granite Reservoir
3. *Grande Ronde River*
4. *Clearwater River*
5. *Tucannon River (and contiguous mainstem Snake River habitat)*

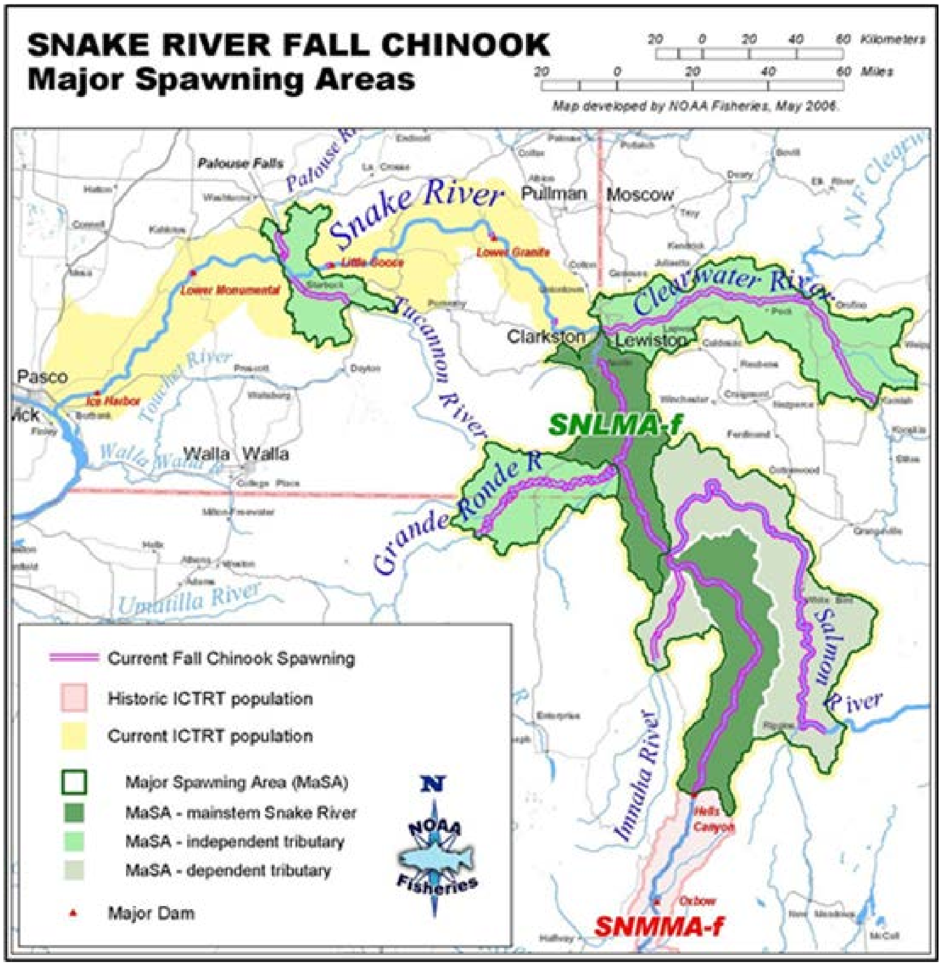


Figure 4-6. Lower Mainstem Snake River fall Chinook salmon population: major spawning areas (MaSAs) with core spawing habitat and associated dependent spawning areas delineated.

The extant Lower Snake River Fall Chinook salmon population consists of a spatially complex set of five historical major spawning areas (ICTRT, 2007), each of which consists of a set of relatively discrete spawning patches of varying size (e.g. Connor et al. 2015). The primary MaSA in the extant Lower Mainstem Snake River population is the 96-km Upper Mainstem Snake River Reach, extending upriver from the confluence of the Salmon River to the Hells Canyon Dam site, where the canyon walls narrow and strongly confine the river bed. A second mainstem Snake River MaSA, the Lower Mainstem Snake River Reach, extends 69 km downstream from the Salmon River confluence to the upper end of the contemporary Lower Granite Dam pool. The lower mainstem reaches of two major tributaries to the mainstem Snake River, the Grande Ronde and the Clearwater Rivers, were also identified by the ICTRT as MaSAs. Both of these river systems currently support fall Chinook salmon spawning in the lower reaches. In addition, there is some historical evidence for production of late spawning Chinook salmon in spatially isolated reaches in upriver tributaries to each of these systems. Attempts are underway to develop a separate early spawning component into the upper Clearwater River using the South Fork Clearwater weir as a broodstock collection point (Hesse and Johnson 2012).

Historical records and geomorphic assessments support the historical existence of a fifth MaSA comprised of spawning habitats in the Lower Tucannon River and the adjacent inundated mainstem Snake River section associated with Little Goose and Lower Monumental Dams. Several other tributaries of varying size (e.g., the Salmon and Imnaha Rivers, Alpowa and Asotin Creeks) enter the mainstem Snake River within each of the MaSAs defined above. Production in those lower mainstem sections are considered part of the adjoining mainstem MaSA (ICTRT 2007). Similar to the Grande Ronde and Clearwater River, anecdotal accounts suggest that late spawning Chinook salmon may have existed in the lower mainstem of the South Fork Salmon River (e.g., Connor et al. 2015). Historically, some level of fall Chinook salmon spawning may have occurred in the lower Snake River in the reach currently inundated by the Ice Harbor Dam pool (Dauble et al. 2003). Spawners using the lowest potential spawning reaches in the Snake River, currently inundated by Ice Harbor Dam, could have been associated with either the Lower Snake River population or a population centered on mainstem Columbia River spawning areas currently inundated by John Day and McNary Dams.

Although annual redd surveys show that fall chinook spawning occurs in all five of the historical MaSAs, the inability to obtain carcass samples representative of the mainstem MaSAs makes assessment of natural-origin spawner distributions difficult. Reconstruction of natural-origin spawners based on hatchery expansions and data from homing/dispersal studies on acclimated hatchery releases indicates that four out of the five MaSAs are contributing to naturally produced returns (Figure 4-7). Carcass samples are obtained in the Tucannon River, expanding the hatchery-marked recoveries in that MaSA account for virtually all of the redds, suggesting negligible natural-origin returns (e.g., Milks and Oakerman 2014).

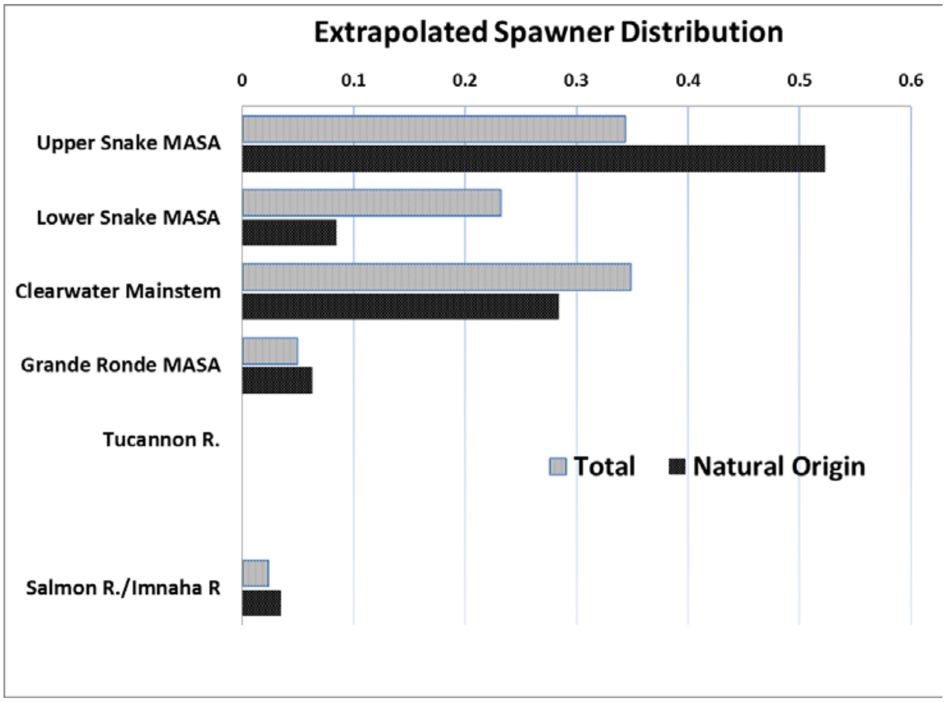


Figure 4-7. Estimated average spawner distributions (2004-2014) across major and minor spawning areas. Total is average distribution of redds from annual multiple pass surveys, produced by combination of hatchery and natural-origin spawners. Natural-origin estimates extrapolated from regional total redd counts, estimated hatchery returns by release area and estimated dispersal/straying patterns from Garcia et al. 2004.

Factor A.1.a. Number and spatial arrangement of spawning areas

Four of the five historical MaSAs currently are known to contain natural-origin spawners regularly. The fifth, the Tucannon MaSA, also has fall Chinook salmon spawners, but recent year surveys indicate that nearly all natural spawners in the Tucannon are hatchery-origin returns from Lyons Ferry Hatchery releases. The lack of natural-origin spawners in the Tucannon suggests that this MaSA is not currently very productive, or alternatively, that natural-origin fish originating from this area stray at high rates to other MaSAs. Based on the ICTRT guidelines, the accessibility of fish to all five MaSAs produces a rating of **very low risk** for this factor.

Factor A.l.b. Spatial extent or range of population

The distribution of current spawning by the Lower Mainstem Snake River fall Chinook salmon population is shown in Figure 4-4. Based on annual redd survey results, four out of five of the major spawning areas in the population area exhibit spawning. It is very likely that four out of five of the major spawning areas include natural-origin spawners and are considered occupied (the two free-flowing Snake River mainstem major spawning areas and lower portions of the Clearwater and Grande Ronde Rivers). Carcass sampling data from the mainstem Clearwater River MaSA confirm the presence of natural-origin spawners. Difficulties associated with environmental conditions in the large mainstem reaches of the Snake River have precluded direct sampling of carcasses in those reaches. However, based on inferences from redd surveys prior to the increase in hatchery returns and projections based on survival estimates from reach-specific hatchery releases, it is likely that natural-origin fish are contributing to spawning. Applying the

ICTRT guidelines for a complex (trellis-structured) population, the Lower Mainstem Snake River fall Chinook salmon population is rated at **low risk** for current spatial structure.

Factor A.1.c. Increase or decrease in gaps or continuities between spawning areas

Four out of the five historical MaSAs in the extant Lower Mainstem Snake River population meet the ICTRT criteria for occupancy. The Tucannon MaSA is not rated as occupied due to the lack of evidence for natural-origin spawners; however, this MaSA is at the downstream end of the overall population. While the lack of occupancy in this MaSA does not create a gap among spawning aggregates within the population, the overall risk to the ESU may have increased somewhat as a result of the loss of natural connectivity between this population and downstream ESUs. Under the ICTRT guidelines for this criterion, this metric is rated **low risk**.

Factor B.1.a. Major life history strategies

Historical habitat conditions associated with the reaches supporting the extant Lower Mainstem Snake River population were likely more diverse than those associated with the two extirpated upstream populations in the ESU. Conditions in the Snake River mainstem reach extending upstream of the Salmon River to the current site of Hells Canyon Dam are currently the most similar to those associated with the historical upstream populations (Connor et al. 2002) and data indicates that most smolts produced from this area migrate as sub-yearlings. Incubation and spring juvenile rearing temperatures in the Snake River mainstem below the Salmon River and in the lower Clearwater River mainstem are relatively cold in comparison. As a result, sub-yearling Chinook salmon must rear later into the summer before reaching sufficient size to begin active migration. Out-migration timing from these reaches is, therefore, likely later relative to historical patterns.

In recent years, otolith analysis, age-specific run reconstructions and scale samples have indicated that a proportion of adult returns of both hatchery- and natural-origin Chinook salmon overwintered somewhere in the Columbia River system prior to entering the ocean (e.g., Marsh et al. 2007). This alternative life history strategy may be a result of the flow and colder temperature conditions in the Clearwater River, and to a lesser extent in the Snake mainstem below the Salmon River confluence. These ultimately yearling migrants spend their first winter in one or more lower Snake River or Columbia River reservoirs and migrate to the ocean as yearlings the following spring/summer.Natural returns from both the sub-yearling and yearling migration types have demonstrated increases in return rates since the early 1990s. Sampling data indicate that the proportion of adult returns demonstrating a freshwater overwintering life history pattern peaked with the early 2000 broods, and has declined since then (Figure 4-8).

The expression of an alternative life history strategy, or a change in the proportion of individuals within a population exhibiting a particular life history strategy, may ultimately serve to reduce the overall extinction risk at both the population and ESU levels. The majority of returning naturally produced adults currently exhibit a sub-yearling life history pattern. The analyses described above indicate that all historical major life history pathways are present and although there has likely been some change in patterns of variation, the current patterns likely represent adaptations to recent environmental conditions. Therefore, the current Lower Mainstem Snake River fall Chinook population is rated **low risk** for life history diversity based on recent patterns in sub-yearling and yearling natural production.

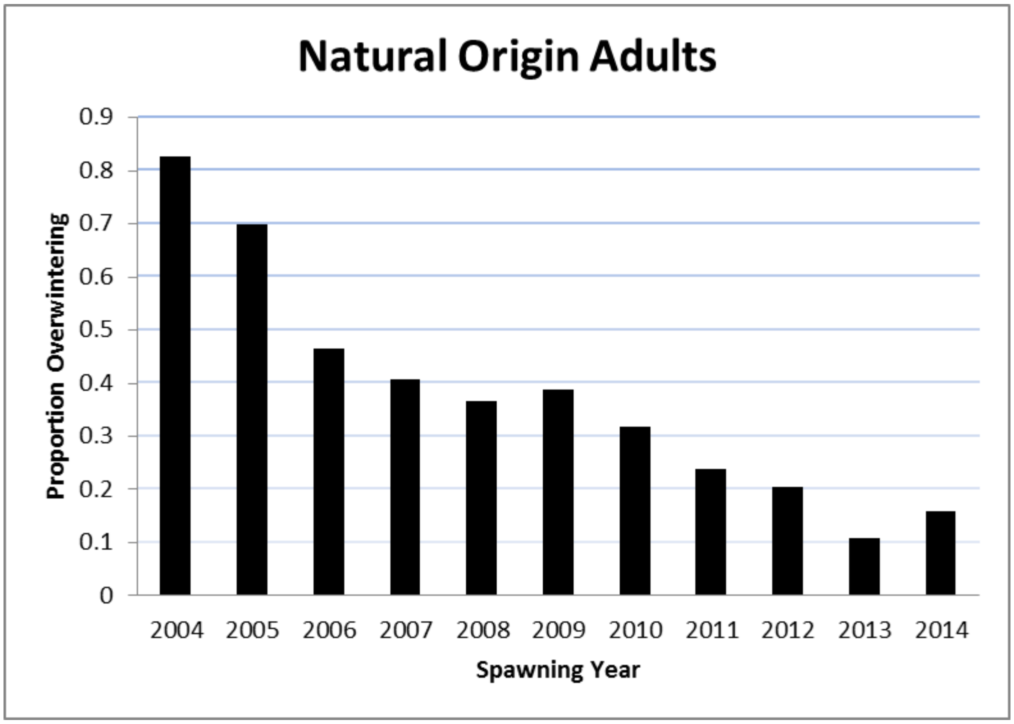


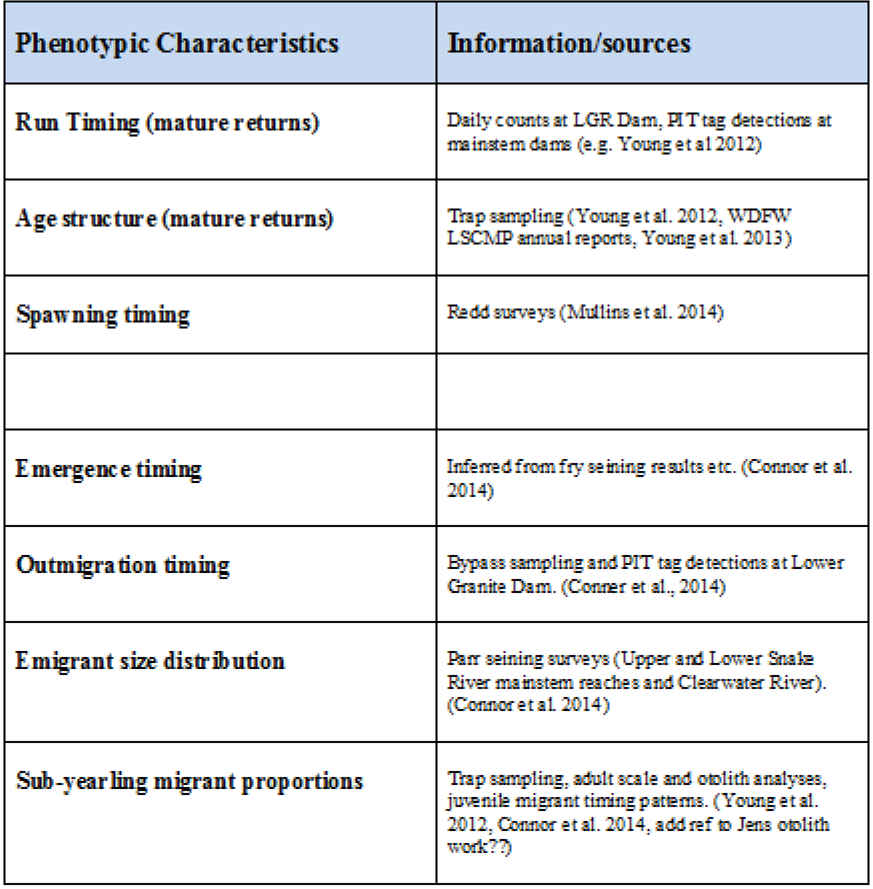
Figure 4-8. Proportion of returning natural-origin Snake River Fall Chinook adults sampled at the Lower Granite Dam trap identified as yearling outmigrants. Extrapolated from age specific estimates of unmarked returns adjusted for potential contributions of unmarked hatchery fish (see Bill Young et al. 2013 for description of run reconstruction methods).

B.1.b. Phenotypic variation

Changes in the means or the variation in phenotypic traits away from levels that reflect natural adaption represent a potential risk to the long-term sustainability of a population. The ICTRT Viability Criteria Report (ICTRT 2007) provided general criteria for assigning a risk rating based on current estimates of the mean and variability in key life history traits. In those examples, the degree of risk is a function of the number of traits lost or substantially shifted vs. natural optimums. As with the other diversity criteria, a population would be assigned a very low risk rating for this factor if there were evidence supporting no loss, shift in means or reduced variability for any trait. A substantial shift in the mean or reduced variability for single trait translates to a low-risk rating. Loss of a particular trait or a meaningful change in the pattern of variation for two or more traits results in a moderate-risk rating. More extensive trait losses, or significant shifts or truncated variability across multiple traits translates to a high risk rating.

Current estimates of seven particular phenotypic traits were reviewed for the Lower Mainstem Snake River fall Chinook salmon population, each of which can be linked to natural selective forces at some life stage (Table 4-4). Three of the traits reflect patterns in mature returning fish. The remaining four traits reflect characteristics of juvenile production. The ICTRT guidance for evaluating diversity noted that it was not appropriate to specify single point estimate ‘targets’ for assessing risk for specific diversity criteria components. Instead, assigning risk would require some judgment that considers whether the current mean and variation reflects an adaptation to current conditions and whether the range of variability in a particular trait encompasses what was likely the historical optimum.

Table 4-4. Summary of phenotypic traits and information sources.



Phenotypic Characteristics	Information/sources
Run Timing (mature returns)	Daily counts at LGR Dam, PIT tag detections at mainstem dams (e.g. Young et al 2012)
Age structure (mature returns)	Trap sampling (Young et al. 2012, WDFW LSCMP annual reports, Young et al. 2013)
Spawning timing	Redd surveys (Mullins et al. 2014)
Emergence timing	Inferred from fry seining results etc. (Connor et al. 2014)
Outmigration timing	Bypass sampling and PIT tag detections at Lower Granite Dam. (Conner et al., 2014)
Emigrant size distribution	Parr seining surveys (Upper and Lower Snake River mainstem reaches and Clearwater River). (Connor et al. 2014)
Sub-yearling migrant proportions	Trap sampling, adult scale and otolith analyses, juvenile migrant timing patterns. (Young et al. 2012, Connor et al. 2014, add ref to Jens otolith work??)

Much more limited empirical data on historical phenotypic patterns for production from this particular population are available. Some insight into patterns that were prevalent historically can also be gained through inference based on habitat conditions and comparisons with other populations of ocean-type mainstem spawning fall Chinook salmon. Adult run timing can be estimated based on adult ladder counts and trap sampling at the lower Snake River dams. This data indicates that there has been a relatively small shift in peak counts passing over Ice Harbor Dam since 1962 (first year of counts). In summary, the seaward migration timing through the mainstem Snake and Columbia Rivers has likely been altered due to flow and temperature changes. Other key life history traits (e.g. age at return, spawning and incubation timing) are consistent with adaptations for the range of freshwater habitat conditions currently inhabited by the populations. The variation in these traits overlaps extrapolated historical patterns. Therefore, applying the ICTRT guidelines for assessing current phenotypic diversity, the Lower Mainstem Snake River fall Chinook salmon population rates at **low risk** for phenotypic diversity.

B.1.c. Genetic variation

The ICTRT intended that this factor address changes in genetic variation for a population resulting from either a) introgression from non-local hatchery spawners or b) adverse genetic effects of small population size or changes in the level of differentiation within the population (ICTRT 2007). We evaluate current genetic variation of the population from both perspectives in order to assign a risk rating to this factor. The ICTRT guidelines for assessing the current status of a population with respect to genetic variation emphasize evaluating patterns in genetic variation from samples representative of the current population. Current and past genetic sampling data can be augmented with inferences from less direct information in assessing risk. The ICTRT status evaluation guidance provides a general framework for determining current status based on both direct and indirect information (ICTRT 2007).

Outbreeding Effects

Outbreeding effects are the consequences of gene flow from one population into another. Altered patterns of gene flow among populations can result in increasing the level of genetic diversity in a receiving population or it can result in outbreeding depression - a reduction in fitness due to altered genetic frequencies (NMFS 2012a). One of the specific factors cited in the listing of Snake River fall Chinook salmon under the ESA (NMFS 1991) was the potential for significant genetic introgression due to increased straying of outside stocks into natural spawning areas above Lower Granite Dam.

Recent year sampling data indicates that 1) straying from the primary source − Umatilla River releases of Priest Rapids fall Chinook salmon stock − has been reduced substantially; 2) broodstock protocols have eliminated known out-of-ESU fish from the ongoing hatchery program; and 3) the overall genetic patterns have been consistent among hatchery- and natural-origin returns.

Because exogenous fall Chinook salmon could not be excluded from natural production in the Snake River, considerable concern arose that these wild fish may become an introgressed population of upper Columbia River and Snake River gene pools (Bugert et al. 1995). This possibility was examined by genetically characterizing naturally produced juvenile progeny of fall Chinook salmon spawning upstream from Lyons Ferry between 1990 and 1994 (Marshall et al. 2000). That study concluded that distinctive patterns of allelic diversity persisted in naturally produced juveniles in the Snake River that: (1) were differentiated from upper Columbia River populations; and (2) supported earlier conclusions that the Snake River fall Chinook salmon ESU remained an important genetic resource.

In summary, genetic samples from the aggregate population in recent years indicate that composite genetic diversity is being maintained and that the Snake River Fall Chinook hatchery stock is similar to the natural component of the population, an indication that the actions taken to reduce the potential introgression of out-of-basin hatchery strays has been effective.

Within-population Diversity

Given the diversity of habitats used across the major spawning areas within the Lower Mainstem Snake River population and evidence of relatively strong reach fidelity for acclimated supplementation releases, it is reasonable to assume some, albeit unknown, level of within-population diversity existed historically. Given the widespread distribution of supplementation releases across major spawning areas within the population, the high proportion of hatchery fish in the aggregate run and evidence for homing fidelity of releases, it is likely that the maintenance or development of diversity among MaSAs has been impeded.

Based on these considerations, the current genetic diversity of the population represents a change from historical conditions and, applying the ICTRT guidelines, the rating for this metric is **moderate risk**.

B.2 Spawner Composition

Spawner composition (relative proportions of natural-origin and hatchery-origin fish on the spawning grounds) is a potential indicator of altered gene flows for a population. Other mechanisms (e.g. gaps in spawning or rearing habitat due to anthropogenic loss) are also possible and are addressed by other ICTRT criteria.

Prior to the early 1980s, returns of Snake River fall Chinook salmon were predominately of natural-origin. As noted in Section 4.1.1, natural-origin return levels declined substantially following the completion of the Hells Canyon Complex (total block to major production areas above Hells Canyon) and the construction of the lower Snake River dams. Hatchery strays made up an increasing proportion of returns at Lower Granite Dam (the uppermost Snake River mainstem dam) through the 1980s. Returns of hatchery-origin Snake River fall Chinook salmon from the Lyons Ferry Hatchery program and strays from outplanting Priest Rapids Hatchery-origin fall Chinook salmon (out-of-ESU stock) were the dominant contributors. Natural-origin returns reached a low of less than 100 fish in 1978.

Total returns of fall Chinook salmon over Lower Granite Dam increased steadily from the mid-1990s to the present. Natural returns increased at roughly the same rate as hatchery-origin returns through the 2000-run year. Since 2000, hatchery returns have increased faster than natural-origin returns (Table 4-5; Figure 4-9). The median proportion of natural-origin Snake River fall Chinook salmon has been approximately 32 percent over the past two brood cycles.

1. *Out-of-ESU spawners:* Over the past two brood cycles, the average proportion of out-of-ESU strays (based on trap sampling at Lower Granite Dam) has been reduced substantially from the levels observed in the 1990s and early 2000’s. The most recent 5-year and 10-year average out-of-ESU contribution rates were both below 2 percent, meeting the ICTRT quantitative criteria for a low risk rating. The 15-year (three-brood cycle) average is

currently 4.6 percent, corresponding to a moderate risk rating. The ICTRT guidelines recommend assigning the highest of the ratings for 1, 2, or 3 brood cycles, resulting in a **moderate risk** rating for this component of the metric. If the most recent pattern of low contributions continues, this rating will shift to low within 5 years.

2. *Out-of-MPG spawners from within the ESU:* There are no other MPGs within the Snake River fall Chinook salmon ESU. This metric is **not applicable**.

3. *Out-of-population spawners from within the MPG:* There are no other extant populations within the MPG and this metric is **not applicable**.

4. *Within-population hatchery spawners:* Returns of releases from the Snake River hatchery program (Lyons Ferry broodstock) along with a small component of out-of-ESU strays have accounted for an average of 68 percent of the escapement into natural spawning areas above Lower Granite Dam over the past 10 years (Figure 4-10). Snake River hatchery fish above Lower Granite Dam include returns from supplementation releases in the mainstem Snake and Clearwater Rivers as well as from releases at Lyons Ferry Hatchery. The relatively high proportion of within-population hatchery spawners results in a **high-risk** rating.

Table 4-5. Five-year mean of fraction wild (sum of all estimates divided by the number of estimates). Blanks mean no estimate available in that 5-year range.

Population	1990-1994	1995-1999	2000-2004	2005-2009	2010-2014
Snake R. Low. Mainstem FR	0.62	0.58	0.38	0.37	0.31

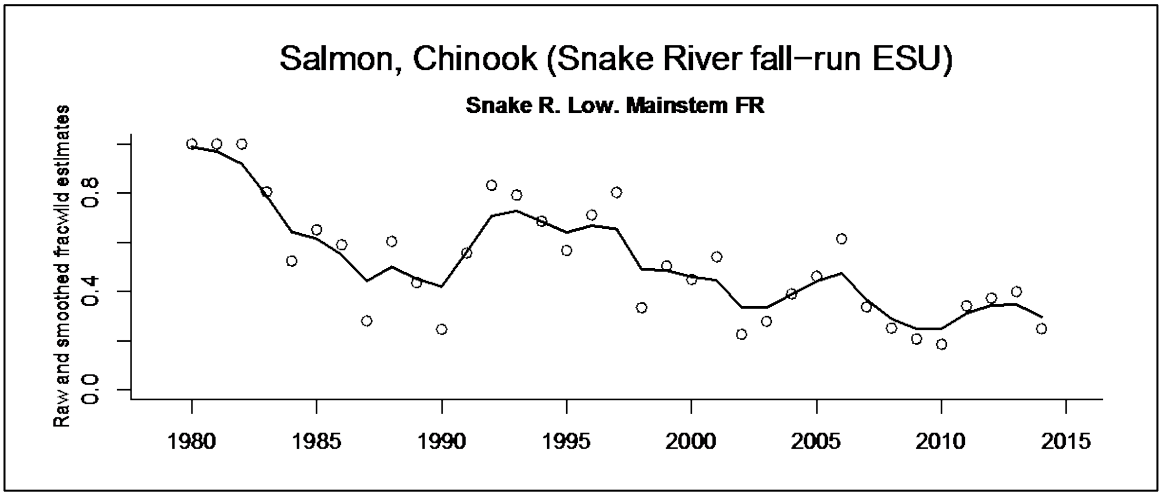


Figure 4-9. Smoothed trend in the estimated fraction of the natural spawning population consisting of fish of natural origin. Points show the annual raw estimates.

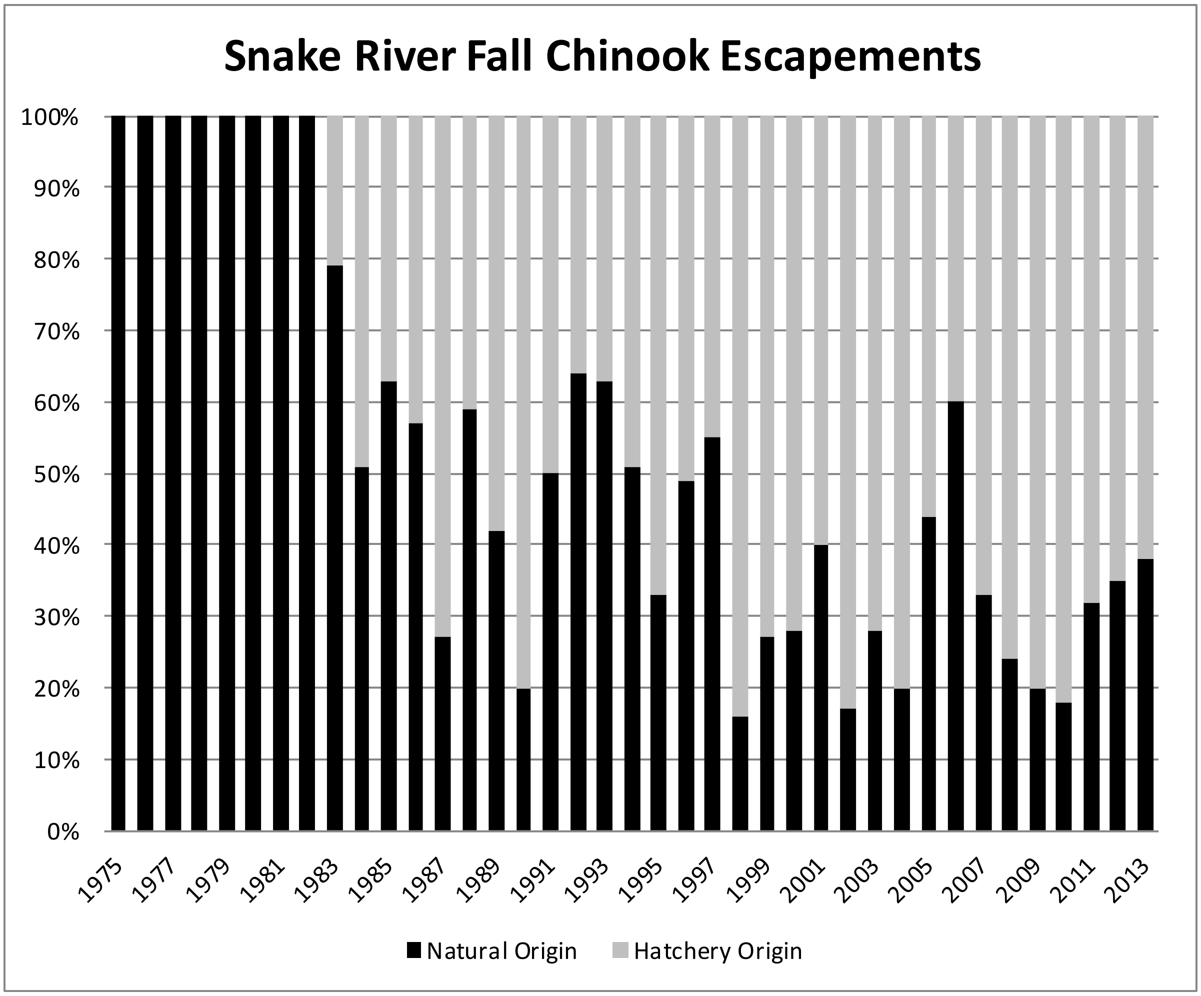


Figure 4-10. Annual adult escapement proportions natural-origin (black) and hatchery-origin (gray).

B.3. Distribution of population across habitat types.

The ICTRT recognized that maintaining spawner occupancy in a natural variety of habitat types would be another indirect means of supporting natural patterns of variation within a population. The ICTRT developed a simple risk index based on the proportional change in distribution across major habitat types (using EPA level IV ecoregions) within a population. The Lower Mainstem Snake River fall Chinook salmon population's spawning areas are distributed across five ecoregions. The Canyons and Dissected Uplands ecoregion contains the majority of spawning habitat for this population, followed by the Lower Clearwater Canyon. There has been some loss of spawning habitat due to inundation in the mainstem (Dissected Loess Uplands ecoregion); however, that ecoregion historically contained less than five percent of the total spawning habitat for the Lower Mainstem Snake River population. Therefore, the extant Lower Mainstem Snake River fall Chinook salmon population rates at **low risk** for distribution across habitat types.

B.4.a. Selective change in natural processes or selective impacts

Human activities at various life stages have the potential to result in substantial changes in phenotypes for populations. The magnitude of the longer-term response of a population to such change is determined by the heritability of the affected trait(s) and the strength or intensity of selection (see ICTRT 2007 for further discussion and relevant citations). Assessing the direct effects of selectivity on fitness within a population is very difficult, especially for 'wild' populations. The ICTRT developed an index for evaluating the relative risks imposed by selectivity across life histories resulting from the combined impacts of harvest, hatchery, habitat, and hydropower actions.

Hydropower system: Naturally produced Snake River fall Chinook salmon from all four occupied major spawning areas pass eight mainstem dams as both juveniles on their downstream outmigration and as adults on their spawning return.

Juvenile migration timing: It is likely that the system of hydroelectric dams and their operations imposed differentially higher mortalities on later migrating smolts than in the years leading up to, and immediately following, ESA listing. Actions have been taken to improve outmigration survivals, including elements targeting in-river conditions affecting a substantial portion of the later timed components. Ongoing studies of annual smolt migration timing and survivals indicated improvements in average survivals and a reduction in the potential for differential mortality across the run. Additional studies are underway or being analyzed that should further reduce uncertainties regarding differential impacts. Although results to date indicate that selective mortality on downstream migrants has been substantially reduced, there is still some uncertainty regarding the remaining effects. Heritability of this trait has not been assessed so we assume a moderate to low heritability. Therefore, the rated impact of the hydrosystem on this trait is **moderate risk.**

Adult migration timing: The relatively late Columbia River entry timing of fall Chinook salmon runs, including Snake River fall Chinook, means they are subjected to relatively high water temperatures and low flows in September and October. There are no direct indications that human actions have resulted in significant and consistent differential survival effects for a substantial component of the annual returns, resulting in a **low risk** rating for this trait.

Harvest: Harvest has the potential to produce selective pressure on migration timing, maturation timing and size-at-age. Snake River fall Chinook salmon are harvested by both ocean and in-river fisheries. No direct estimates are available of the degree of selective pressure caused by ocean harvest impacts on natural-origin Snake River fall Chinook salmon. However, ocean exploitation rates based on coded wire tag (CWT) results for sub-yearling releases of Lyons Ferry Hatchery fish are used as surrogates in fisheries management modeling (Chinook Technical Committee 2007).

Age-at-return: The primary potential for selective impacts in harvest on natural-origin Snake River fall Chinook salmon would be on maturation timing, reflected in the relative age composition of fish arriving on the spawning grounds. Age composition data collected at Lower

Granite Dam indicate that female Snake River fall Chinook salmon currently return primarily at age-4 and age-5. Male returns are skewed to younger ages, returning at age-2 through age-5. The immediate impact of differential harvest on the average age compositions can be calculated using the average harvest rates by age after accounting for both ocean and in-river fisheries. In the absence of harvest, the average age-at-return to the spawning grounds for females is predicted to be shifted upwards a relatively small amount, approximately 2 percent from 4.39 to 4.48 years. The largest shift in average age-at-return would be in male returns, which would be predicted to shift upwards approximately 8 percent from 3.30 to 3.58 years. The estimated shift in male age-at-return meets the ICTRT criteria for moderate selection intensity. Heritability of age-at-return is moderate, resulting in an age-at-return trait risk rating of **moderate**. It should be noted that the evolutionary response to selective harvest is uncertain and is likely to be countered or influenced by other selective forces (e.g., Hard et al. 2008; Riddle 1986).

Selection caused by non-random removals of fish for hatchery broodstock: Prior to 2003, the broodstock used for Snake River fall Chinook salmon hatchery programs were adult returns from previous program releases. The original broodstock was established in the 1980s and early 1990s through adult capture at lower Snake River dams (Burgert et al. 1995). Beginning with the 2003 return, natural-origin broodstock collected across the run by trapping at Lower Granite Dam have been included in the program (Milks et al. 2006). Given current removal levels and broodstocking protocols, selective intensity is assumed to be **negligible**.

Habitat: The primary changes in habitat conditions for this population are temperature and flow related. These changes have been assessed as impacts on production at the population aggregate or major spawning area level under the appropriate factors evaluated above (e.g., productivity, spatial structure, life history diversity, phenotypic diversity). The potential for selective mortality due to temperature and flow alternations associated with the management of the Hells Canyon Complex (mainstem Snake River) or Dworshak Dam (Clearwater River) was likely higher during the years leading up to, and immediately following, the ESA listing decision. Changes to operations, particularly for the Hells Canyon Complex, have generally stabilized conditions during spawning, incubation and rearing time windows. Therefore, actions impacting current spawning and rearing habitats of Snake River Fall Chinook salmon are considered to have **negligible** selective effects.

Other: Predation rates by both fish and birds on sub-yearling Chinook salmon have resulted in increased mortalities during the smolt outmigration. Northern pikeminnow, smallmouth bass and avian predators selectively target sub-yearling Chinook salmon relative to larger yearling migrants. However, size frequency comparisons of sub-yearlings consumed by predators with in-river sub-yearling migrants support assuming **negligible** size selective mortality (Poe et al. 1991; Zimmerman 1999; Fritts and Pearsons 2006).

Selective pressures on two trait components were currently rated at moderate risk for the Snake River Fall Chinook population. Applying the ICTRT guidelines assigning overall population risks associated with results in a **moderate risk** for selective effects.

Spatial Structure and Diversity Summary

The Lower Mainstem Snake River fall Chinook salmon population was rated at **low risk** for Goal A (allowing natural rates and levels of spatially mediated processes) and **moderate risk** for Goal B (maintaining natural levels of variation) resulting in an overall spatial structure and diversity rating of **Moderate Risk** (Table 4-6). The moderate risk rating was driven by changes in major life history patterns, shifts in phenotypic traits, and high levels of genetic homogeneity in samples from natural-origin returns. In addition, risk associated with indirect factors, specifically the high levels of hatchery spawners in natural spawning areas, and the potential for selective pressure imposed by current hydropower operations and cumulative harvest impacts contribute to the current rating level.

Table 4-6. Lower Mainstem Snake River fall Chinook salmon population spatial structure and diversity risk ratings. Overall rating determined as the highest risk among (1) spatial mechanism, (2) direct diversity mechanism, and (3) average across direct and indirect diversity mechanisms.

Metric	Risk Assessment Scores				
	Metric	Factor	Mechanism	Goal	Population
Major Spawning Areas: NUMBER	VL (2)	VL (2)	Low Risk (Mean = 1.33)	Low Risk (Mean = 1.33)	**Moderate Risk** **(Highest of Goal Risks = 0)**
Major Spawning Areas OCCUPIED	L (1)	L (1)			
Major Spawning Areas: GAPS	L (1)	L (1)			
Major Life History Patterns	L (1)	L(1)	Moderate (Highest of metrics=0)	Moderate Risk (Avg. of Mechanisms = 0)	
Phenotypic Patterns	L (1)	L(1)			
Genetic Diversity	M (0)	M (0)			
Art. Prop. OUT of ESU	M (0)	High (-1)	High Highest of metrics=-1)		
Art. Prop OUT of MPG	N/A				
Art.Prop From MPG	N/A				
Art Prop. From POPULATION	H (-1)				
ECOREGION DISTRIBUTION	L (1)	L (1)	L (1)		
SELECTIVE IMPACTS	M (0)	M (0)	M (0)		

4.2 Overall Population Risk Rating

Overall population viability for the Lower Mainstem Snake River fall Chinook salmon population is determined based on the combination of ratings for current abundance and productivity and combined spatial structure and diversity (Figure 4-11).

		Spatial Structure/Diversity Risk			
		Very Low	**Low**	**Moderate**	**High**
Abundance/ Productivity Risk	**Very Low** (<1%)	**HV**	**HV**	**V**	**M**
	Low (1-5%)	**V**	**V**	**V** **Lower Main. Snake**	**M**
	Moderate (6 – 25%)	**M**	**M**	**M**	**HR**
	High (>25%)	**HR**	**HR**	**HR**	**HR**

Figure 4-11. Lower Mainstem Snake River fall Chinook salmon population risk ratings integrated across the four viable salmonid population (VSP) metrics. ***Viability Key: HV – Highly Viable; V – Viable; M – Maintained; HR – High Risk; Green shaded cells – meets criteria for Highly Viable; Gray shaded cells – does not meet viability criteria (darkest cells are at greatest risk).***

The overall current risk rating for the Lower Mainstem Snake River fall Chinook salmon population is **viable**. All of the potential delisting options described in Section 3 would require the population to meet minimum requirements for Highly Viable (green-shaded combinations in Figure 4-11). Achieving the desired rating of Highly Viable will require at least an 80 percent certainty that the combination of abundance and productivity exceeds the 1 percent viability curve and that spatial structure/diversity is rated at low risk.

The current rating described above is based on evaluating current status against the criteria for the aggregate population spawning above Lower Granite Dam (e.g., the single population viability scenario described in Section 3). The current (2015) overall risk rating is based on a low risk rating for abundance/productivity and a moderate risk rating for spatial structure/ diversity. For abundance/productivity, the rating reflects ongoing uncertainty that recent increases in abundance can be sustained over the long run. The geometric mean natural-origin abundance for the most recent 10 years of annual spawner escapement estimates (2005-2014) is 6,418 fish. Using the ICTRT simple 20-year R/S method, the current point estimate of productivity for this population (1990-2009 brood years) is 1.5. The combination of these two estimates do not exceed the ICTRT Very Low risk (1% in 100 years) viability curve by a sufficient amount to meet the 80 percent confidence requirement called for in the recovery plan. Using the alternative approach of fitting stock-recruit functions to the 1991-2014 brood year data series results in the same conclusion: the Beverton Holt model including a PDO parameter was statistically the best fit. Although the parameter estimates differed from the simple averages, the probability that the 'true' underlying relationship exceeded the Very Low risk viability curve was similar and therefore did not meet the 80 percent probability requirement.

For spatial structure/diversity, the moderate risk rating was driven by changes in major life history patterns, shifts in phenotypic traits, and high levels of genetic homogeneity in samples from natural-origin returns. In particular, the rating reflects the relatively high proportion of within-population hatchery spawners and the lingering effects of previous high levels of out-of-ESU strays. In addition, the potential for selective pressure imposed by the combined current hydropower operations and cumulative harvest impacts contribute to the current rating level.

Because of the widespread distribution of hatchery returns across the major spawning areas within the population and the lack specific information supporting differential hatchery vs. natural spatial distributions, the population is currently not meeting the requirements for Highly Viable under the alternative single population scenario natural production emphasis area option. Under this variation on the single population scenario, one or more major spawning areas would need to be producing the bulk of natural-origin production with relatively low hatchery spawner proportions.

4.3 Gap between Current and Desired Viability Status

Under the viability criteria in Section 3 for delisting with a single population, the extant population must achieve a viability rating of Highly Viable (Very Low risk) with a high degree of certainty before the ESU may be delisted. Achieving an overall population risk rating of Very Low will require that the population demonstrate a very low risk rating for combined abundance and productivity along with at least a low risk rating for spatial structure and diversity.

Abundance/Productivity: To achieve highly viable status with a high degree of certainty requires a combination of recent geometric mean natural-origin spawner abundance and intrinsic productivity exceeding the 1 percent viability curve by a buffer reflecting the statistical uncertainty in the current estimates (uncertainty buffer). Viability Scenario B would require the combination of natural-origin abundance and productivity to exhibit an 80 percent or higher probability of exceeding the viability curve for a 1 percent risk of extinction over 100 years. Potential abundance and productivity metrics for the Natural Production Emphasis Area scenarios would depend on population-level pHOS and proportion of natural-origin broodstock (pNOB) at the time.

Given the information available in 2015, an increase in estimated productivity (or a decrease in the year-to-year variability associated with the estimate) would be required, assuming that natural-origin abundance of the single extant Snake River fall Chinook salmon population remains relatively high. An increase in productivity could occur with a further reduction in mortalities across life stages. Such an increase could be generated by actions such as a reduction in harvest impacts (particularly when natural-origin spawner return levels are below the minimum abundance threshold) and further improvements in juvenile survivals during downstream migration. It is also possible that survival improvements resulting from actions (e.g., more consistent flow-related conditions affecting spawning and rearing and increased passage survivals resulting from expanded spill programs) in recent years have increased productivity, but that increase is effectively masked as a result of the relatively high spawning levels in recent years. A third general possibility is that productivity levels may be decreasing over time as a result of negative impacts of chronically high hatchery proportions across natural spawning areas. Such a decrease would also be largely masked by the high annual spawning levels. Given the possibility of such an effect, it is possible that substantial reductions in the hatchery fractions in one or more major spawning areas could lead to increased natural productivity. The Recovery Strategy in Section 6 and Research, Monitoring, and Evaluation Section 7 of this plan include provisions for further addressing these uncertainties.

Spatial structure/diversity: To achieve highly viable status with a high degree of certainty for Scenario B, the spatial structure/diversity rating needs to be low risk. This status assessment used the ICTRT framework for evaluating population-level status in terms of spatial structure and diversity organized around two major goals: maintaining natural patterns for spatially mediated processes and maintaining natural levels of variation (ICTRT 2007). Based on our evaluation of an explicit series of factors associated with each goal, the current rating for spatial structure/diversity is moderate risk for the extant Lower Mainstem Snake River population.

Under the Natural Production Emphasis Area variation of the single population recovery scenario, achieving low risk for spatial structure/diversity would require that one or more major spawning areas produce a significant level of natural-origin spawners with low influence by hatchery-origin spawners relative to the other major spawning areas. At present (escapements through 2013), given the widespread distribution of hatchery releases and hatchery-origin returns across the major spawning areas within the population, and the lack of direct sampling of reach-specific spawner compositions, there is no indication of a strong differential distribution of hatchery returns among major spawning areas.

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5. Limiting Factors and Threats Assessment

NMFS generally describes the reasons for a species' decline in terms of limiting factors and threats. NMFS defines limiting factors as the biological and physical conditions that limit a species' viability, and defines threats as those human activities or natural processes that cause or contribute to the limiting factors. Threats may exist in the present or be likely to occur in the future. While the term "threats" carries a negative connotation, it does not necessarily mean that activities identified as threats are inherently undesirable. They are typically legitimate and necessary human activities that may have unintended negative consequences for fish populations. These activities have the potential to also be managed in a manner that minimizes or eliminates the negative impacts. As described in Section 2, there have been many significant improvements in management activities that affect limiting factors and survival of Snake River fall Chinook salmon since they were listed.

Snake River fall Chinook salmon threats and limiting factors operate across all stages of the life cycle. While each of these factors independently affects the viability of the ESU, they also have synergistic and cumulative effects throughout the ESU's life cycle. Achieving viability depends on concerted efforts to address all limiting factors and threats working together, not cancelling each other out, and adjusting over time as the ESU and ecological conditions change. Designing effective recovery strategies and actions requires understanding limiting factors and threats collectively, and also understanding the feasibility of managing activities to reduce negative impacts. Effective recovery also requires agility to adjust actions and priorities as new information on threats, both individually and synergistically, emerges.

Limiting Factors and Threats Contributing to Listing

As discussed in Section 2, many human activities contributed to Snake River fall Chinook salmon's threatened status. Human activities that have influenced the species are summarized in Table 5-1. NMFS status reviews identify factors that led to the steady and severe decline in abundance of Snake River fall Chinook salmon, and to the original listing decision and subsequent affirmations of the species' threatened status (NMFS 1991, 1999a, 2005a; Waples et al. 1991; Busby 1999; Good et al. 2005).

Factors contributing to the listing decisions include: loss of primary spawning and rearing areas upstream of the Hells Canyon Complex, the effects of the FCRPS in the Snake River downstream of Hells Canyon and in the mainstem Columbia River through the estuary, the increase in nonlocal hatchery contribution to adult escapement over Lower Granite Dam and possibility of significant introgression of outside stocks, and the relatively high aggregate harvest impacts by ocean and in-river fisheries (Good et al. 2005). The 1991 status review (Waples et al. 1991) and most recent status reviews (ICTRT 2010 and NMFS 2011a) also stated concerns about the effects on natural-origin productivity and diversity from hatchery operations and increasing proportions of hatchery-origin fish on the spawning grounds.

Since the ESA listing, combined management actions implemented by different entities have addressed several of the factors that led to the listing decision and are helping improve the species' abundance and viability. While historical spawning and rearing habitats upstream of Hells Canyon Dam remain inaccessible and uninhabitable, actions have boosted adult and juvenile survival of the single extant population through the FCRPS hydropower system, reduced losses to harvest, lowered predation rates, improved habitats, reduced straying of out-of-ESU hatchery fish, and increased natural production using hatchery supplementation. Consequently, many more fall Chinook salmon now return to the Snake River than in the 1990s when the species was listed.

This section discusses the current status of the factors that led to the species' ESA listing. It also describes other concerns related to the five ESA section 4(a)(1) listing factors that now impede Snake River fall Chinook salmon recovery.

Table 5-1. History of Activities Contributing to Snake River Fall Chinook Salmon Decline and Recovery.

Date	Human Activities Affecting Snake River Fall Chinook Salmon	Habitat and Harvest Status	Estimated Fish Abundance
Late 1800s	Mainstem and tributary habitat degradation begins due to mining, timber harvest, agriculture, livestock production, and other activities.		Annual return of 408,500 to 536,180 adult fall Chinook salmon to Snake River mouth
1890s	Commercial harvest of Columbia River salmon turns from spring and summer Chinook to fall Chinook	Harvest peaks near 80% of returning fall Chinook adults	Run begins decline
1901	Swan Falls Dam constructed on Snake River (RM 457.7)	Access blocked to 157 miles mainstem	Substantial reduced abundance and distribution in middle mainstem Snake River
1902	First full-scale hatchery constructed at Swan Falls; operated 1902-1909		
1904-1925	Harvest regulations on lower Columbia. Commercial fisheries move above Celilo Falls in 1904. Fish wheels outlawed: Oregon (1928) and Washington (1935).		Run continues decline
1927	Lewiston Dam constructed on Clearwater River (RM 6)	Access blocked to Clearwater R. 1927-73	
1938-1947	Bonneville Dam completed in 1938 on Columbia River (RM 146)	Harvest rate on returning fall Chinook adults in Columbia River at 64.1% to 80.2%	Annual return of 89,800 to 197,290 SR fall Chinook salmon to Columbia River mouth; 47,600 adults highest annual return to Snake River
1950s	McNary Dam completed in 1953 on Columbia River (RM 292) The Dalles Dam completed in 1957 on Columbia River (RM 191.5)		29,000 adults average annual return
1958-1967	Hells Canyon Complex dams constructed on middle Snake River: Brownlee (1958), Oxbow (1961) and Hells Canyon (1967) (RM 285, 273, and 247 respectively)	Access blocked to 210 miles of habitat.	Fall Chinook salmon population in Middle Snake River is extirpated
1960-1975	Four dams constructed on lower Snake River: Ice Harbor (1961), Lower Monumental (1969), Little Goose (1970), Lower Granite (1975)	Dams inundate 135 more miles of mainstem; 83% of mainstem habitat lost.	Abundance declines further.
1964-1968	John Day Dam completed in 1968 on Columbia River (RM 215.6)		12,720 adults average annual return to Snake River
1969-1976	Lower Snake River Compensation Plan starts compensation for losses (1976).		2,814 adults return to Snake River in 1974; 2,558 return in 1975
1975-1980	Transportation of juvenile fall Chinook past lower Snake River dams begins late 1970s.		610 adults average annual return, reaches low or 100 adults in 1978
1980s	Hatcheries begin to play major role in production of Snake River fall Chinook salmon. Lyons Ferry Hatchery begins fall Chinook production in 1984.		
Late1980s to mid-90s	Hatchery production increases. Agreements reduce harvest impact from ocean/Columbia River fisheries.	Total exploitation rate on run averages 62% (1988-94)	100 +/- natural-origin adults average annual return. Stray out-of-ESU hatchery fish major risk.
1990			350 adults return, includes 78 natural-origin fish
1992	Snake River fall Chinook salmon listed under the ESA as threatened.		
1993	Corps of Engineers begins drafting Dworshak Dam to enhance juvenile migration.		
1995	Fall Chinook Acclimation Program implemented.		
1996-2001	Actions in 1995 FCRPS BiOp implemented in 1996. Improve dam passage/operations for migration.		2,164 average annual adult return to Snake River; includes 1,055 natural-origin fish (1997-2001)
2000-02	IPC Hatchery Program begins in 2000. Nez Perce Tribal Hatchery program begins in 2002. Together, four hatchery programs release up to 5.5 million fish.		Abundance increases.
2000-2007	Actions in 2000 FCRPS BiOp implemented. Improve dam passage/ operations for migration (include increased summer spill from 2005 Court Order.)		Abundance increases.
2003-08	Snake River fall Chinook salmon ESA listing reaffirmed (2005). Agreements further reduce harvest impact from ocean/Columbia River fisheries.	Total exploitation rate on run averages 31% (2003-2010)	11,321 average annual adult return to Snake River; includes 2,291 natural-origin fish
2008-2014	Actions in 2008 FCRPS BiOp implemented to improve dam passage/ operations for migration. Include increased summer spill and final installations of surface passage routes (spillway weirs, sluiceways, corner collectors) at all mainstem dams. Snake River fall Chinook salmon ESA listing reaffirmed (2011).		50,000+ average annual adult return to Snake River; includes 5,942 natural-origin annual return (2005-2013)

Section Organization

This section discusses the different threats and limiting factors that affect Snake River fall Chinook salmon throughout their life cycle. Sections are arranged by threat category (habitat, hydropower, harvest, etc.) and are organized to coincide with the five ESA section 4(a)(1) listing factors: A) destruction, modification, or curtailment of habitat or range; B) over-utilization for commercial, recreational, scientific or educational purposes; C) disease or predation; D) inadequacy of existing regulatory mechanisms; and E) other natural or human-made factors. Section 3.3 of this plan overviews the section 4(a)(1) listing factors and the associated listing factor (threats) criteria.

The sections for each threat category provide detailed discussions of the threats and factors that affect Snake River fall Chinook salmon at different stages in their life cycle, and then identify and summarize the threats and priority limiting factors. These sections reflect results to date from RM&E activities and various consultations.

- Section 5.1, Hydropower and Habitat, discusses the effects from mainstem hydropower and habitat, which are the two primary threat categories responsible for the present or threatened destruction, modification, or curtailment of the species' habitat or range (ESA Section 4(a)(1) listing factor A). We discuss these two threat categories together because Snake River fall Chinook salmon spawn primarily in the mainstem Snake River where habitat conditions are greatly affected by hydropower development and operations. The section is organized accordingly, providing discussions of hydropower and habitat limiting factors and threats through the historical Snake River fall Chinook salmon life cycle: the historical middle mainstem Snake River upstream of Hells Canyon Complex (Section 5.1.1); the mainstem Snake River from below Hells Canyon Dam to the Salmon River (Section 5.1.2); the lower mainstem Snake River from the mouth of Salmon River to Lower Granite Dam reservoir (Section 5.1.3); the mainstem Lower Snake and Columbia Rivers migration corridor with FCRPS reservoirs and dams (Section 5.1.4); tributary major spawning habitat areas (Section 5.1.5); and the estuary, plume, and ocean (Section 5.1.6). These reach-level discussions of habitat and hydropower factors are followed by a discussion on current and potential influences from climate change on habitat conditions in these areas (Section 5.1.7), and a discussion of the effects of hydropower and habitat on species viability (Section 5.1.8).
- Section 5.2, Harvest, identifies threats and limiting factors related to fisheries management. This threat category contributes to over-utilization for commercial, recreational, scientific, or educational purposes (ESA section 4(a)(1) listing factor B).
- Section 5.3, Predation, Competition, and Other Ecological Interactions discusses threats and limiting factors related to predation by birds, marine mammals, and non-native fish. It also describes effects from other ecological interactions, including competition with hatchery fish and other species for spawning habitat and changes in food web (ESA section 4(a)(1) listing factors C and E).

- Sections 5.4, Hatcheries, describes the effects of hatchery operations and programs on natural-origin fall Chinook salmon. This threat category contributes to human-made factors that affect the species' continued existence (ESA section 4(a)(1) listing factor E).
- Section 5.5, Toxic Pollutants, discusses threats and limiting factors related to exposure to chemical contaminants from municipal, agricultural, industrial, and urban land uses. This threat category is also a contributing human-made factor that affects the species' continued existence (ESA section 4(a)(1) listing factor E).

Our understanding of the risks posed by the various threats and limiting factors for Snake River fall Chinook salmon continues to improve. Information gained through ongoing RM&E, and refined through use of life cycle models and other tools, should increase our understanding of how and where the different factors affect the species, as well as each factor's overall importance in relation to other threats across the species' life cycle or at a specific life stage. Sections 6.2 and 6.4 describe our adaptive approach for gaining new information on the effects of different threats on the survival and long-term viability of natural-origin Snake River fall Chinook salmon, and for integrating this information into recovery efforts across the species' life cycle.

5.1 Hydropower and Habitat

The loss of habitat due to hydropower project development is extensive: Snake River fall Chinook salmon once spawned in the mainstem of the Snake River from its confluence with the Columbia River upstream to Shoshone Falls (RM 615). While hydropower projects on the mainstem Snake River blocked access to, or inundated, most of this area in the past century, the spawning grounds between Huntington (RM 328) and Auger Falls (RM 607) were historically the most important for the species. In comparison, only limited spawning activity occurred downstream of RM 273, about one mile below the present location of Oxbow Dam (Waples et al. 1991) and where the majority of the species' spawning now occurs. In addition, conditions in the mainstem Columbia and Snake River migration corridor have also changed. Today Snake River fall Chinook salmon must pass eight major hydropower dams - Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams on the lower Snake River and McNary, John Day, The Dalles, and Bonneville Dams on the Columbia River - as they travel to the ocean, and then again as they return to spawn. Hydro system modifications to the mainstem habitat are significant; the mainstem migration corridor runs through contiguous reservoirs formed by the system of dams. Habitat changes have also occurred in the estuary and plume.

Together, these various changes shape the viability of Snake River fall Chinook salmon by influencing abundance, productivity, spatial structure, and diversity. The most dramatic effect of the current hydropower system on Snake River fall Chinook salmon is blocked access to important historical production areas. Below these blocked areas, mainstem hydropower operations continue to affect conditions for spawning, rearing, and migration. In fact, as discussed previously, the loss of primary spawning and rearing areas upstream of the Hells

Canyon Complex and effects of mainstem hydropower from Hells Canyon through the estuary were two of the main factors leading to the decline in Snake River fall Chinook abundance and the eventual ESA listing of the species as threatened.

The following sections discuss the hydropower and habitat-related conditions that affect Snake River fall Chinook salmon viability throughout their life cycle. The discussion begins with a short description of the historical habitats that once supported Snake River fall Chinook salmon. This historical perspective is crucial for understanding current threats and factors responsible for the species' decline and ESA listing. Reach-level discussions of the specific effects of current hydro operations and other threats on Snake River fall Chinook salmon habitat follow the summary of historical conditions. The reach-level discussion begins with the historical spawning and rearing habitat upstream of Hells Canyon Dam, then moves to the lower mainstem Snake River to Lower Granite Dam, followed by the mainstem migration corridor through FCRPS reservoirs and dams on the Lower Snake and Columbia Rivers, and finally through the estuary, plume, and ocean. The reach-level discussions also identify the primary related threats and priority limiting factors within a particular reach. These reach-level discussions are followed by a discussion on the potential effects of climate change on Snake River fall Chinook salmon. The information presented in this section was used to identify site-specific actions needed to recover the species. It will inform future analysis of Snake River fall Chinook salmon status under ESA section 4(a)(1) listing factors A and D.

Historical Conditions

Historically, most fall Chinook salmon returning to the Snake River traveled into the Middle Snake River reach to spawn (Figure 5-1). Flows in this reach, supplemented by spring water from the Eastern Snake Plain Aquifer, created uniquely supportive conditions for spawning, egg incubation and early rearing of fall Chinook salmon. The springs releases stretched from Shoshone Falls (RM 615) to Bancroft Springs (RM 552.8), historically contributing about 4,000 cfs of flow at an average temperature of around 15.5 °C to the river reach between Milner Dam and Bancroft Springs (Stearns 1936; Connor et al. 2015; Chandler 2015). The springs influenced water temperatures in the Middle Snake River downstream from Auger Falls, diminishing between the mouths of the Boise and Burnt Rivers. Evermann (1896), an ichthyologist with the U.S. Fish Commission, described Millet Island as "the largest and most important salmon spawning ground of which we know in the Snake River". The island sits well within the influence of the aquifer. Evermann also noted substantial spawning between Millet Island and Swan Falls. The reach stretching downstream of Swan Falls Dam to the mouth of the Burnt River and near the town of Marsing, Idaho (RM 425), was also highly productive in terms of redd capacity and juvenile rearing capacity (Dauble et al. 2003). Further, fall Chinook salmon historically had access to the lower portions of nine major tributaries that joined the Snake River in this reach: Salmon Falls Creek and the Owyhee and Bruneau Rivers, which originated in northern Nevada; the Boise, Payette, and Weiser Rivers originating in central Idaho; and the Malheur, Burnt, and Powder Rivers originating in eastern Oregon. The significance of these rivers to fall Chinook salmon production is not known, as they were impacted early on from mining and agricultural activities, but the tributaries were likely of less importance to the ESU than the mainstream spawning areas.

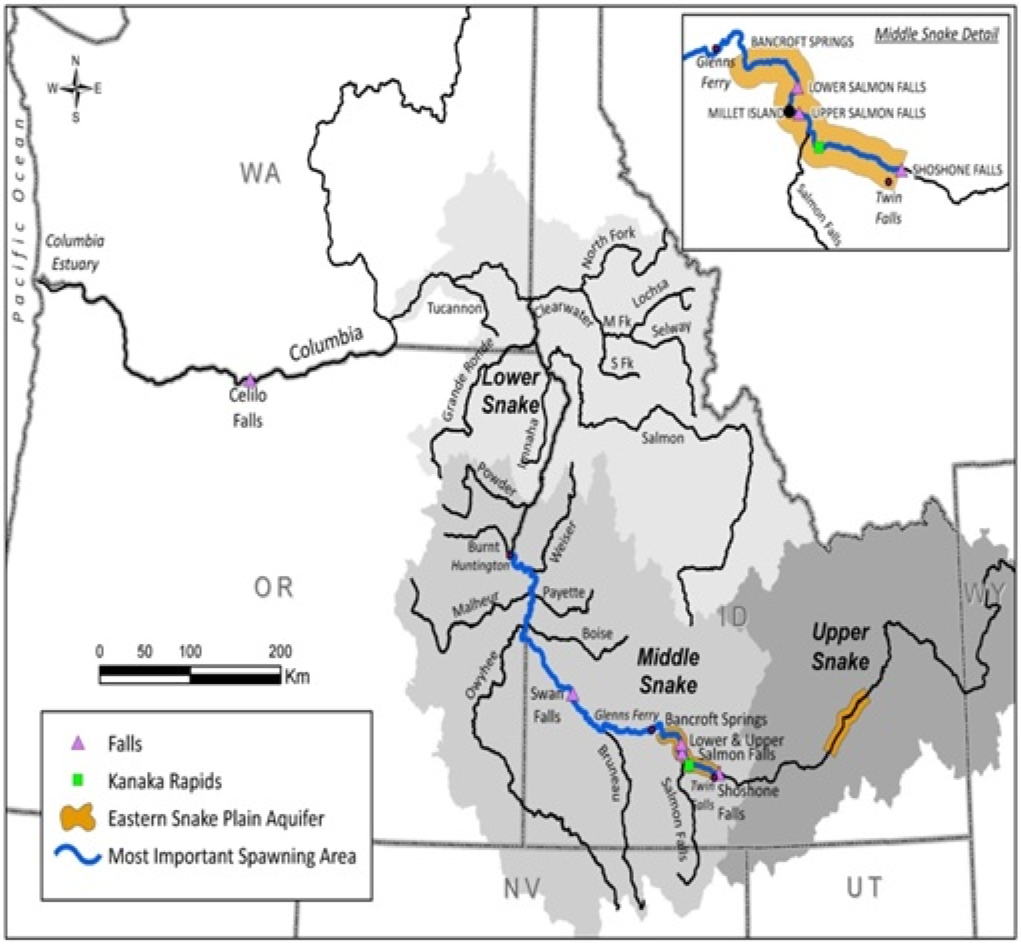

Figure 5-1. Historically imporant spawning areas for Snake River fall Chinook salmon (Connor et al. 2015).

Redd surveys conducted between 1947 and 1952, after Swan Falls Dam construction but before the Hells Canyon Complex construction, support claims that the middle mainstem Snake River provided the core fall Chinook salmon spawning habitat after completion of Swan Falls Dam (Zimmer 1950). The Zimmer study determined that about 95 percent of the spawning occurred upstream of the town of Marsing and about 5 percent occurred downstream of Marsing to the confluence of the Boise River. Very few observations of redds were made downstream of the Boise River confluence or in the lower portions of the larger tributaries (Zimmer 1950; Chandler 2015).

Historically, areas of the mainstem Snake River from the confluence of the Boise and Owyhee Rivers and downstream through Hells Canyon provided less productive habitat conditions. Water temperatures in this reach of the mainstem Snake River were significantly influenced during the incubation and rearing period by colder tributary streams, first by contributions from the Boise and Owyhee Rivers, and then from inflow from the Payette, Weiser, Malheur, and other rivers. The confined river channel, steep hydraulic gradient, and lesser abundance of alluvial features in the Hells Canyon area further restricted spawning and incubation by fall Chinook salmon in this relatively cold environment. Without the influence of the aquifer observed upstream in the middle Snake River, the river reach froze over heavily during the fall Chinook salmon incubation period in some years (Dauble and Giest 2000; Connor et al. 2015). The geomorphologic setting and winter climate became somewhat more conducive for fall Chinook salmon production as the river progressed downstream through the lower 168-mile stretch of the lower Snake River. Here, the channel elevation ranges from 1,128 to 2,680 feet above sea level, compared to elevations that range from 2,680 to 5,761 feet above sea level in Hells Canyon (Dauble and Geist 2000). Nevertheless, potential spawning and rearing conditions in the lower Snake River basin's arid high desert environment remained challenging. Water temperature varied little throughout the day, became very cold in the winter during incubation, and warm enough during summer to preclude summer rearing or cause reduced growth and survival of subyearling Chinook salmon that did not migrate seaward (Connor et al. 2015).

The different reaches of historical habitat that supported fall Chinook salmon fostered phenotypic diversity in spawn timing, rearing, and initial seaward migration as temperature varied among the rivers (Connor et al. 2015). Fall Chinook salmon would have emerged earliest in the aquifer-fed spawning areas of the middle mainstem Snake River, which fostered rapid incubation as well as growth. The spring inflow from the aquifer would have comprised an estimated 31 percent of the flow volume in the middle mainstem Snake River down to Bancroft Springs. Mean estimated temperature at Bancroft Springs during incubation fell from a high of 11.9 °C during the last week of October to a low of 9.1 °C in January and increased to 9.5 °C by mid-February (Connor et al. 2015). Consequently, emergence in the Middle Snake River upstream from the present site of C.J. Strike Reservoir occurred earliest, with a median estimated date of March 15. The historical timing of emergence in the Marsing area was approximately 25 days later than in the upper Middle Snake River, with a median date of April 10. Emergence in the Weiser and the upper Hells Canyon reaches occurred a little later, with median dates of April 19 and 21, respectively. Fry emerged in the lower mainstem Snake River reach later still, with a median date of April 30 (Chandler et al. 2003). Fall Chinook salmon fry emerged the latest in the much colder Salmon River, median estimated emergence date of June 4, and in the Snake River at the present site of Oxbow Reservoir, median estimated emergence date of May 23 (Figure 5-2). Connor (2001) also reported a late estimated emergence date for the lower Clearwater River of June 17. Fall Chinook salmon emergence was completed by April 13 in the upper Snake River, by May 2 in the Marsing Reach, by May 18 in the upper mainstem Snake River reach, and by June 4 in the pre-Hells Canyon Complex Oxbow reach (Chandler et al. 2003).

The warmer winter and early spring habitat conditions that fostered early emergence also allowed for a faster progression through other life stages that precede downstream dispersal from natal riverine habitat. The warmer reaches likely produced more food for juvenile Chinook salmon than did colder reaches, and early-emerging juveniles were able to feed, rear, and grow in their productive natal areas and then outmigrate before summer water temperatures rose to potentially lethal levels. In comparison, the later emergence times for fall Chinook salmon produced from cold habitats, such as in the Clearwater River and Hells Canyon reach of the Snake River, did not allow much time for juveniles to rear and grow before they needed to migrate to avoid rising summer water temperatures. The young fall Chinook salmon likely did not thrive when exposed to temperatures that remained above 20 °C throughout the day for a month or more each summer in the lower portions of the Middle Snake River, the Lower Snake River and its tributaries, as well as the Columbia River downstream to the point of ocean influence (Connor et al. 2015). Thus, the viability of fall Chinook salmon in these spawning areas likely depended on localized traits, such as spawning from late September to early October, and rapid outmigration at a smaller size soon after emergence, to help compensate for the cooler incubation temperatures (Connor et al. 2015).

The predominant Age-0 life history of Snake River fall Chinook salmon allowed the vast majority of the subyearlings to migrate seaward before mid-summer. The different populations of outmigrants continued to grow during their seaward journey, supported by unrestricted access to pristine, abundant, and diverse habitats along the Columbia River and estuary. The juveniles had the opportunity to either enter the Pacific Ocean as subyearlings, or overwinter in fresh or brackish water and enter the ocean as yearlings.

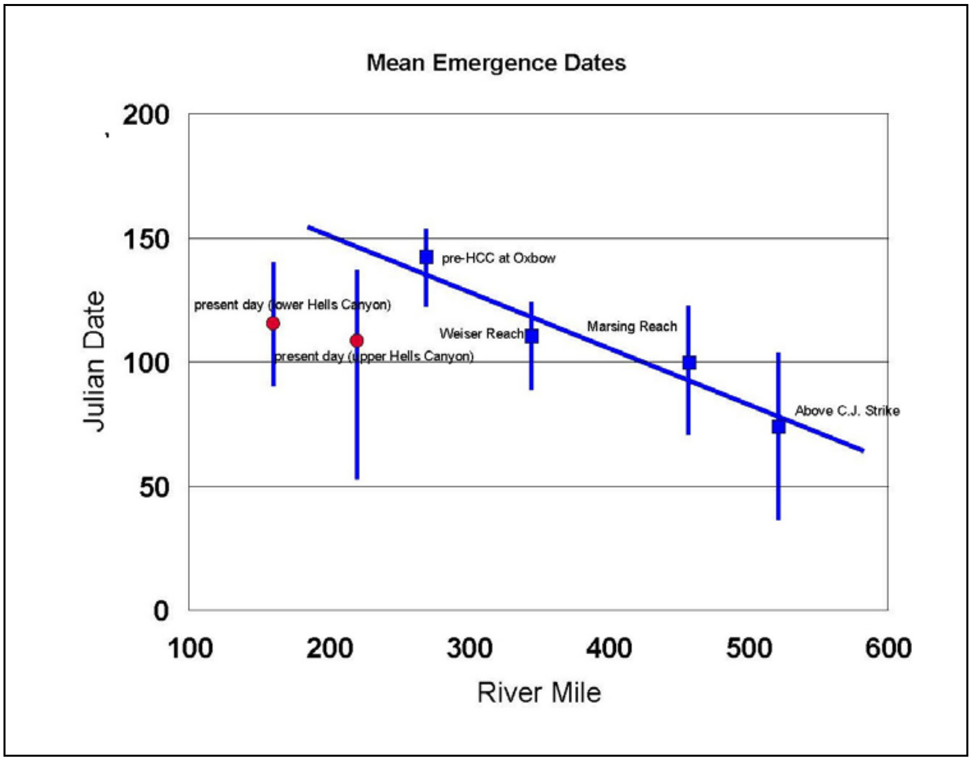

Figure 5-2. Estimated mean emergence dates of juvenile fall Chinook salmon representing the correlation between river mile and emergence day during the pre-Hells Canyon Complex era (blue quares and trend lines) and the post-Hells Canyon Complex era (red circles). Vertical bars represent the range of emergence estimated for individual year for each of the data sets (Chandler et al. 2003).

Habitat conditions today in the mainstem Snake and Columbia Rivers are much different than they were historically. Sections 5.1.1 through 5.1.6 discuss the habitat conditions, threats, and priority limiting factors at different stages in the Snake River fall Chinook salmon life cycle. Section 5.1.7 describes how climate change could further influence the species. Section 5.1.8 summarizes the effects of hydropower development and operations on species viability in each of the different reaches that historically supported fall Chinook salmon.

5.1.1 Historical Habitat for Middle Snake River Population Upstream of Hells Canyon Complex

Historical accounts confirm that this reach was once the primary production ground for Snake River fall Chinook salmon. As discussed previously, fall Chinook salmon returned to spawn in the Middle Snake River below Shoshone Falls, primarily within the area where the aquifer-fed thermal regime fostered good conditions during spawning, egg incubation, and emergence.

Today, although successful reintroduction of a fall Chinook salmon population above the Hells Canyon Complex may improve the probability of persistence of the ESU, the mainstem habitat upstream of the Hells Canyon Complex is presently too degraded to support anadromous fish. Water quality factors include excessive nutrients, excessive algal growth, and anoxic or hypoxic conditions in spawning gravels. Other factors affecting the quality of this habitat include altered flows, inundated habitat, and increased sediment loads. Substantial information on water quality upstream of the Hells Canyon Complex is available in the Idaho Power Company's application to FERC for relicensing (IPC 2003).

In its Comments and Preliminary Recommended Terms and Conditions for the Hells Canyon Hydroelectric Project, NMFS recommended additional funding to accelerate habitat restoration in the upstream mainstem (NMFS 2006b)[17]. NMFS has not, however, used its fishway authority under section 18 of the Federal Power Act to require fish passage at any of Idaho Power Company's dams. This is because first, the poor water quality in the Snake River upstream of the Hells Canyon Complex would, at present, prevent the successful reintroduction of naturally producing fall Chinook, and second, because insufficient information is available to identify an alternative fish passage method for juveniles that has a high likelihood of success. NMFS recommended that future studies to inform decisions regarding fish passage be required as part of the new license conditions (NMFS 2006b).

The following subsections review limiting factors and threats in the historically accessible mainstem upstream of the Hells Canyon Complex in more detail.

5.1.1.1 Blocked Access/Inundated Areas

As described in Section 2 of this plan, the Hells Canyon Complex of dams and reservoirs and other middle Snake River dams and reservoirs blocks access to, or inundates, the historically most productive spawning areas of the Snake River, a total of 367 mainstem river miles.

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[17] FERC must consult with NMFS regarding the effects of the proposed license action on essential fish habitat (EFH), as required by the Magnuson-Stevens Fishery Conservation Act (MSA), and on listed species under the Endangered Species Act (ESA).

The impact of lost upstream habitat cannot be overstated. Historically accessible spawning areas above Hells Canyon were very productive; first, because of geomorphology; they contained more of the wide alluvial floodplains with unconsolidated sediment, bars and islands, such as the historic Middle Snake River reach, that are favorable to spawning (Dauble et al. 2003) than do the current areas. These areas were also more productive because of inflowing springs, such as Thousand Springs, near Hagerman, Idaho, which moderated seasonal water temperature changes. Compared to reaches of the Lower Snake River, winter temperatures in the reaches downstream of the springs area are substantially warmer during the winter and cooler during summer; conditions that would be expected to provide substantial survival benefits to pre-spawning adults, incubating eggs, fry, and rearing juveniles. The area is now altered by several hydroelectric projects (see Table 2-1 and Figure 2-2).

5.1.1.2 Altered Life History Strategies

An earlier fry emergence, several weeks earlier in the warmer upstream incubation areas than in cooler downstream areas, would have influenced their entire life history, including downstream migration. The earlier emerging fish from the Middle Snake River reach would have progressed earlier than in areas downstream of direct aquifer influence, particularly compared to the historical lower Snake Hells Canyon reach (NMFS 2006b).

This effect is corroborated by the work of Krcma and Raleigh (1970) and Mains and Smith (1964). Krcma and Raleigh’s (1970) data indicate that about 98 percent of the Snake River fall Chinook salmon juveniles from the Marsing Reach attained parr size and started emigrating by the end of May (1962 and 1963). In comparison, today, only about 50 percent of the fish rearing in the lower Snake Hells Canyon reach have reached parr size and started to emigrate by the end of May (Connor et al. 2002). Mains and Smith (1964) observed that downstream migration of subyearling fall Chinook salmon was largely completed at RM 82 by mid-June, compared to mid- to late July since 2002, a difference of 2 to 4 weeks.

The critical difference here is early emergence. Historically, the early emergence timing gave fall Chinook salmon from the Middle Snake River a unique advantage. Fall Chinook salmon smolts migrating from historically accessible spawning areas in the Middle Snake River experienced lower water temperatures, higher turbidity (which reduces predation), and higher flows and thus, higher survival levels compared to subyearlings emigrating from historical and contemporary cooler spawning areas (Connor et al. 1998; Connor et al. 2003b; Smith et al. 2003; as cited in NMFS 2006b).

5.1.1.3 Degraded Water Quality

Degraded water quality starts far upstream of the Hells Canyon reach, and even upstream of Shoshone Falls, the upstream historical limit for anadromous fish. Development of the Snake River plain for irrigated and dryland agriculture, livestock grazing, confined animal-feeding operations (Buhidar et al. 1999), mining, timber harvest, and urban and residential settlements has been underway for two centuries. Through the first half of the 20th century, the Bureau of Reclamation and some private companies began a series of public works projects to provide irrigation to Idaho farmlands on the Snake River plain. Many storage reservoirs for irrigation water supply were constructed in the upper Snake River basin (upstream of Shoshone Falls) and in many of the tributaries to the Snake River, and several mainstem Snake River dams downstream of Shoshone Falls. Major storage reservoirs in the upper Snake River basin included: Jackson Lake (1916), Palisades (1957), and American Falls (1925). Milner Reservoir (1905) was not a storage reservoir, but rather was constructed to divert the Snake River into large canals to distribute irrigation water to southern Idaho. Downstream of Shoshone Falls, Swan Falls Dam was the first mainstem Snake River dam constructed to provide electricity for mining activity in the Owyhee Mountains. It was not a storage project, but operated as run-of-the river. Several other private mainstem dams upstream of Swan Falls soon followed, again operated as run-of-the river with relatively little storage. The primary purpose of these mainstem dams was to provide electricity. Another phase of dam construction began in the 1950s, including construction of the Hells Canyon Complex.

Agricultural runoff into the Snake River and its tributaries returns some of the irrigation water, which now carries additional pollutants from activities on land. For example, Milner Dam, upstream of Shoshone Falls, diverts most or all of the Snake River for agricultural irrigation. A percentage of this diverted water then returns to the Snake River through agricultural runoff or as spring flows that are supplemented by injection wells designed for that purpose (Chandler et al. 2001). Habitat in this area is now severely degraded, with high nutrient inputs and significantly reduced spring freshet flows compared with predevelopment times (Chandler et al. 2001). In short, a host of anthropogenic factors have resulted in extremely large nutrient loads in the mainstem Snake River that result in nuisance algal growth and anoxic conditions (and toxic hydrogen sulfide) in the spawning gravels. These conditions would not support incubating fall Chinook salmon through emergence (Groves and Chandler 2005).

Currently, many segments of the Snake River above the Hells Canyon Complex, with associated tributaries, are listed in the state of Idaho’s Integrated Water Quality Report to the Environmental Protection Agency as impaired waters. The river segments that have been assessed show water quality problems related to sediments, nutrients, pH, bacteria, dissolved oxygen levels, temperature, and flow alterations. Total Maximum Daily Loads (TMDLs) have been completed to address many of the water quality issues and other TMDLs are scheduled to be completed in the future. Elevated water temperatures above the cold water aquatic life temperature standard are typically observed in July and August (IDEQ 2014); however, this is not likely at a time when fall Chinook salmon yearlings would have been present in the reach.

High concentrations of organic matter, along with chlorophyll *a* and nutrients, contributed by upstream tributaries into the Snake River and accumulated in sediment in low-flow years (Myers et al. 2003) create eutrophic conditions in Brownlee Reservoir. Snake River chlorophyll *a* concentrations measured at the headwaters of Brownlee Reservoir can be five times higher than concentrations measured 120 miles upstream at Swan Falls Dam (Worth 1994). The nutrient loads, primarily phosphorous and nitrogen compounds, fuel the explosive growth of algae (both attached and free-floating) in the Snake River. The nutrients and algae settle out in the transition zone of Brownlee Reservoir where they are biologically processed (oxidized). The biological processing of these large quantities of algae results in increasingly hypoxic (low oxygen) conditions within the lower strata of Brownlee Reservoir (NMFS 2006b, Myers et al. 2003). These hypoxic waters are eventually drawn into the turbines at Brownlee Dam during late summer and fall and are exported downstream through the other two projects. Dissolved oxygen levels in Oxbow and Hells Canyon reservoirs usually are approximately the same as in Brownlee (Myers et al. 2003). The effects of these conditions downstream of Hells Canyon Dam are discussed in Section 5.1.2.1.

Flows that exceed power house capacity (30,000 cfs) or, more rarely, lack of electrical demand, periodically require hydrosystem operators to release water over the spillway bays at the three Hells Canyon Complex dams. Flows exceed the 30,000 cfs threshold for several days in approximately 25-35 percent of years. These high flows occur most often from March to June; less frequently, high flows due to water releases also occur from December to February and in July (FERC 2007). Spilled water entrains atmospheric gases into the water column, resulting in supersaturated levels of total dissolved gases (TDG). The effect of elevated TDG levels downstream of Hells Canyon Dam are discussed in Section 5.1.2.1.

5.1.1.4 Altered Flows

Current flows above the Hells Canyon Complex are significantly altered by agricultural storage and irrigation. However, historically, low summer flows were probably not an issue because, as cited earlier, juvenile fall Chinook salmon had already migrated out of the system by mid-May. Flows are also altered by hydroelectric power plants operations, which can dramatically alter river flows as a result of load-following. Outflows frequently fluctuate significantly on a daily basis. Load-following operations may strand or entrap rearing juvenile fall Chinook salmon in shallow water rearing areas.

5.1.1.5 Summary of Threats and Priority Limiting Factors in Historical Habitat above Hells Canyon Complex

Threat: Hydropower projects.

Related priority limiting factors: Fish passage and migration timing, blocked and inundated habitat, total dissolved gas levels below Brownlee and Oxbow Dams.

Threat: Reservoirs – water storage (including those in the Upper Snake River basin above Shoshone Falls), and hydroelectric facilities.

Related priority limiting factors: Altered hydrologic regime, leading to disrupted hyporheic conditions, reduced river flow, and reduced water velocities and inundated habitat within the reservoir environment.

Threat: Load-following.

Related priority limiting factors: Potential stranding and entrapment of juveniles.

Threat(s): Land uses that alter river habitat: irrigated and dryland agriculture, livestock grazing, confined animal-feeding operations, mining, timber harvest, and urban and residential settlements.

Related priority limiting factors: Excessive nutrients, sedimentation, toxic pollutants, low dissolved oxygen in water and spawning gravels, and altered flows.

5.1.2 Hydropower and Lower Mainstem Snake River Habitat from below Hells Canyon Dam to the Salmon River (Upper Mainstem Snake River MaSA)

The Upper Mainstem Snake River reach (RM 247 to 188) includes the Snake River from below Hells Canyon Dam to immediately upstream of the mouth of the Salmon River. Here the river is rapid flowing and narrow, characterized by high, steep canyon walls and stretches of white water. The flow and volume of this reach is dominated by the outflow of the Hells Canyon Complex reservoirs, especially Brownlee reservoir. The mainstem reach serves as the major production area for Snake River fall Chinook salmon in the Upper Mainstem Snake River MaSA. The lower reaches of two tributaries, the lower Imnaha River and Salmon River (discussed in Sections 5.1.5.4 and 5.1.5.5), support low levels of fall Chinook salmon spawning in the MaSA.

While the historically cold environment in this reach was not a high production area for fall Chinook salmon, the thermal environment is warmer today during the incubation period, allowing for earlier emergence. The reach is now one of the two main spawning areas for Snake River fall Chinook salmon and is the major spawning area with the highest proportion of spawning of the major spawning areas (See Figure 2-5). The altered thermal regime as a result of the Hells Canyon Complex has increased the productivity of this reach, although other threats associated with operation of the Hells Canyon Complex contribute to other factors that limit Snake River fall Chinook salmon viability in this reach. For example, long-term fluctuations in flow have altered riparian vegetation and daily fluctuations can result in stranding fry in the shallows.

5.1.2.1 Water Quality

Water quality changes for fall Chinook salmon below Hells Canyon Dam include altered thermal regime, low dissolved oxygen, high total dissolved gas, and changes in sediment processes and turbidity.

Altered Thermal Regime

The current thermal regime in the reach is warmer in the late summer, fall, and early winter months than it was historically, and cooler in the late winter and spring months (Groves and Chandler 2003; Connor et al. 2015). Consequently, the reach does not freeze in the winter, as it did historically. In addition, because of the US Army Corps of Engineers flood control requirements (drafts of up to 101 feet in extreme runoff years), this effect is greater in low flow years when drafts for flood control are not required, and lower in high runoff years when large drafts for flood control are required.

Water temperatures in this reach of the mainstem Snake River are warmer from October through January during spawning and incubation than in the lower reach of the mainstem Snake River. Water temperatures are similar between the two reaches from February until roughly the third week of April depending on year, after which the upper reach becomes warmer than the lower reach through emergence (Appendix C).

Snake River water temperatures naturally decrease through the fall. Water temperatures upstream of the Salmon River confluence typically range from 20 °C to 23 °C in early September, fall below 20 °C in late September, and continue to decline through the month of January (Figure 5-3). Elevated temperatures in late August and September could affect the behavior of adult migrants. For example, in the mainstem lower Columbia River, median passage times and the rate at which fall Chinook salmon enter into cool-water tributaries increases substantially when temperatures exceed 21 °C as a daily mean (Mann and Peery 2005; Gonia et al. 2006).

The daily mean water temperature at the Lower Granite Dam forebay currently ranges from 20.5 °C in mid-August to 13.5 °C by late October. During the peak passage of adult fall Chinook salmon in the mainstem Snake River (approximately the last two weeks in September), temperatures decline from 20.0 to 18.0 °C (Chandler et al. 2003).

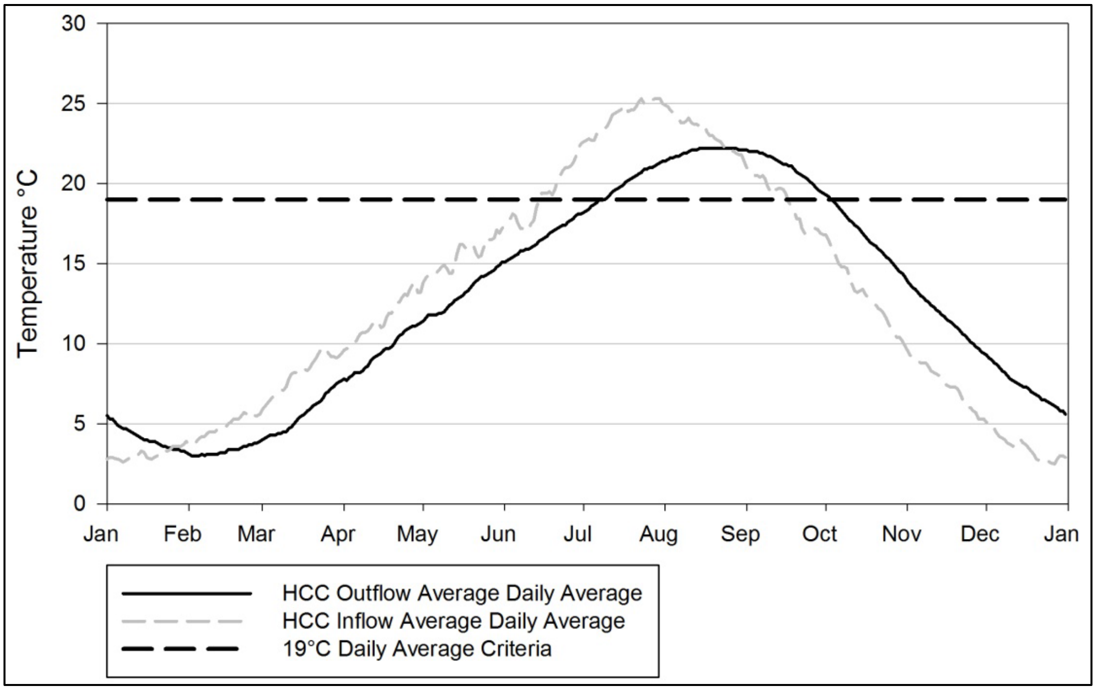

Figure 5-3. Daily average temperature in °C inflow to Brownlee Reservoir and outflow from HCD for the 1996–2012 period of record compared with Idaho’s daily average criteria.

Effects on adults

About 90 percent of adult fall Chinook salmon pass Lower Granite Dam and enter this reach between late August and early October. This, along with delayed fall cooling downstream of

Hells Canyon Dam, means that the great majority of adult fall Chinook salmon migrating, holding, and spawning downstream of Hells Canyon Dam are currently exposed to warmer temperatures for longer periods of time than occurred historically, either in the presently available mainstem Snake River habitat or the habitat formerly accessible upstream.

Effects on Pre-spawning Adults: Potential impacts on early migrating and spawning adults from water temperatures in the reach below Hells Canyon Dam remain uncertain. Literature concerning maximum temperature for salmon in general, and the water quality standards set in relation to that information, indicates that some level of increased pre-spawning mortality (lethal effects) and decreased spawning viability or egg viability (non-lethal effects) occurs when fish are exposed to temperatures above 20 °C (ODEQ 1995a; McCullough 1999; WDOE 2000a; EPA 2003; EPA 2001; Mann and Peery 2005; Jensen et al. 2005). However, fish-to-redd ratios documented in the Snake River do not suggest that significant pre-spawn mortality of fall Chinook salmon is occurring (Appendix C). It is possible that the size of the non-confined environment of the river in this reach below Hells Canyon Dam, a declining thermal regime, and potential cool water refuges (e.g., the confluences of the Clearwater River, Salmon River, and other tributary streams) make the fish less susceptible to disease and mortality than laboratory studies might indicate. It is also possible that fall Chinook salmon are more tolerant of higher temperatures than other stocks of Chinook salmon (see discussion below). However, adults passing Lower Granite Dam in late August and early September may still be exposed to 18-22 °C water temperatures for several weeks prior to spawning, which could potentially result in decreased egg or fry viability (Mann and Peery 2005, Jensen et al. 2005, and Jensen et al. 2006).

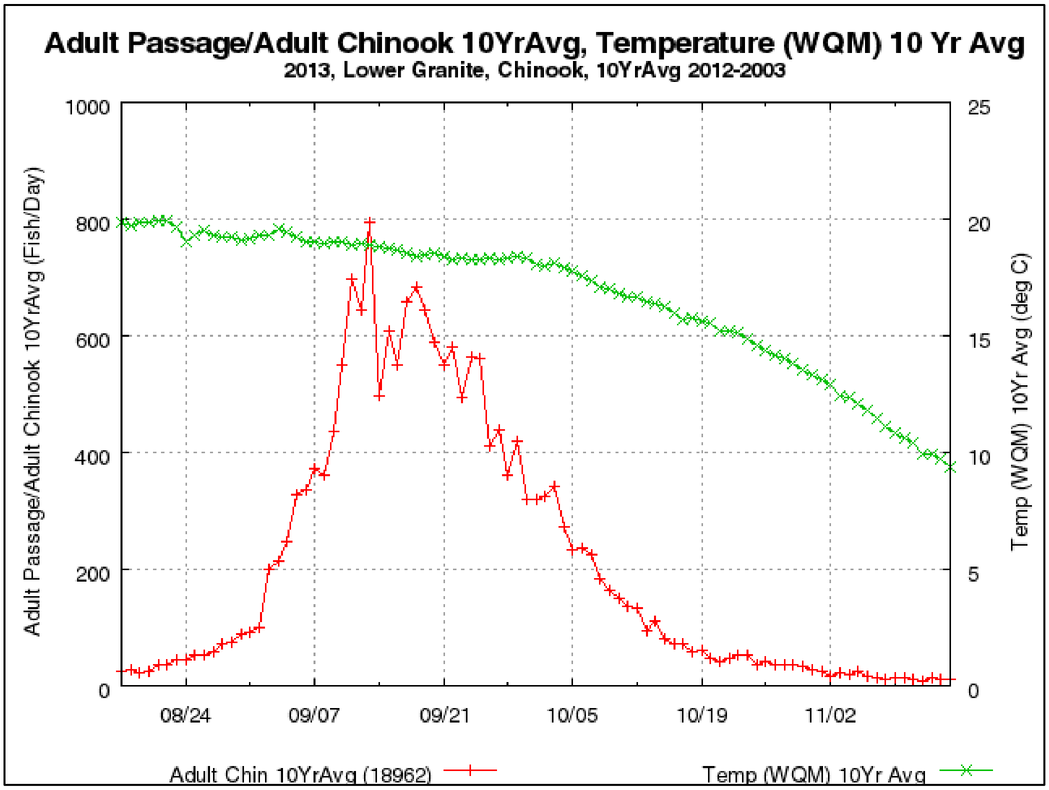

Figure 5-4. Average 10-year migration timing of adult Snake River fall Chinook salmon in relation to average 10-year daily temperatures at Lower Granite Dam.

Recent (2003-2012) average migration timing of fall Chinook salmon and average daily temperatures at Lower Granite Dam are presented in Figure 5-4. The timing and distribution of adults upstream of Lower Granite Dam is not well known. Fall Chinook salmon thermoregulate by delaying migration and using localized cool water areas (Goniea et al. 2006; Clabough et al. 2006). Some adult fall Chinook salmon - especially those migrating past Lower Granite Dam in late August and early September when water temperatures are highest ─ likely hold downstream of the Clearwater River confluence (which is typically cooled below historical temperatures by releases of cold water at Dworshak Dam). The fish probably also hold temporarily downstream of the confluence with the Salmon River, which cools more rapidly than the Snake River (primarily because of Brownlee Reservoir) in the fall.

In the upper mainstem Snake River reach, there are multiple cold-water inflows from tributaries flowing in from the high elevations of the Seven Devil mountains. Some of the larger tributaries include Sheep Creek, Bernard Creek, Granite Creek, and Deep Creek. Deep Creek is located in the immediate tailrace of Hells Canyon Dam. The cold water plumes from these tributaries also offer thermal refugia. By providing pockets of cooler water temperatures, these areas help minimize potential effects relating to the delayed cooling of Snake River water temperatures resulting from the Hells Canyon Complex. However, it remains uncertain whether, or to what extent, the delay in cooler temperatures ultimately impacts spawn timing and success, as well as incubation. Further study is needed to determine the potential impacts of these conditions on early migrating and spawning adults.

Effects on Spawning Adults: The current temperature standard in the Snake River for spawning salmon species is 13 °C (Oregon and Idaho have a 13 °C 7DADM criterion starting on October 23). Chinook salmon that enter freshwater in the summer and fall, such as fall Chinook salmon, generally tolerate and spawn in warmer water than fish that enter freshwater in the spring, such as spring/summer Chinook salmon (comparing Chambers 1956 [spring Chinook] to Seymour 1956 [fall Chinook] in Raleigh et al. 1986). A recent study using Snake River fall Chinook salmon suggests that spawning at initial temperatures between 14.5 °C and 16.0 °C with a declining temperature regime does not result in significant decreases in egg survival[18] (Geist et al. 2006). However, there are some questions relating to these results because the adults were held at 12 °C prior to spawning, a temperature that is considerably cooler than that observed in the Hells Canyon Reach prior to spawning. Several studies (Seymour 1956; Olsen et al. 1970;

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[18] Geist et al. (2006) fertilized Lyons Ferry Hatchery fall Chinook salmon eggs and assigned them to replicated, starting temperature treatments (13.0 °C, 15.0 °C, 16.0 °C, 16.5 °C, and 17.0 °C). Dissolved oxygen in the 13.0 °C and 17.0 °C treatment replicates was held at saturation; the remaining three treatment replicates were subdivided and held at oxygen levels of 4 mg/L, 6 mg/L, 8 mg/L and saturation. Temperature was programmed to drop by about 0.2 °C/d for 40 d, while increasing the dissolved oxygen level by 2 mg/L/d starting 16 d post fertilization. The 40-d temperatures were selected to bound the1991–2003 interannual mean thermal regime in the Snake River upper reach (Hells Canyon Dam to Salmon River), and the 4 mg/L oxygen treatment represented the lowest level observed at a spawning site along the reach. After 40 days, the temperatures were equilibrated among the treatments to match the 2001 drought year temperatures. Mean (± SD) survival from fertilization to emergence calculated across the three coolest temperature treatments and the corresponding oxygen treatments was 92.7 ± 4.7% compared to 93.1 ± 1.4% for fish in the 16.5 °C treatment and 1.7 ± 1.6% for fish in the 17.0 °C treatment (Appendix C).

Geist et al. 2006) indicate that initial spawning temperatures greater than 16.5 °C results in substantially increased levels of egg mortality.

Temperature data during weekly spawning surveys from 1991 through 2013 show that spawning often occurred at water temperatures in excess of 13 °C (Figures 5-4 and 5-5); however, only a small percentage of all fall Chinook salmon spawning activity occurred in the reach at a time when water temperatures were above 16.5 °C (Appendix C). The majority of Snake River fall Chinook salmon in the Hells Canyon reach spawn from around October 22, when water temperatures are about 16 °C, through November 20, when water temperatures drop to about 12 °C. During the 13-year period (1991-2003), only 4 percent of redds surveyed were initiated when water temperatures were greater than 16.5 °C, when substantial egg and fry viability impacts would be expected. Generally, these redds (the 4 percent) represent spawners during the initial interval of spawning activity when, during the 13-year period, water temperatures peaked as high as 19.8 °C and averaged 15.5 °C. The large majority of spawning activity begins after water temperatures have dropped below 16.5 °C (Appendix C). Roughly 10 to 20 percent of redds are deposited between October 23 and 31, when water temperatures are 14.5-16 °C and within a range there is still uncertainty regarding potential impacts (if they are occurring, and if so, to what degree) to egg and fry viability.

Connor found that water temperatures were above 16.5 °C during the first survey interval[19] when redds were counted in 1994, 1996, 1999–2001, 2003–2007, 2010–2012, and 2014. Temperatures above 16.5 °C were also observed in the reach during the second survey interval in 2001 and 2005, and during the third survey interval in 2001. Connor determined that the exposure to temperatures above 16.5 °C during spawning contributed to annual fry loss. He calculated that fry loss due to water temperatures above 16.5 °C in the reach during 2014 averaged (± SD) 2.0 ± 2.3 percent and ranged from 0.2 to 7.3 percent (Appendix C).

The Snake River fall Chinook salmon and Upper Columbia River summer/fall Chinook salmon ESUs have genetic similarities and similar habitat needs (NMFS 2011d). Fall Chinook salmon from the Upper Columbia River summer/fall Chinook salmon ESU that spawn in the Hanford reach of the Columbia River (a robust population that is not listed under the ESA) also spawn in water temperatures in excess of 13 °C (Figure 5-6), though they are less exposed to elevated pre-spawning temperatures than are Snake River fall Chinook salmon.

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[19] The first survey interval was established based on the flight date when redds were first counted minus 7 (i.e., start date) and the flight date minus 1 (End date). The duration of a survey interval was six days. The same steps were taken to establish the second and third survey intervals. Together the three intervals covered contiguous periods of time (e.g., 1991 lower reach; first interval 21-Oct to 27-Oct; second interval 28-Oct to 3-Nov; third interval 4-Nov to 10-Nov (Appendix C).

Figure 5-5. Snake River fall Chinook salmon ESU redd counts in Hells Canyon in relation to maximum water temperatures.

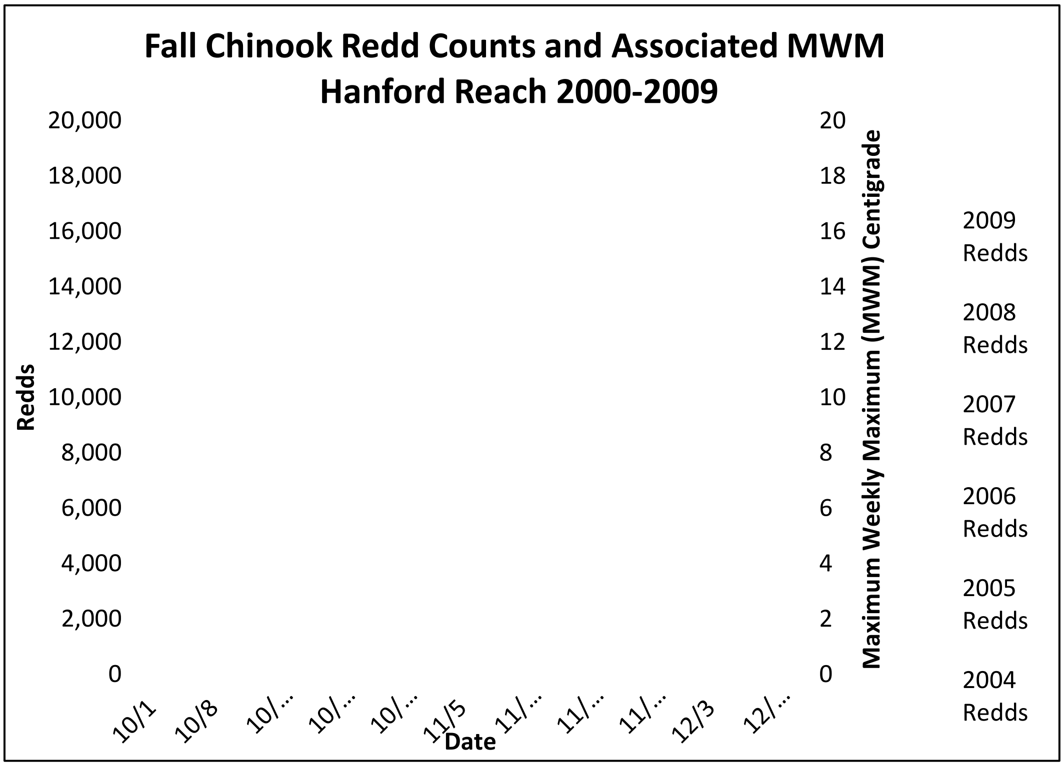

Figure 5-6. Middle Columbia fall Chinook salmon ESU redd counts at Hanford Reach in relation to maximum water temperatures.

Effects on eggs and fry

Although other studies suggest that impacts to egg and fry viability might occur at warmer water temperatures, above about 13 °C (see discussion above relating to effects on spawners), Geist et al. (2006) concluded that exposure to water temperatures up to 16.5 °C during egg fertilization will not have deleterious effects on survival or growth from egg to emergence, if temperatures decline at a rate of 0.2 °C per day or more after spawning and dissolved oxygen levels remain above 4 mg/L (see earlier discussion of this study).

As previously noted, the current thermal regime in the reach between Hells Canyon Dam and the mouth of the Salmon River is warmer than existed historically during part of the egg incubation period, until about January 1. This altered thermal regime below Hells Canyon Dam has shifted present-day emergence to an earlier date than that in the same reach in the pre-Hells Canyon Complex era (see Figure 5-2). As discussed earlier in this section, fish spawned in the Hells Canyon reach’s cold environment would have emerged later than fish in the aquifer-fed reach upstream of Hells Canyon. The warmer water temperatures present in the reach today foster accelerated incubation and fry emergence (Connor et al. 2015). Research by Connor et al. (2002, 2003, 2005) indicates that when water temperatures are warmer during the incubation period of fall Chinook eggs, the timing of the various life history stages (emergence, parr, and smolt) also occur earlier. During egg incubation, water temperatures in the reach generally range from near 5.9 to 6.4 ^{o}C. For brood year 1992 to 1994, emergence timing estimates for the reach ranged from April 16 to April 27 (Connor et al. 2003a).

For subyearling migrants, maximum juvenile survivals occur nearest the peak of the spring freshet and decline throughout the summer as flows and turbidity levels decline and temperatures increase. Controlled releases from the Hells Canyon Complex create conditions in the reach that are similar to those in historically accessible upstream habitat. The conditions are conducive to the fish population’s Age-0 life history, supporting early emergence and allowing the fish to migrate early before unfavorable summer water temperature conditions exist. For example, in 2011, the median date for passage of juvenile fall Chinook salmon from this reach at Lower Granite Dam was June 16 (Connor et al. 2012).

Effects on nearshore environment and predation

Nearshore areas in this reach of the Snake River are important foraging environments for fall Chinook salmon smolts as they migrate (Waples et al. 1991). Temperature during this shoreline rearing time continues to influence growth rates, and consequently the timing of dispersal from riverine habitat into downstream reservoirs. For example, in spring 1995, water temperature in this reach of the Snake River averaged 11.8 ^{o}C, and fall Chinook salmon parr along the shorelines grew an average (± SD) of 1.2 ± 0.3 mm/d compared to parr rearing downstream along the Snake River that experienced a mean spring temperature of 10.9 ^{o}C and grew an average of 1.0 ± 0.3 mm/d (Connor and Burge 2003). More recent work by Geist et al. (2010) indicate that juvenile fall Chinook salmon can tolerate some warmer temperatures. The work showed that: (1) exposure of juvenile fall Chinook salmon to a naturally increasing thermal regime of 14.0 ^{o}C to 20.0 ^{o}C does not raise large concerns relevant to growth, physiological development, and survival; (2) exposure to 24.0 ^{o}C can have severe growth and physiological consequences, and (3) temperatures above 26.0 ^{o}C are almost instantaneously lethal even if the fish are gradually acclimated to warm water (Appendix C).

For example, juveniles are known to rear in nearshore areas of Lower Granite Reservoir until temperatures exceed 18 °C (Connor et al. 2002), when they are likely to move closer to the thalweg (the fastest, deepest water available). Connor et al. (1999) noted that the number of juveniles captured in nearshore areas along the free-flowing Snake River decreased markedly with increasing temperatures (approximately 17 °C) and decreasing flows. This behavior greatly increases the rate at which smolts migrate by placing them in the thalweg of the free-flowing river (Connor et al. 1999). In a free-flowing river, such as this reach, this behavior would improve smolt survival by reducing the likelihood of smolts encountering predators associated with shorelines and reducing the amount of time smolts are exposed to predators. The juveniles that linger longer in the riverine habitat may also experience higher mortality as water temperatures increase through the summer. However, water temperature in this Snake River reach rarely exceeds the 24.0 ^{o}C benchmark for severely reduced growth and retarded physiological development, or the 26.0 ^{o}C for direct mortality. The results on growth were particularly important because a high rate of parr growth in the upper reach is a large factor for parr-to-smolt survival (Connor et al. 2012; Appendix C).

<u>Summary of temperature effects</u>

Chinook salmon literature for all run types suggests that the present thermal regime resulting from the Brownlee Dam impoundment would be expected to result in some level of pre-spawning mortality and reduced egg viability or egg-to-fry survival rates. However, there is currently not enough information specific to Snake River fall Chinook salmon to determine to what degree the altered thermal regime might affect spawning or incubating fall Chinook salmon. Prior to the construction of Hells Canyon Dam, relatively few fish spawned in this reach, probably due in part to winter temperatures that were too cold for successful incubation and dispersal; generally, the altered temperature regime in this reach appears to have created conditions that are potentially more stressful for pre-spawning adults and more beneficial for incubating eggs than the historical thermal regime.

Temperatures below Hells Canyon Dam typically do not fall below the EPA-recommended 20 °C criterion for migrating adult Chinook salmon until mid-to-late September (see Figure 5-4). However, the releases of water from Dworshak Reservoir through mid-September cool flows in the lower Snake River, as do flow contributions from the Salmon River, which cools more quickly than the Snake River in the fall. The cooler water may be providing thermal refugia for migrating adults. Comparisons of adult escapement estimates and redd counts do not suggest that substantial numbers of adult fall Chinook salmon are currently dying prior to spawning as a result of their exposure to elevated fall temperatures. Nonetheless, there is potential for some egg and fry mortality associated with prolonged exposure of adults to elevated temperatures in the migration corridor and spawning areas.

Geist et al. (2006) suggest that fall Chinook salmon eggs exposed to an initial incubation temperature of up to 16.5 °C (and a declining temperature regime of 0.2 °C per day) survive and grow at rates similar to those exposed to cooler initial incubation temperatures. This comports well with observations that spawning in the upper mainstem Snake River reach typically does not occur until temperatures fall below 16.5 °C (Groves and Chandler 1999; Groves et al. 2013; Appendix C). However, a small fraction of the redds in the Hells Canyon reach (about 4 percent on average) have been documented when temperatures may have exceeded 16.5 °C, likely resulting in a high levels of egg and fry mortality in these redds. Lesser impacts could be occurring to redds deposited in late October when temperatures are usually 14.5 – 16 °C; there is, however, substantial uncertainty in the literature because very few studies have attempted to measure egg and fry mortality from elevated spawning temperatures in a declining temperature regime. Fall Chinook salmon in the Hanford Reach of the Columbia River also begin to spawn when temperatures fall below about 16 °C.

The altered thermal regime downstream of the Hells Canyon Complex is also more conducive to the fish population’s Age-0 life history than likely existed historically in this reach. Warmer water temperatures during the egg incubation period foster early emergence, as well as the timing of other life history stages (emergence, parr, and smolt). Consequently, the early emerging fish are able to migrate earlier than historically and before unfavorable summer conditions exist.

Assessing the potential effect of the current temperature regime in the Upper Mainstem Snake River reach on the productivity of fall Chinook salmon remains a key information need. While the temperatures are not always optimum, and a fraction of the Upper Mainstem Snake River spawning aggregate may be negatively affected, existing Snake River fall Chinook salmon specific studies, and recent high adult returns of naturally produced Snake River fall Chinook that are spawning in the area, suggests that this is not currently one of the more significant limiting factors for the recovery of the Snake River fall Chinook salmon ESU. However, we acknowledge that uncertainty exists regarding the effect of the altered temperature regime on Snake River fall Chinook survival and consider this to be a key information need that should be resolved through ongoing work and future studies. Additionally, Snake River temperatures are projected to increase due to global climate change in the coming decades. At present, it is uncertain how, or to what extent, the behavior of Snake River fall Chinook (migration timing, spawn timing, etc.) can accommodate these changes. This underscores the importance of continuing monitoring programs documenting passage timing, redd counts, and river temperatures in order to detect changes and assess their effects on fall Chinook salmon.

Dissolved Oxygen (DO)

As described in Section 5.1.1.2, hypoxic waters from Brownlee, Oxbow, and Hells Canyon reservoirs are drawn into the turbines in the late summer and fall and exported downstream.

Dissolved oxygen levels released from Hells Canyon Dam often do not meet state water quality criteria for coldwater biota (8 mg/L water column DO as an absolute minimum) between August and October or for salmonid spawning (11 mg/L water column DO as an absolute minimum) between October and December (NMFS 2006b). This water is reoxygenated by rapids downstream of Hells Canyon Dam; however, the effect likely lasts for 10 or more miles, through important spawning habitat, depending upon starting dissolved oxygen levels in water releases, temperature, and mixing rates at rapids in downstream areas (Graves 2000).

Exposure to dissolved oxygen levels between 3 and 6 mg/L on pre-spawning adults is not well understood, but can include negative impacts such as avoidance, delayed migration, reduced swimming speeds, reduced fecundity, reduced spawning condition, and death (ODEQ 1995b; WDOE 2000b). The effects of constant exposure to low dissolved oxygen levels on early life history stages of salmonids are relatively well known. Below 8 mg/L, the size of fish at emergence and the survival of fish can be negatively impacted. Below 5 or 6 mg/L, the survival of embryos is often low (ODEQ 1995b; WDOE 2000b).

In summary, low dissolved oxygen levels could be resulting in the death of exposed fall Chinook salmon eggs below Hells Canyon Dam, or reduced fitness of exposed fry upon emergence (in redds created within the affected area below the dam). Aerial surveys indicate 17 to 18 percent of total redds are located within 10 miles downstream of Hells Canyon Dam (e.g. Garcia et al. 2004).

Total Dissolved Gas

Idaho Power Company manages the Hells Canyon Complex to prevent spill to the extent possible. However, flows routinely exceed powerhouse capacities during the spring months (March through June) and sometimes exceed these flow levels during the winter as well (IPC 2003). When powerhouse capacities are exceeded, over-generational (uncontrolled) spill occurs. Spilling water at hydroelectric plants often causes atmospheric gases to be entrained in the water column, causing the water to become supersaturated with these gases, primarily with dissolved nitrogen.

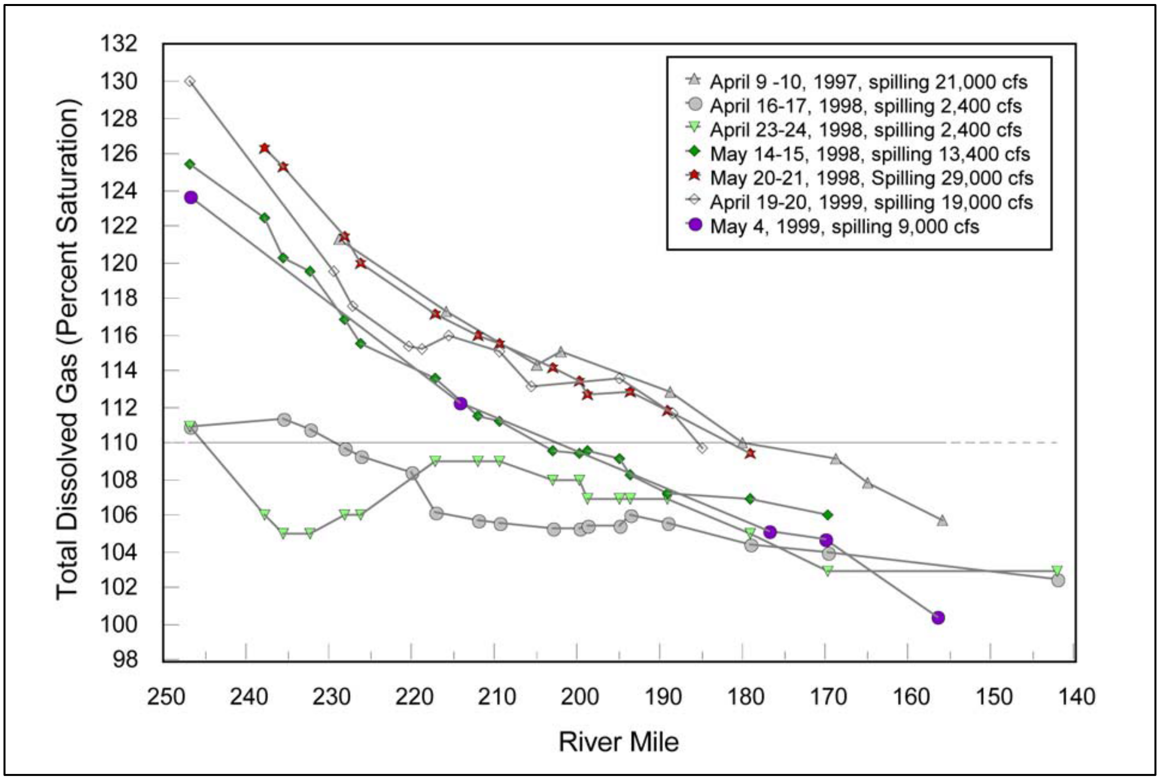

Figure 5-7. Downstream dissipation of total dissolved gas within Hells Canyon relative to the 100% saturation standard. Source: FERC 2007, Figure 34.

Figure 5-7 depicts the dissipation of the supersaturated gases downstream of the Hells Canyon Complex. TDG levels increase rapidly as spill volumes increase to 20 kcfs (1,000 cubic feet per second), from 110 to 130 percent. Between 20 and 40 kcfs, TDG levels increase more slowly, from about 130 to 135 percent (Figure 5-5). TDG levels exceeding 120 percent do not reach 110 percent saturation (i.e. equilibrate to Idaho or Oregon's TDG standard) for 40 to 70 miles below the Project.

The tolerance of anadromous salmon and steelhead to TDG supersaturation varies greatly by life stage. Weitkamp (1977) summarized TDG research on various life stages of species of fish. For salmonids, eggs appear quite resistant to the effect of high TDG levels, while sac-fry are particularly sensitive. The susceptibility of juvenile fish to TDG supersaturation appears to increase with increasing size. Prior to emergence from the gravel, eggs and fry benefit from hydrostatic compensation. That is, each one meter of depth compensates for approximately 10 percent of TDG saturation (Weitkamp 1977).

Based on the distribution of over-generational flows at the Hells Canyon Complex (IPC 2003), fall Chinook salmon eggs, alevins (or sac-fry), fry, and rearing juveniles are most likely to be affected by elevated TDG levels below the complex. Because of hydrostatic compensation, only those eggs and sac-fry in the shallowest redds (those within about 2 meters of the water's surface) face any real exposure to TDG supersaturated waters. Those in the shallowest areas (less than 1 meter in depth), most proximally situated to Hells Canyon Dam, would experience the highest TDG levels (between 125 and 135 percent at the highest spill levels) and would most likely be impacted by gas bubble disease (Weitkamp 1997; Ryan et al. 2000; McGrath et. al. 2005). However, the natural juveniles seined in the Hells Canyon Reach are free of external symptoms of gas bubble disease. It may not be a problem because fish movement up and down in the water column allows for compensation; however, microscopic examinations have not been conducted (Billy Connor, FWS personal communication 2013).

Sediment and Turbidity

The Hells Canyon Complex prevents the downstream movement of sediments, thus cutting off a substantial source of these materials in the existing fall Chinook salmon spawning habitat downstream of Hells Canyon Dam. However, before construction of the Hells Canyon Complex, the heavy loads of sediment and organic nutrients from agricultural runoff had a significant impact on spawning habitat quality in the middle Snake River. Today, these loads are trapped in Brownlee Reservoir (Falter and Burris 1996; Myers et al. 2003; Groves and Chandler 2005; Connor et al. 2015). As a result, the Hells Canyon Complex has helped preserve the relatively high quality of the limited spawning habitat in Hells Canyon, as well as the more abundant spawning habitat downstream of the Grande Ronde River mouth (Bennet and Peery. 2003; Connor et al. 2015).

Reduced turbidity levels however, may increase predation on juvenile migrants in areas where lower flows and warmer water temperatures exist. Smith et al. (2002) observed substantially (up to 60 percent) reduced survival of juvenile fall Chinook salmon released at Pittsburg Landing (in the upper mainstem Snake River reach) compared to those released at Billy Creek (in the lower mainstem Snake River reach) in 2000 and 2001. The authors attributed the reduced survival to lower flows and turbidity levels than were observed in previous years in which this study was conducted. Clearer water (lower turbidity) likely increases the vulnerability of juvenile salmonids to sight-feeding predators by increasing predator reactive distance and predator encounter rates (NMFS 2000).

5.1.2.2 Altered Flows

Daily and hourly flow fluctuations in the Snake River below the Hells Canyon Complex in response to changing electricity demands (load following) are likely to result in entrapment or stranding of juveniles, or dewatering of redds. However, since 1991, Idaho Power Company has followed a program to provide stable flow from Hells Canyon Dam during fall Chinook salmon spawning season and “a minimum discharge throughout the incubation period until fry emergence is considered complete” (Groves and Chandler 2001). Brink and Chandler (2007) describe Idaho Power Company’s management plan for preventing juvenile entrapment.

Seasonally, Hells Canyon Complex flood control and refill operations contribute to substantially reduced flows in the mainstem migration corridor, Columbia River estuary, and plume during the spring outmigration (USBR 2004; NMFS 2004; NMFS 2005a). Reduced spring flows in the lower Snake River and Columbia River are correlated with increased juvenile travel times;

adversely affect the estuary; and diminish the size of the Columbia River plume in the Pacific Ocean, all of which are areas of special importance to rearing and migrating juvenile Chinook (as well as coho, chum, sockeye salmon, and steelhead) (NMFS 2004; NMFS 2005a).

5.1.2.3 Summary of Lower Mainstem Snake River Habitat from below Hells Canyon Dam to the Salmon River (Upper Mainstem Snake River MaSA) Threats and Priority Limiting Factors

Threat: Hells Canyon Complex hydropower operations; upstream reservoirs and Hells Canyon Dam.

Related priority limiting factors: (1) Reduced water quality, altered flows and geomorphological processes: low dissolved oxygen levels in late summer and fall that could be resulting in the death of exposed fall Chinook salmon eggs below Hells Canyon Dam, or reduced fitness of exposed fry upon emergence (in redds created within the affected area below the dam); elevated TDG levels in winter and spring that could cause some gas bubble disease in juveniles, and potentially altered thermal regime[20] that could affect spawning success and egg viability to a limited, but probably not substantial degree, gas bubble disease. (2) Altered flows (on a seasonal, daily, and hourly basis), resulting in altered migration patterns, juvenile fish stranding and entrapment. (3) Interruption of geomorphological processes (entrapment of sediment), resulting in reduced turbidity, higher predation.

5.1.3 Hydropower and Lower Mainstem Snake River Habitat - from Mouth of Salmon River to Lower Granite Dam (Lower Mainstem Snake River MaSA)

The Lower Mainstem Snake River reach (RM 188 to 147) includes the Snake River from the mouth of the Salmon River downstream to the beginning of the Lower Granite Dam reservoir near Lewiston, Idaho.

The Salmon, Clearwater, and Grande Ronde Rivers contribute flow to this reach of the Snake River, along with some smaller tributaries, including the Imnaha River and Asotin Creek. The channel widens near RM 180, with gently sloping shorelines and a lower gradient than in the Hells Canyon Reach. Downstream of the Salmon and Grande Ronde Rivers, there are long, deep pools and runs and low-gradient rapids (Groves and Chandler 2003). Here spawning gravels and rearing areas are more often contiguous.

This mainstem reach of the lower Snake River was historically less productive than the middle Snake River reach, but also supported fall Chinook salmon. Historical accounts indicate that spawning occurred in the lower Snake River, especially below the confluence of the Clearwater River. Both Fulton (1968) and Parkhurst (1950) referred to significant spawning areas between the mouth of the Snake River and the confluence of the Clearwater River (Chandler et al. 2001). Historically, however, the warming influence of the large volume of spring flows into the middle Snake River was absent in this lower Snake River reach. Instead, the reach responded to conditions in the arid high desert environment, with cooler winter and early spring water

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[20] See "Summary of temperature effects" above.

temperatures and higher summer temperatures. The absence of the spring-fed flow likely caused fry emergence timing to become later than in warmer upper reaches, and temperature-dependent growth opportunities and survival to decline in this lower Snake River reach, especially as temperatures rose above 20 °C (Connor et al. 2015).

Altered Flows

As in the Upper Mainstem Snake River MaSA reach of the Snake River, long-term fluctuations in flow have altered riparian vegetation. Daily fluctuations can potentially result in stranding fry in the shallows. However, the effects of the Hells Canyon Complex in this reach are substantially attenuated due to the influence of the Salmon and Grande Ronde Rivers. These tributaries have water quality and flow issues of their own (see Section 5.1.5), with varying effects on water quality in the mainstem.

Altered Temperature Regime

High water temperatures (late summer and fall) in this reach have the potential to affect abundance, productivity, and spatial structure of fall Chinook salmon. Juveniles spend time rearing in nearshore reaches and within Lower Granite Reservoir during their outmigration. Adults use the area for holding and spawning. IDEQ is conducting temperature studies for the Snake River below the Hells Canyon Complex to determine the thermal potential of the habitat and will develop TMDLs for temperature as appropriate (IDEQ 2014). A preliminary comparison of USGS temperature gage data from 1999 to 2005 found peak summer water temperatures in the Salmon River and the mainstem Snake River to be quite similar, reaching 24 °C (75 °F) in both reaches (Don Zaroban, IDEQ, personal communication, June 2011). Importantly, adult fall Chinook salmon do not begin to arrive in the lower mainstem Snake River until late August after water temperatures begin to cool. The daily mean water temperature at the Lower Granite Dam forebay currently ranges from 20.5 °C in mid-August (due to releases of cool water from Dworshak Dam) to 13.5 °C by late October. During the peak passage of adult fall Chinook salmon in the mainstem Snake River (approximately the last two weeks in September), temperatures decline from 20.0 to 18.0 °C.

Many juvenile outmigrants likely arrive in this reach before water temperatures become a concern. As discussed in Section 2, the dates of peak dispersal from the Snake River Hells Canyon upper mainstem reach and the lower mainstem reach into Lower Granite Reservoir were May 28 and June 4 in 1995 (Connor et al. 2002). Once in Lower Granite Reservoir, these early dispersing fish have the opportunity to grow. Tiffan et al. (2009c) found that young fall Chinook salmon move up and down in the water column to maintain an optimum body temperature for growth.

Effects on nearshore environment

Nearshore areas in this reach of the Snake River are important foraging environments for fall Chinook salmon smolts as they migrate downstream (Waples et al. 1991). For example, juveniles are known to rear in nearshore areas of Lower Granite Reservoir until temperatures exceed 18 °C (Connor et al. 2002), when they are likely to move closer to the thalweg (the fastest, deepest water available). As discussed in the previous section, Connor et al. (1999) noted that the number of juveniles captured in nearshore areas along both the free-flowing Snake River and Lower Granite Reservoir decreases markedly with increasing temperatures (approximately 17 °C) and decreasing flows, with smolts moving to the thalweg of the free-flowing river (Connor et al. 1999). In a free-flowing river, this behavior would improve smolt survival by reducing the likelihood of smolts encountering exposure to shoreline predators. This behavior would also improve survival in the upstream, more riverine reaches, of the lower Snake River impoundments. However, in the lowermost, lacustrine, reaches, where greatly increased cross-sectional area of the river results in tremendously reduced water velocities, this behavior probably provides less benefit because predators can more easily maintain their position at any point in the reservoir (Tiffan et al. 2009b).

5.1.3.1 Summary of Lower Mainstem Snake River Habitat - from Mouth of Salmon River to Lower Granite Dam Reservoir (Lower Mainstem Snake River MaSA) Threats and Priority Limiting Factors

Threat: Upstream dam operations.

Related priority limiting factors: Altered thermal regime[21], altered flows (seasonal, daily, and hourly).

Threat: Land uses adjacent to Snake River and tributaries.

Related priority limiting factors: Degraded water quality, altered thermal regime, lowered disease resistance, higher stress and mortality.

5.1.4 Hydropower and Mainstem Migration Corridor Habitat - FCRPS Reservoirs and Dams on Lower Snake and Columbia Rivers

The mainstem migration corridor runs from the estuary and plume through the four federal dams on the Columbia River: Bonneville, The Dalles, John Day, and McNary Dams, and the contiguous reservoirs formed on the lower Snake River by Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Dams. In addition to inundating historical production areas (inundated by Little Goose and Lower Granite Dams), hydropower system development and operations also reduce mainstem habitat quality and affect both juvenile and adult migration.

5.1.4.1 Adults - Migrating

Generally, adult passage has steadily improved since development of the FCRPS and facilities at the lower Snake and Columbia River dams are now considered highly effective. In 2008, NMFS estimated the average survival for adult Snake River fall Chinook salmon migrating upstream between Bonneville Dam and Lower Granite Dam at 81 percent for those that migrated in river

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[21] See "Summary of temperature effects" in Section 5.1.2.1 above.

as juveniles and approximately 75 percent for those that were transported as juveniles, equating to a per project adult survival (7 dams) of 97 percent and 96 percent, respectively (NMFS 2008b, based on Adult Survival Estimate Appendix of NOAA's Supplemental Comprehensive Analysis [NMFS 2008d]). Recent data (2008, 2009, 2010 and 2014) are higher, showing closer to 90 percent survival for both categories (NMFS 2012a). The current estimate of average adult Snake River fall Chinook salmon survival (conversion rate estimates using known-origin adult fish after accounting for natural straying and mainstem harvest) between Bonneville and Lower Granite dams (2008-2012) is approximately 90.5 percent (NMFS 2014c).

Adult passage, however, can still be delayed. Salmon may have difficulty finding ladder entrances, and may also fall back over the dam, either voluntarily (e.g., adults that "overshoot" their natal stream and migrate downstream through a dam on their own volition) or involuntarily (entrained in spillway flow after exiting a fish ladder). Some adults that fall back or migrate downstream pass through project turbines and juvenile bypass systems (NMFS 2008b). Telemetry studies have shown that fish that fall back through the spillways are less likely to reach spawning grounds than those that do not fall back.

The relationships between water temperatures and migration rates, temporary tributary use, and run timing of adult fall Chinook salmon were studied in the lower Columbia River by Goniea et al. (2006). They collected movement data between Bonneville Dam and John Day Dam from 2,121 upriver fall Chinook salmon that were radio-tagged over 6 years (1998, and 2000–2004). Weekly median migration rates (distance traveled per day) through the lower Columbia River between Bonneville Dam and John Day Dam slowed by approximately 50 percent when daily mean water temperatures were above about 20 °C. Slowed migration was strongly associated with temporary use of tributaries, which averaged 2 to 7 °C cooler than the mainstem river. Overall, 18 percent of all radio-tagged salmon entered lower Columbia River tributaries, and 9 percent used tributaries for more than 12 hours. The proportions of salmon that used tributaries increased exponentially with increasing mean weekly Columbia River water temperature, from less than 5 percent when temperatures were below 20 °C to about 40 percent when temperatures neared 22 °C. Goniea et al. (2006) noted the need to protect thermal conditions in cool-water tributaries in the face of predicted increases in global temperature, and noted the risk of fishing pressure in these waterways.

Snake River adult upstream migrants are also affected by thermal blocks that are longer in duration and larger in size than would have existed historically in the Columbia River and lower Snake River mainstems. The relatively late entry of these fish subjects the earlier migrants to relatively high temperatures and low flows compared to the migrants that enter the reach later when temperatures are somewhat lower (ICTRT 2010). This threat to adult fall Chinook salmon migrants in the Snake River has been greatly reduced since about 1995 when the Corps of Engineers began operating Dworshak Dam on the North Fork Clearwater River to maintain cooler summer temperatures in the lower Snake River during July, August, and September.

The cooler water released from Dworshak Dam generally benefits migrating adults and over-summering juvenile fall Chinook salmon, but high summer water temperatures continue to affect Snake River fall Chinook migrants in some years when the cool water does not mix with the warmer water in Lower Granite reservoir. For example, in 2013 a combination of low summer flows, high air temperatures and little wind created thermally stratified conditions in Lower Granite reservoir during late July, and again in September. The reservoir's warm surface water entered the adult fish ladder and disrupted fish passage for more than a week. In response, the Corps of Engineers modified dam operations and pumped cooler water from deeper in the forebay to reduce water temperatures in the fish ladder. This change, along with cooler weather, allowed the fish to resume passage at the dam. Still, the event resulted in an estimated 7 percent of fall Chinook salmon failing to pass Lower Granite Dam (NMFS 2014c). The Corps of Engineers is currently evaluating options to deliver cooler water into the ladder entrance and adult trap with the intent of designing and constructing the needed structures in time for the 2016 migration.

5.1.4.2 Adults – Spawning

The reservoir above Lower Granite Dam inundates historical Snake River fall Chinook spawning habitat. The upper end of the Lower Granite Dam pool (near Lewiston, Idaho) is now considered the downstream limit of the Snake River fall Chinook salmon spawning habitat; however, limited spawning continues to occur in the lower Snake River dam tailraces. Although historical habitat conditions in this mainstem reach were likely less productive than upstream spawning areas, they likely fostered phenotypic diversity in spawn timing as water temperature varied from upstream areas and tributary reaches.

5.1.4.3 Juveniles – Rearing and Migrating

Passage through the FCRPS dams and reservoirs results in juvenile mortality from various sources. Snake River juvenile migrants pass eight federal mainstem dams on their way to the ocean, via turbines, spillway bays or weirs, or a screened juvenile bypass system. Juvenile salmonid survival typically is highest through spillways, followed by bypass systems, then turbines (Muir et al. 2001).

Survival of Snake River fall Chinook salmon juveniles has been studied primarily with hatchery fish, because of the methodological complications of the fall Chinook salmon dual life history. NMFS used the survival of hatchery released subyearling Chinook salmon from Lower Granite to McNary Dam, expanded to the Lower Granite to Bonneville Dam reach, as surrogates in the 2008 FCRPS BiOp to assess mainstem survival rates. This analysis estimated current average survival rates of surrogate hatchery fish to range between 18.7 percent and 53.4 percent (NMFS 2008b). NMFS conservatively assumed that structural and operational changes at the mainstem dams would have no additional benefits for subyearling Chinook salmon (i.e., that future prospective survival rates would be no different than current survival rates). Studies showed that juvenile salmon experienced approximately an 11 percent mortality rate per mainstem dam when they passed by way of turbines (Whitney et al. 1997). Increased reservoir volumes also create slower water velocities and slow juvenile migration rates (ICTRT 2010) (Tiffan et al. 2009c).

Juvenile passage rates have improved in recent years. As discussed in Section 2 (Section 2.6), before 2005 survival estimates for subyearling Snake River fall Chinook salmon ranged from 25 to nearly 80 percent, declining later in the season. More recently (2009-2012) in years when both summer spill and surface passage routes were in effect, survival rates ranged from 66 to 89 percent for individual fall Chinook salmon cohorts (fish grouped into two-week intervals), and all but two cohorts of fish tracked during this period exceeded the highest average survival rate (71 percent) targeted with full implementation of actions in the 2008 FCRPS BiOp.

While estimates show that direct survival through spillways and bypass systems tends to be high for juvenile migrants, there is evidence that fish bypass systems are associated with some latent, or delayed, mortality in the estuary and ocean (NMFS 2014c). The relative magnitude of latent mortality effects, the specific mechanism causing these effects, and the potential for interactions with other factors (toxic pollutants, ocean conditions, etc.) remain key uncertainties (NMFS 2014c). While latent mortality rates undoubtedly include some mortalities stemming from fish being injured within the bypass systems or from predation in the vicinity of the bypass system outfall, there is likely also some latent mortality of fish that enter the bypass systems with already compromised health (sick, distressed, or injured fish).

A number of juvenile Snake River fall Chinook salmon are collected and transported by barge around the lower Snake River and mainstem Columbia River dams to below Bonneville Dam. Compared to previous operations, transport rates decreased since 2005, when increased spill levels were enacted at the Snake River collector projects and remaining dams were equipped with surface oriented spillway weirs. Since 2008, roughly 1 to 2 million juvenile fall Chinook salmon have been collected at Lower Granite, Little Goose, and Lower Monumental Dams. A much smaller, but unknown, number of Snake River fall Chinook salmon juveniles were also collected and transported at McNary Dam on the Columbia River until 2013, when transportation operations were ended. Because of their varied life history strategies, current hatchery marking protocols, and seasonal shutdown of juvenile bypass facilities, it is not possible to precisely estimate what proportion of the juvenile population is transported, or estimate how many of these are hatchery-origin and how many are natural fish (NMFS 2014c). Though developed to improve juvenile survival by avoiding losses in the mainstem migration corridor, transportation could potentially have negative effects (NMFS 2014a, Appendix E). For example, the transportation could be selective against the smaller-sized migrants (ICTRT 2010). Adult returns from a six-year Snake River fall Chinook transportation study should be complete in a few years, allowing managers to assess seasonal patterns and the relative benefit of transport versus in-river migration.

In addition, ecosystem alterations attributable to hydropower dams, increases in non-native piscivorous fish, and modification of estuarine habitat have increased predation on Snake River fall Chinook salmon juveniles. This is discussed in more detail in Section 5.5, Predation.

5.1.4.4 Summary of Mainstem Migration Corridor FCRPS Threats and Priority Limiting Factors

Threat: FCRPS reservoirs and multiple dams, turbines, transportation.

Related priority limiting factors: (1) For adult fish, difficulty finding fish ladders, temperature-related delayed/blocked migration, fallback, reduced spawning area, impaired homing ability (of transported fish) (see Section 5.3). (2) For juvenile fish, slowed migration, increased mortality, increased predation, sublethal injuries or stress due to passage through dams.

5.1.5 Tributary Major Spawning Areas and Habitat

Three primary tributaries to the Lower Snake River ─ the lower Clearwater, Grande Ronde, and Tucannon Rivers ─ likely supported fall Chinook salmon production historically. These three tributary reaches are considered MaSAs for Snake River fall Chinook salmon but are secondary to the two mainstem Snake River MaSAs. Historically, two other tributaries, the Imnaha and Salmon Rivers, are also believed to have supported limited spawning by fall Chinook salmon. Today these two areas are considered part of the Upper Mainstem Snake River MaSA. They provide relatively low production potential and contemporary use. This section discusses habitat conditions in these major tributary spawning areas.

5.1.5.1 Lower Clearwater River MaSA

The Lower Clearwater River MaSA includes the lower mainstem Clearwater River reaching upstream from the confluence with the Snake River at Lewiston, Idaho. It also includes lower reaches of the South Fork Clearwater River, Middle Fork Clearwater River, and Selway River. Dworshak Dam, without fish passage, is located about two miles up the North Fork from its confluence with the mainstem Clearwater. Snake River fall Chinook salmon reach the Clearwater subbasin from late August through December and spawn in the mainstem below the confluence with the North Fork (Arnsberg et al. 1992; Garcia et al. 1999, as cited in Ecovista et al. 2003). However, spawning adults have been observed throughout the mainstem Clearwater River and Middle Fork Clearwater River, and in the lower portions of the Potlatch River, South Fork Clearwater River, and Selway River.

Habitat conditions in the Clearwater River drainage affect fall Chinook salmon abundance, productivity, and spatial structure. They also influence species diversity: Conditions in the lower Clearwater River favor earlier spawn timing compared to the Snake River mainstem, resulting in a prolonged incubation and early rearing life-history phase. These conditions have contributed to the development of an alternative life history strategy. Limiting factors for salmonids spawning and rearing in the Lower Clearwater River include temperature, sediment, and flow issues (variability and base flow) (Ecovista et al. 2003). The IDEQ listed 432 miles of streams within the Lower Clearwater and its tributaries as water quality limited, mainly for thermal modification, sediment, habitat alteration, and flow (Ecovista et al. 2003).

The Clearwater River contributes approximately one-third the flow of the Snake River and ten percent of the flow of the Columbia River system annually (USFS 1969 as cited in Maughan 1972). The Clearwater drains approximately 9,645 square miles, originating in the Bitterroot Mountains and flowing through mainly federal lands on the eastern half and private and tribal lands on the western half of the subbasin, including the Nez Perce Reservation. From the town of Ahsahka, where the North Fork of the Clearwater enters, the Lower Clearwater flows through semi-arid canyons and prairie (Ecovista et al. 2003). Land uses in the area include livestock grazing, timber harvest, agriculture, roads, rural residences, mining, and recreation, with the addition of industry in or near the city of Lewiston. Impoundments, irrigation projects, and small water diversions have a significant impact, with 56 dams of varying size counted in the Lower Clearwater subbasin (Ecovista et al 2003).

The Lower Clearwater River is highly influenced by operations at Dworshak Dam, located 1.9 miles up the North Fork Clearwater, which alters natural temperature and flow regimes (Ecovista et al. 2003). Dworshak Dam is operated to meet both local and regional flood control requirements during the winter and spring each year. Refilling the project reduces spring flows in the lower Clearwater, Snake, and Columbia Rivers. Starting in 1992, releases at Dworshak Dam have been made to improve migration conditions (temperature and flow) in the lower Snake River. Recent operations to cool temperatures and augment flows include releases of up to 14,000 cfs between late June and mid-September.

Assessing the effects of the release of cold water from Dworshak Dam in the summer is complex. Summer water temperatures in the lower Snake River can otherwise rise to harmful levels in some years, delaying or even killing both adult migrants (steelhead, sockeye, and summer and fall Chinook salmon) and juvenile migrants (fall Chinook salmon). Cold water releases from Dworshak Dam benefit the migrants by reducing temperatures in the lower Snake River during the adult and juvenile fall Chinook salmon migrations. The cold water released into the Lower Clearwater River can also slow the growth of juvenile salmonids incubating and rearing in this area of the Clearwater River, disrupt the cues that prompt outmigration (Connor et al. 2001, ICTRT 2010), and provide thermal refuges in the lower Snake River reservoirs where juveniles can oversummer.

The summer flow augmentation appears to contribute substantially to juvenile fall Chinook salmon from the Clearwater River holding over an extra year in freshwater. The cooler water temperatures cause fall Chinook salmon parr to grow more slowly in the lower Clearwater River and linger in riverine habitat longer than parr in warmer Snake River reaches. Thus, most parr in the lower Clearwater River do not begin downstream dispersal before a partial thermal barrier forms in July. This thermal barrier forms when the warm Snake River water from the south arm of Lower Granite Reservoir meets the cool lower Clearwater River water from the east arm of the reservoir (Cook et al. 2006). The barrier does not dissipate until water temperatures decline in September, and parr from the Clearwater River can be delayed in the east arm until this dissipation occurs (B. Arnsberg, unpublished data). While the delayed fish continue to grow (e.g., 103 mm fork length in August), it is unlikely that many resume active migration as subyearlings because their late schedule of development coincides with environmental conditions that do not favor smoltification (e.g., declining photoperiod and temperature). This new adaptation represents “the expression of an alternative life history strategy [which] may ultimately serve to reduce the overall extinction risk at both the population and ESU levels”

(ICTRT 2010), but there is some concern that if the yearling migrant life history strategy became predominant, it would represent a loss of the historical life history pattern and could increase the risk to the ESU. At this time, it appears that the subyearling life-history strategy continues to be conserved in the Snake River rearing areas and the relative contributions of each life history strategy to the ESU is fairly stable.

Habitat conditions to support fall Chinook salmon spawning and rearing in minor spawning areas within the Clearwater River drainage, including the South Fork Clearwater and Selway Rivers, remains poorly understood. More information is needed to determine the quality and quantity of habitats in these and other minor spawning areas.

Summary of Clearwater River Threats and Priority Limiting Factors

Threats: Land uses that affect river habitat, including livestock grazing, timber harvest, agriculture, roads, rural residences, mining, and recreation.

Related priority limiting factors: High water temperatures, increased sediment, excessive nutrients, channel alterations, pollutants.

Threat: Urban development and industry.

Related priority limiting factors: Toxic pollutants.

Threat: Impoundments, irrigation projects, and small water diversions.

Related priority limiting factors: Reduced habitat quantity, degraded water quality, entrapment and stranding.

Threat: Dworshak Dam.

Related priority limiting factors: Blocked access, altered flows, altered thermal regime, encouragement of new life history pattern.

5.1.5.2 Lower Grande Ronde River MaSA

The Lower Grande Ronde MaSA includes the lower mainstem Grande Ronde River. The Grande Ronde River begins in the Blue and Wallowa Mountains of Oregon and flows generally northeast 212 miles, including through 40 miles of southeast Washington, to join the Snake River in Hells Canyon at RM 169. The lower river flows through rocky, exposed, arid canyons and sparely vegetated terrain. Land uses surrounding the Grande Ronde River are primarily agriculture (water diversions), livestock grazing, roads, timber harvest, and recreation (NMFS 2010, NPCC 2004).

Habitat conditions in the lower Grande Ronde River currently limit fall Chinook salmon spawning and rearing. Factors limiting the ability to improve species viability (abundance, productivity, spatial structure, and diversity) by increasing natural-origin production in the lower Grande Ronde River MaSA include lack of habitat quantity and diversity (primary pools, large wood, glides, and spawning gravels), excess fine sediment, degraded riparian conditions, low summer flows, and poor water quality (high summer water temperatures, low concentrations of dissolved oxygen, nutrients). The Oregon Department of Environmental Quality (ODEQ) identified many stream segments within the lower Grande Ronde subbasin as water quality limited for bacteria, dissolved oxygen, pH, sedimentation, and temperature (ODEQ 2000; NPCC 2004; ODEQ 2010). A TMDL document for the lower Grande Ronde subbasin sets TMDLs to address 303(d) listings for temperature and bacteria.

Human activities that have contributed to altered stream conditions include logging, fire suppression, grazing, cultivation and other agricultural development, draining of wetlands, ditching and diking of streams, water withdrawal, and the introduction of non-native plant and animal species.

Summary of Grande Ronde River Threats and Priority Limiting Factors

Threats: Logging, fire suppression, grazing, cultivation and other agricultural development, draining of wetlands, ditching and diking of streams, water withdrawal, and the introduction of non-native plant and animal species.

Related priority limiting factors: Lack of habitat quantity and diversity (primary pools, large wood, glides, and spawning gravels), excess fine sediment, degraded riparian conditions, low summer flows, and poor water quality (high summer water temperatures, low concentrations of dissolved oxygen, nutrients).

5.1.5.3 Lower Tucannon River MaSA

The Lower Tucannon River MaSA includes the lower mainstem Tucannon River and the tailrace reaches of the mainstem Snake River influenced by the lower Snake River dams. The 2000-2014 interannual mean (± SE) percentages of the Snake River basin-wide redd counts show 5.6 (± 0.5%) of the redds were counted in the Lower Tucannon MaSA. Many of these fish were likely Lyons Ferry Hatchery fish. Milks et al. (2003) documented fall Chinook salmon use of the lower Tucannon River and observed that RM 0.0 to 0.1 was used primarily for migration, RM 0.1 to 0.4 primarily for rearing and migration, and RM 0.4 to 17.3 primarily for spawning and rearing. Limited spawning (0.1 ± 0.04%) occurred in the tailrace areas; however, the tailrace areas of the lower Snake River dams continue to contribute to species productivity and diversity. Loss of occupancy of naturally produced spawners in the Tucannon MaSA increased the distance between the Snake River Fall Chinook ESU and downstream ESUs in the Columbia Basin (ICTRT 2007).

The Tucannon River originates in the Blue Mountains and enters the Snake River at RM 62.2 near the mouth of the Palouse River. Melting snow from the Blue Mountains provides much of the annual runoff to the streams and rivers in the subbasin; the water level in many streams diminishes greatly during the summer months. Vegetation in the subbasin includes grasslands and agricultural lands at lower elevations, and evergreen forests at higher elevations. Major land uses in the subbasin are related to agriculture; cropland, forest, rangeland, pasture, and hay production account for more than 90 percent of the land within the watershed. Approximately 75 percent of the Tucannon subbasin is in private ownership; most of this land is in the lower portion of the watershed (Columbia Conservation District 2004).

Only limited information exists on the quality and quantity of spawning and rearing habitat in the Tucannon River to support additional fall Chinook salmon spawning and rearing. WDFW classified sediment load and habitat quantity as “primary” limiting factors for fall Chinook salmon in the Tucannon River subbasin and habitat diversity and channel stability as secondary (WDFW 2004). Sediment impacts on egg incubation and fry colonization are moderate to high in most reaches (WDFW 2004). Losses of key habitat quantity are considered small to moderate for most life stages; however, losses for fry and juveniles less than one year old are high in some stream reaches (WDFW 2004).

Summary of Lower Tucannon River MaSA Threats and Priority Limiting Factors:

Threat: Agriculture.

Related priority limiting factors: sediment load and habitat quantity, habitat diversity and channel stability.

Summary of Tailrace Areas Threats and Priority Limiting Factors:

Threat: Hydropower development and operations.

Related priority limiting factors: Altered thermal regime, altered flows, habitat diversity.

5.1.5.4 Lower Imnaha River

The lower approximate 20 miles of the Imnaha River provide habitat for fall Chinook salmon in the Upper Mainstem Snake River MaSA. Data from 2000-2014 redd counts indicate that the reach of the Imnaha River contributes a small percentage (1.8 ± 0.2%) of the basin-wide redd counts.

Fall Chinook are present only in the mainstem below the town of Imnaha (Ecovista and NPT 2004). The Imnaha River joins the Snake River at RM 191.7, approximately 48 river miles upstream of Lewiston, Idaho, and 3.4 miles upstream of the Salmon River confluence. The headwaters of the Imnaha River drain the eastern escarpment of the Wallowa Mountains. The subbasin is sparsely populated and contains only the small town of Imnaha (population 25) within its boundaries. The subbasin is 71 percent publicly owned.

Little empirical research exists on limiting factors for fall Chinook salmon production in the Imnaha River. Adult fall Chinook salmon enter the Imnaha River at a time of year when water temperatures are dropping and base flows are increasing (October through the end of November). It is not known whether fine sediment in the mainstem could be limiting substrate availability. Outmigration of subyearlings is also coincident with a period of favorable flow and reduced stream temperatures (end of May through the first half of July) (Ecovista 2004).

The ODEQ developed a TMDL for the Imnaha River ODEQ 2010). The ODEQ listed the entire Imnaha River mainstem and some stream reaches in key tributaries as limited in water quality (the §303[d] list), all for temperature, based on 50 ºF (10 ºC) for year round bull trout spawning, rearing, and adult presence. However, some fisheries biologists and hydrologists contend that the current temperature regime is within the natural potential, given the low-elevation grassland ecosystem, the size of the drainage basin, and limited amounts of riparian modification (USFS 1998d, USFS 2000, cited in Ecovista and NPT 2004).

Summary of Lower Imnaha River Threats and Priority Limiting Factors

Threats: Uncertain.

Related priority limiting factors: Not studied.

5.1.5.5 Lower Salmon River

The lower Salmon River is included as part of the Upper Mainstem Snake River MaSA. Data from 2000-2014 redd counts indicate that the lower Salmon River contributes a small percentage (0.8 ± 0.1%) of the basin-wide Snake River redd counts. Anecdotal accounts suggest that late spawning Chinook salmon may have existed historically in the lower mainstem of the South Fork Salmon River. Burns (1992) found anecdotal evidence for fall Chinook salmon spawning in the lower most portion of the South Fork Salmon River during 1895–1890, the 1930s, and as recent as 1982 (Connor et al. 2015).

The lower portion of the Salmon River flows through private and public lands. The area consists of steep forested mountain slopes, transitioning to drier slopes with shrubs and grasses along the Salmon River canyon. The plume created by cold-water releases from the Salmon River can provide thermal refugia for fall Chinook salmon in the Snake River. Habitat conditions in the lower Salmon River and lower South Fork Salmon River are affected by excess fine sediment and reduced riparian vegetation.

Summary of Lower Salmon River Threats and Priority Limiting Factors

Threats: Uncertain.

Related priority limiting factors: Not studied for fall Chinook salmon.

5.1.6 Estuary, Plume and Ocean

The Columbia River estuary and plume and the Pacific Ocean are inter-connected habitats that have a major effect on the viability of Snake River fall Chinook salmon and other species. These habitats, and their use by Snake River fall Chinook salmon and other species, are discussed in the Estuary Module (NMFS 2011b, Appendix F) and Ocean Module (Fresh et al. 2014, Appendix D) and summarized in this section.

5.1.6.1 Estuary and Plume

The estuary and plume provide important habitat for juvenile Snake River fall Chinook salmon to rear, feed, avoid predators, and acclimate to salt water. Juveniles from this ESU enter the estuary (based upon passage of PIT-tagged fish at Bonneville Dam) in two peaks over a long time period. The peak of the first mode, which are likely the yearlings, is early to mid-May while the peak of the second mode, which is likely the subyearlings, has been late June to early July. In the estuary, the two life history types have distinct residence times. The yearlings spend an average of around a week in the estuary. In comparison, some subyearlings can rapidly migrate through the estuary while others can rear for an extended period of up to several months in the estuary. Habitat use varies with migrating fish more associated with the mainstem and larger distributaries and rearing subyearlings often associated with shallow water areas such as wetlands and shoreline areas (Fresh et al. 2014).

Over the last 100 years, the estuary and plume have undergone significant change as a result of human development, both throughout the Columbia River basin and in the estuary itself. These changes have altered the function of these areas as habitat for salmon and steelhead (NMFS 2011b; Fresh et al. 2005). Where historically marshes, wetlands, and side channels along the lower river provided salmon with food and refuge, most of these shallow water habitats have been diked off from the river (Figure 5-8). Corbett (2013) estimated losses of 70 percent for vegetated tidal wetlands and 55 percent for forested uplands. Much of this area has been converted for agriculture, but significant areas have been lost to industrial, commercial, and residential uses.

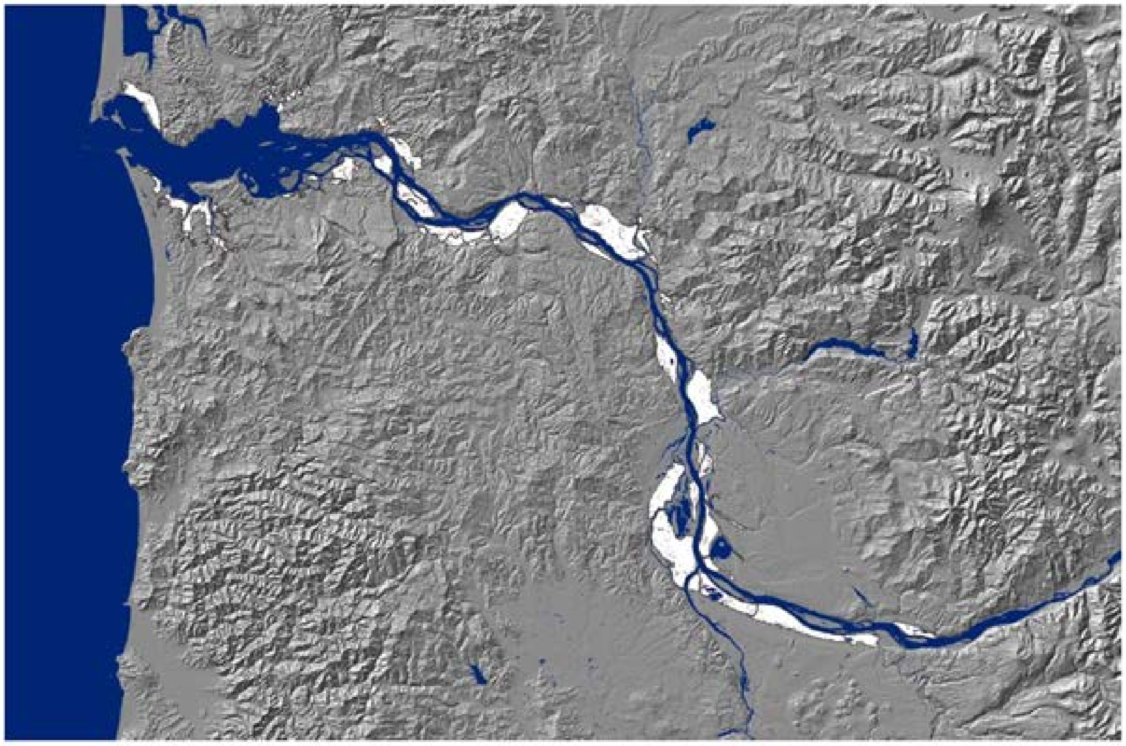

Figure 5-8. Diked Areas in the Columbia River Estuary (NMFS 2011b).

The timing and volume of river flows below Bonneville Dam has changed as a result of construction and operation of the Columbia River hydropower system, diversion of water for agriculture and other uses, and measures to control river flooding. Spring freshets or floods have been significantly reduced, and the annual timing, magnitude, and duration of flows no longer resemble those that historically occurred (NMFS 2011b). These flow alterations, combined with diking and filling practices, have separated the river from its floodplain and nearly eliminated overbank flows into shallow areas of the estuary, significantly reducing the availability of prey - insects, crustaceans, and other particulate organic material derived from the marshes, wetlands, and shallow habitats of the estuary (NMFS 2011b; Bottom et al. 2005). In addition, access to and use of floodplain habitats by subyearling migrants has been severely compromised. Sediment transport processes have also changed significantly along with changes in flow, and while the full impact of these changes is unknown, where the river historically was murky with sediment washed down from above, dams now block sediment flow and thereby increase the exposure of salmon to predatory fish and birds (NMFS 2011b).

Water quality in the estuary and plume has also been degraded by human practices from within the estuary and from upstream sources. Elevated water temperatures and toxic contaminants both pose risks to salmon and steelhead in the estuary (NMFS 2011b). A number of other limiting factors and threats to salmon and steelhead in the estuary are less well understood. These include shifts in the food web and species interactions (including competition and predation), overwater and instream structures, and ship-wake stranding of juveniles (NMFS 2011b).

5.1.6.2 Ocean

The conditions that juvenile and adult fall Chinook salmon experience in the ocean environment also have a significant effect on productivity and survival. Conditions in the ocean vary considerably between years; poor ocean conditions can result in poor salmonid survival and low returns to the Columbia River, while good ocean conditions can boost survival, health and body size of returning fish. Much remains unknown about Snake River fall Chinook salmon use of ocean habitats, and when and where mortality occurs in the ocean. The Ocean Module (Fresh et al. 2014) describes what we know about the ocean environment and its connection to the estuary, the use of this environment by different species, and the risks to salmon during their ocean life. Ocean-related limiting factors and threats are summarized here.

Evidence suggests that early marine life is a period of critical mortality for some salmonid stocks. Mortality during this phase is highly variable from year to year and can be an important determinant of year-class strength. The first of two critical periods is thought to occur during the first few weeks to months of ocean life and to be controlled by predation (MacFarlane 2010; Duffy and Beauchamp 2011; Tomaro et al. 2012; Miller et al. 2013; Burke et al. 2013; Trudel and Hertz 2013; Brosnan et al. 2014; Fresh et al. 2014). Based on work with coho salmon, the second period, during and following the first winter at sea, is thought to be a result of starvation (Beamish and Mahnken 2001). The hypothesis for the second period is that the fish have to consume enough food during their first spring and summer at sea to achieve a critical size with enough accumulated energy reserves to allow them to successfully survive the winter. Thus, the condition and size of salmon as they leave the estuary and first enter the ocean are likely to be an important determinant of subsequent survival and adult returns.

Snake River fall Chinook salmon subyearlings and yearlings generally stay in nearshore areas but exhibit different strategies in the ocean. Subyearlings in general (independent of origin) migrate slower, are found closer to shore in shallower water, and do not disperse as far north as yearlings.Yearling Snake River fall Chinook salmon do not move as far north as yearling Snake River spring and summer Chinook salmon, but by the beginning of their second year at sea they appear to move off the continental shelf and into the Gulf of Alaska. Yearling Snake River fall Chinook salmon can be found in the Gulf of Alaska by fall, although most of these fish move only as far north as southeast Alaska during their first ocean year. At the beginning of their second ocean year, most fish move off the shelf and into oceanic habitats (Fresh et al. 2014). From the end of their first year until they return to the Columbia River as adults, little is known about the ocean life of this ESU. What is known is that the ocean ecosystem has a strong influence on the health and survival of the fish during their time in the ocean, and their condition upon returning to the Columbia River. This influence was illustrated in 2014, when fall Chinook salmon returns were correlated with a single index, the northern “cold water” copepods. The copepods, an invertebrate, are one of the main food sources for juvenile Chinook salmon, and their prey, in the Northern California Current (NCC). The NCC, which the fish enter directly after leaving the Columbia River plume, flows between the coasts of Vancouver Island, Washington, Oregon, and California. Juvenile fall Chinook salmon are found chiefly in these nearshore waters, within a few miles of the coast. Recent findings relating fall Chinook salmon abundance to copepod condition illustrates the importance of ocean food and growth. Studies indicate that the copepod condition had improved over the previous two years such that nearly 80 percent of the variation in fall Chinook salmon counts at Bonneville Dam could be explained by northern copepods alone (Peterson et al. 2014).

There is some evidence that flow during seaward migration through the mainstem Columbia influences mortality rates during one or both of these periods. Studies by Petrosky and Schaller (2010) and Haeseker et al. (2012) correlated lower mainstem flows with reduced marine survival for Snake River spring/summer Chinook salmon; however, the mechanisms to explain these statistical relationships were unclear. Flow can influence arrival timing in the estuary (Scheuerell et al. 2009; Tomaro et al. 2012), but so can transportation, which has also been related to subsequent mortality (see summary in Williams et al. 2005). Flow also affects plume characteristics (Burla et al. 2010) with additional potential effects on salmon survival. For example, Miller et al. (2013) found that returns of upper Columbia subyearling Chinook salmon to Priest Rapids Dam were related to plume volume at the time of emigration in most years studied.

5.1.6.3 Summary of Estuary, Plume and Ocean Threats and Priority Limiting Factors

The Estuary Module prioritized limiting factors at the estuary scale for yearling and subyearling salmon and steelhead. The limiting factors and associated threats identified in the module as the highest priorities for subyearling and yearling migrants are summarized below and discussed in more detail in the Estuary Module (NMFS 2011b).

Threat: FCRPS flow management: reduced spring flows and other flow alterations in the estuary and plume; diking, filling and other agricultural practices; reservoir-related temperature changes; industrial and urban practices; altered predator/prey relationships.

Related priority limiting factors for subyearling migrants: Reduced in-channel habitat opportunity as a result of changes in flow and sediment/nutrients; reduced off-channel habitat opportunity as a result of changes in flow and bankfull elevation; water temperature; food source changes as a result of reduced macrodetrital inputs; toxic contaminants.

Related priority limiting factors for yearling migrants: Flow-related plume changes; competition and predation (from native birds and native marine mammals).

Related priority estuary and plume limiting factors for both subyearling and yearling migrants: Reduced in-channel and off-channel habitat availability due to flow regulation and changes in sediment/nutrient supplies; predation; toxic contaminants.

Summary of Ocean Threats and Priority Limiting Factors

Threat: Direct or indirect effects from human actions.

Related priority limiting factors: Little known. Research is needed.

5.1.7 Climate Change

Likely changes in temperature, precipitation, wind patterns, and sea-level height have implications for survival of Snake River fall Chinook salmon, in both their freshwater and marine habitats. Relevant recent descriptions of expected changes in Pacific Northwest climate include Elsner et al. (2009), Mantua et al. (2009), Mote and Salathe (2009), Salathe et al. (2009), Mote et al. (2010), Chang and Jones (2010), and Crozier (2012, 2013). Reviews of the effects of climate change on salmon and steelhead in the Columbia River basin include ISAB (2007), NMFS (2010), Hixon et al. (2010), Dalton et al. (2013), and NMFS (2014c). The NMFS Northwest Fisheries Science Center will also 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. The following is a short summary of potential climate change effects that may be pertinent to Snake River fall Chinook, as derived from the above sources.

Freshwater Environments

Climate records show that the Pacific Northwest has warmed about 0.07 °C since 1900, which is about 50 percent more than the global average warming over the same period (Dalton et al. 2013). As the climate changes, air temperatures in the Pacific Northwest are expected to increase <1 °C in the Columbia Basin by the 2020s and 2 °C to 8 °C by the 2080s (Mantua et al. 2010). While total precipitation changes are uncertain (-4.7% to +13.5%, depending upon the model), increasing air temperature will result in more precipitation falling as rain rather than snow. (Figure 5-9).

Climate experts predict physical changes to rivers and streams in the Columbia Basin that include:

- Warmer temperatures will result in more precipitation falling as rain rather than snow.
- Snow pack will diminish, and stream flow volume and timing will be altered. More winter flooding is expected in transitional and rainfall-dominated basins, and historically transient watersheds will experience lower late summer flows.

A trend towards loss of snowmelt-dominant and transitional basins is predicted. Water temperatures will continue to rise.

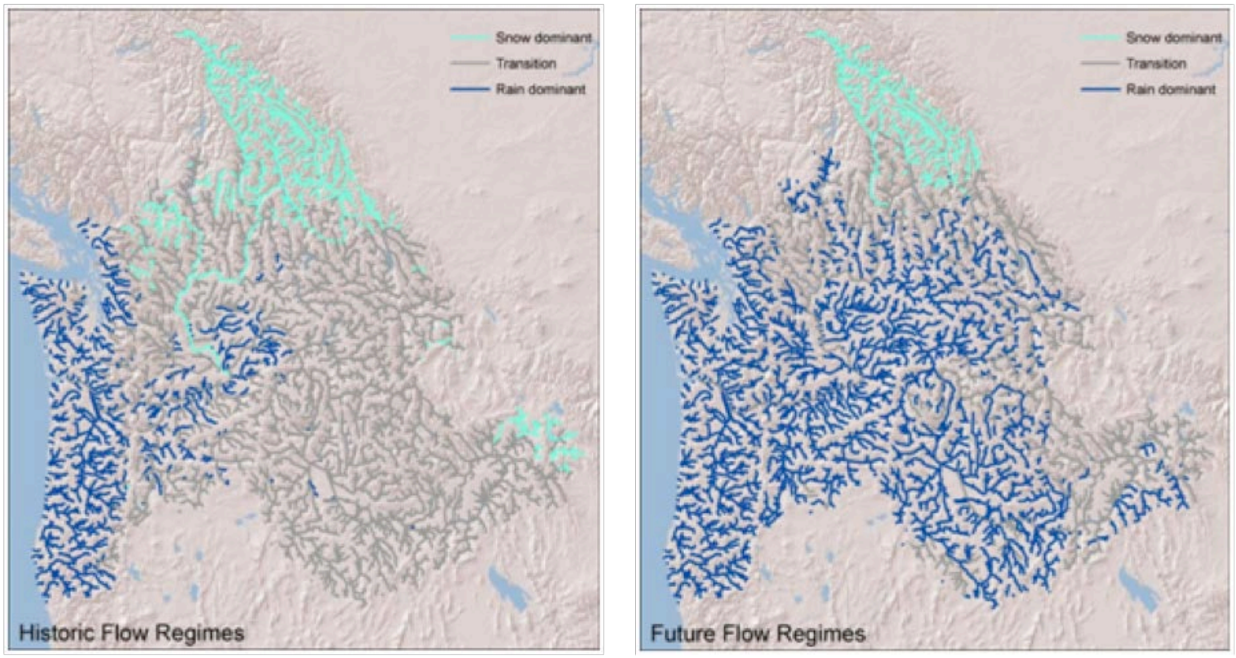

Figure 5-9a & b. Preliminary maps of predicted hydrologic regime for (A) the period 1970-1999 and (B) the period 2070-2099 using emission scenario A1B and global climate model CGCM3.1(T47), based on classification of annual hydrographs as in (Beechie et al. 2006). Data from University of Washington Climate Impacts Group (http://www.hydro.washington.edu/2860/).

These changes in air temperatures, river temperatures, and river flows are expected to cause changes in salmon and steelhead distribution, behavior, growth, and survival, in general; however, the magnitude and timing of these changes, and specific effects on Snake River fall Chinook salmon, remain unclear.

One potential impact of climate change is that increased water temperatures in the lower Snake River could cause migrating adult Snake River fall Chinook salmon to delay passage or fail to enter fish ladders due to high temperatures. This situation occurred at Lower Granite Dam in July and September 2013, when high water temperatures created dangerous conditions for Snake River fall Chinook salmon and other migrants during the period. Higher mainstem temperatures during adult passage is also identified in the FCRPS BiOp 2010, 2014c) as a key concern requiring ongoing monitoring and evaluation, and possibly additional actions to improve survival through the 2008 BiOp's adaptive management provisions (NMFS 2014c).

The effects of climate change will depend on how Snake River fall Chinook salmon migration, spawning timing, emergence, and dispersal are affected by increased water temperatures. Presently, there is not a common understanding among managers about how fall Chinook salmon will respond. RM&E - as described in Section 6 (Recovery Strategy), Section 7 (Research, Monitoring, and Evaluation), and Appendix B - will assess how the species responds to expected increased annual temperatures throughout their life cycle. Information gained from these studies will help determine whether water temperature increases are significant limiting factors for species recovery and what steps could be taken to best address them.

Climate change could affect Snake River fall Chinook salmon in the following ways:

Mainstem Snake River Habitat:

- Adult migration and spawn timing could stay the same or be delayed compared to current timing. Higher water temperatures during adult migration may lead to increased mortality or reduced spawning success due to lethal temperatures, delay, increased fallback at dams, loss of energy reserves due to increased metabolic demand, or increased susceptibility to disease and pathogens.
- If a delay in adult migration and spawn timing occurs, it could trigger a delay in fry emergence and dispersal. If delays in emergence timing are long, i.e. weeks, then timing of smolt migration may be altered such that there is a mismatch with ocean conditions and predators. It is uncertain, however, whether delays in adult run timing would result in delayed fry emergence and dispersal, given that warmer winter temperatures would also increase incubation rates. This uncertainty will need to be monitored.
- If water temperatures accelerate the rate of egg development, it could lead to earlier fry emergence and dispersal. Research by Connor et al. (2002, 2003, 2005) indicated that when water temperatures are warmer during the incubation period of fall Chinook eggs, the timing of the various life history stages (emergence, parr and smolt) occurs earlier. This could be either beneficial or detrimental, depending upon location and prey availability. If juvenile fall Chinook salmon move out of protected shallow, nearshore habitats earlier, and potentially at a smaller size, than it could increase their exposure and vulnerability to predators.
- Warmer temperatures will increase metabolism, which may increase or decrease juvenile growth rates and survival, depending upon availability of food.
- If water temperatures in the lower Snake River warm during spring, summer and fall sufficiently that they cannot be maintained at a level suitable for salmon by cold water

releases from Dworshak Reservoir, then the portion of the Snake River juvenile fall Chinook population that exhibits a “reservoir-type” life history may be diminished or lost. Migrating adults could also be exposed to higher pre-spawning mortality and disease.

- Increases in water temperatures in Snake and Columbia River reservoirs could increase consumption rates and growth rates of predators and, hence, predation-related mortality on subyearling fall Chinook salmon. Juvenile salmonid consumption rates of the three major predators (northern pikeminnow, walleye, and smallmouth bass) in Columbia and lower Snake River reservoirs is highest in July concurrent with maximum availability and temperature (Vigg et al. 1991) and the maximum daily consumption of juvenile salmonids by northern pikeminnow increases exponentially as a function of temperature (Vigg and Burley 1991). Sublethal thermal stress also increases vulnerability to predation (ISAB 2007).
- Higher temperatures may favor food competitors of juvenile fall Chinook salmon, such as American shad in late July or August. Larval and juvenile shad are suspected to reduce the abundance and size of *Daphnia* spp. in Columbia River reservoirs. This could reduce food for over-summering (yearling-type) fall Chinook salmon that prefer *Daphnia* spp. and rear in the reservoirs (Rondorf et al. 1990; ISAB 2007).
- Reduced flow in late spring and summer may lead to delayed migration of juvenile fall Chinook salmon and higher mortality passing dams.

The degree to which phenotypic or genetic adaptations may partially offset these effects is being studied but is currently poorly understood. The subyearling life history strategy allows different avoidance mechanisms than for species that have to over summer. Consequently, potential impacts on Snake River fall Chinook salmon could be reduced compared to fish with juveniles that over-winter before migration if the fish adjust their migration timing accordingly.

Estuary and Plume Environments

Climate change will also affect Snake River fall Chinook salmon in the estuary and plume. In the estuary, Snake River fall Chinook salmon would be primarily affected by predation. Snake River fall Chinook salmon appear to move through the estuary relatively quickly and use the estuary habitat less than some other Chinook salmon ESUs with subyearling life histories. Juvenile fall Chinook salmon may also be affected by changes in the plume; however, use of plume habitat by the species remains poorly understood. Effects of climate change on fall Chinook salmon in the estuary and plume may include:

- Higher winter freshwater flows and higher sea levels may increase sediment deposition and cause 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 predation if higher temperature of freshwater inflows and seasonal expansion of freshwater habitats extends the range of non-native, warm-water species that are normally found only in freshwater.

In all of these cases, the specific effects on Snake River fall Chinook salmon abundance, productivity, spatial distribution and diversity are unclear.

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 (PDO), 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. However, because there is currently a paucity of research directly related to the effects of ocean acidification on salmon 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 abundance in the Pacific Northwest and Alaska are likely to be reduced.

Summary of Likely Climate Change Impacts to Snake River Fall Chinook Salmon

It is possible that Snake River fall Chinook salmon may be among those salmonids either least affected by, or most likely to adapt to, climate change effects on the mainstem and tributary habitat. Climate change could pose less impact on the species because: 1) adults are able to avoid peak summer temperatures and still spawn; 2) juveniles will likely grow faster if winter/spring conditions are warmer and migrate earlier - avoiding elevated summer temperatures; 3) current use of tributary habitat seems to be limited by low winter water temperature and could improve if the temperatures rise; and 4) the fish appear to rely less on estuary habitat than other Chinook salmon ESUs with subyearling life history patterns.

Nevertheless, the effects that climate change will have on species abundance, productivity, spatial structure, and diversity remain poorly understood. It is possible that increased water temperatures in the lower Snake River could cause migrating adult Snake River fall Chinook salmon to delay passage or fail to enter fish ladders due to high temperatures. As a result, the higher water temperatures could increase mortality or reduce spawning success due to lethal temperatures, delay, increased fallback at dams, loss of energy reserves due to increased metabolic demand, or increased susceptibility to disease and pathogens. It is also possible that the portion of the Snake River juvenile fall Chinook salmon population that exhibits a “reservoir-type” life history may be diminished or lost if water temperatures in the lower Snake River rise sufficiently during spring, summer, and fall that they cannot be maintained at a level suitable for salmon by cold water releases from Dworshak Reservoir. In addition, the fish could also be very susceptible to changes in the estuary, plume, and ocean environments. These possibilities reinforce the importance of achieving survival improvements throughout the entire life cycle.

Remaining uncertainty regarding the effects of climate change also reinforces the importance of conducting studies to document climatic effects on freshwater, estuary and ocean productivity, and adjust actions accordingly through adaptive management. Current modeling studies are designed to integrate across various effects, including climate change. Studies to date focus on the effects of increased summer temperatures and late summer or fall flows on juvenile survival.

Summary of Climate Change Threats and Priority Limiting Factors

Threat: Climate change: warmer air and water temperatures, changes in precipitation and flow patterns, and increased acidification in the Pacific Northwest and ocean.

Related priority limiting factors: Passage delay; gamete viability; pre-spawn mortality.

5.1.8 Effects of Hydropower and Habitat on Species Viability

This section summarizes how the hydropower- and habitat-related threats and priority limiting factors in each reach affect Snake River fall Chinook salmon viability. In general, the discussions in this section focus on how the limiting factors affect viability by influencing several or all of the VSP parameters (abundance, productivity, spatial structure, and diversity) at once, rather than trying to dissect the effects by VSP parameter. This is because the different limiting factors -

altered temperature regime, altered flows, passage, blocked habitat, etc. - are often interrelated and work together to influence several of the VSP parameters simultaneously.

Historical Mainstem Snake River Habitat Upstream of Hells Canyon Complex

The most dramatic effect of hydropower projects on Snake River fall Chinook salmon viability in this reach is blocked access to important historical production areas. Lack of access to this area restricts fall Chinook salmon to the area downstream of the tailrace of Hells Canyon Dam, which represents a small percentage of the species' historical range. The loss of this historical habitat has significantly affected the species' abundance and productivity. It has reduced the species spatial structure to a small fraction of its historical distribution. It reduced the ESU to a single fall Chinook salmon population and led to the extirpation of the historical population, which was very productive. The historical population's early emergence and migration timing once contributed significantly to the species' life history and genetic diversity.

Successful reintroduction of a fall Chinook salmon population above the Hells Canyon Complex could improve the probability of persistence of the ESU by improving abundance, productivity, spatial structure, and diversity. However, historical habitat areas upstream of the complex are presently too degraded to support anadromous fish at a level that would contribute to species' viability. Currently degraded water quality conditions - excessive nutrients and algal growth, sedimentation, toxic pollutants, and low dissolve oxygen - reduce the quality and quantity of habitats needed to support a viable population.

Upper Mainstem Snake River MaSA ─ Mainstem Snake River from below Hells Canyon Dam to the Salmon River mouth

Historically, this reach was not a high production area for fall Chinook salmon because of a cold thermal environment during the incubation and rearing period. The confined river channel further restricted spawning and incubation of fall Chinook salmon in the reach. Today, operations from the Hells Canyon Complex improve the thermal environment in the reach. They provide warmer flows during the incubation period that allow for earlier fry emergence and higher productivity than historically. The reach is now one of the two main spawning areas for Snake River fall Chinook salmon and produces the highest proportion of redds of all the major spawning areas.

Nevertheless, operation of the Hells Canyon Complex contributes to factors that limit Snake River fall Chinook salmon viability in this reach. While the warmer thermal regime during the incubation period supports an earlier life history timing (emergence, parr, and smolt) and allows fish to outmigrate before water temperatures in the reach rise to potentially lethal levels, it may also affect abundance and productivity by causing some pre-spawning mortality, reduced egg viability, or egg-to-fry survival. Currently, there is not enough information to determine conclusively how exactly the altered thermal regime affects spawning or incubating fall Chinook salmon. Regardless, spawning densities in this area are high with the major spawning area in this reach producing the largest proportion of the redds for the entire population, approximately 30 percent (see Section 2.4, Distribution). Other factors associated with operation of the Hells

Canyon Complex that limit Snake River fall Chinook salmon viability include low dissolved oxygen, high total dissolved gas, changes in sediment processes and turbidity, as well as daily and hourly flow fluctuations that can result in entrapment or stranding of juveniles, or dewatering of redds. These factors influence viability by reducing species abundance and productivity.

Lower Mainstem Snake River MaSA ─ Lower Mainstem Snake River from mouth of Salmon River to Lower Granite Dam

Historically, habitat conditions in this mainstem reach were less conducive to fall Chinook salmon production than in productive areas of the Middle Snake River above the Hells Canyon Complex. The reach exhibited conditions typical of its arid high desert environment, with cooler winter and early spring water temperatures and higher summer temperatures. Today, habitat conditions in this reach reflect operations from the Hells Canyon Complex. Flow fluctuations reduce riparian vegetation in the reach and can strand fry in the shallows. High water temperatures can affect adult holding and spawning, as well as juvenile rearing in nearshore areas. These factors have the potential to reduce species abundance, productivity, and spatial structure; however, it is currently not clear whether the factors are significantly impacting the fish. Many juveniles may arrive in the reach before temperatures become a concern and then outmigrate before temperatures rise. Most adults may also miss the high water temperatures, arriving in the reach after temperatures decline. In addition, the effects on fall Chinook salmon in this reach may be weakened by the influence of colder flows contributed by the Salmon and Grande Ronde Rivers. However, these tributaries have water quality and flow issues of their own (Section 5.1.5), with varying effects on water quality in the mainstem.

Mainstem Migration Corridor ─ FCRPS reservoirs and dams on the Lower Snake and Columbia Rivers

The mainstem migration corridor stretches from Lower Granite reservoir to the Columbia River estuary. Migrating fall Chinook salmon must pass four federal dams on the Columbia River: Bonneville, The Dalles, John Day, and McNary Dams, and four lower Snake River dams: Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Dams. Hydropower system development and operations have also inundated historical production areas and reduce mainstem habitat quality.

While recent changes in the migration corridor have reduced impacts associated with the hydropower system and boosted survival; hydropower-related threats and limiting factors in this reach continue to affect Snake River fall Chinook salmon viability. The system of dams and reservoirs contributes to reduced abundance, productivity, and spatial structure by lowering survival through the mainstem corridor, as well as the amount of spawning rearing habitat available to fall Chinook in historical production areas. This impact on spawning and rearing habitats could also affect life history diversity. Still, both adult and juvenile passage rates have improved in recent years. Adult passage facilities are now considered highly effective but mortality and passage delays continue to occur. Snake River adult upstream migrants are also affected by thermal blocks that are longer in duration and larger in size than would have existed historically. Juvenile mortality also continues to occur during passage through the FCRPS dams and reservoirs. Snake River juvenile migrants pass the eight federal mainstem dams via routes through turbines, by way of the spillway, or through the juvenile bypass system. Research shows that direct survival through spillways and bypass systems tends to be high for juvenile migrants, although there is evidence that fish bypass systems are associated with some latent, or delayed, mortality in the estuary and ocean. Currently, about half of juvenile migrants are transported around the dams and released below Bonneville Dam to reduce mortality; however, this practice may affect species diversity by selecting against smaller migrants. Ecosystem alterations attributable to the hydropower dams also reduce species abundance and productivity by creating conditions that favor non-native piscivorous fish and increase predation by birds and marine mammals on Snake River fall Chinook salmon juveniles.

Tributary major spawning areas and habitat

Three tributary reaches - the lower Clearwater, Grande Ronde, and Tucannon Rivers - are considered MaSAs for Snake River fall Chinook salmon but are secondary to the two mainstem Snake River MaSA reaches. Two other tributaries, the Imnaha and Salmon Rivers, provide smaller amounts of habitat for fall Chinook salmon and are considered part of the Upper Mainstem Snake River MaSA. Current degraded habitat conditions in these tributary areas restrict species abundance, productivity, spatial structure, and diversity.

Lower Clearwater River MaSA. Several factors reduce habitat quality and quantity in the lower Clearwater River for spawning and rearing fall Chinook salmon, including an altered thermal regime, sediment, and altered flows (variability and base flow). The lower Clearwater River is highly influenced by operations at Dworshak Dam, located 1.9 miles up the North Fork Clearwater, which alters natural temperature and flow regimes. Together, these factors affect fall Chinook salmon abundance, productivity and spatial structure. They also influence species diversity since conditions in the lower Clearwater River favor an earlier spawn timing compared to the Snake River mainstem, resulting in a prolonged incubation and early rearing life-history phase. These conditions have contributed to the development of an alternative life history strategy. Several tributaries to the Clearwater River, including the South Fork Clearwater and Selway Rivers, also support some fall Chinook salmon spawning and rearing. Improving conditions in these tributary minor spawning areas would support efforts to increase the abundance, productivity, spatial structure, and diversity of fall Chinook in the Clearwater MaSA.

Lower Grande Ronde River MaSA. Several factors currently limit abundance, productivity, spatial structure, and diversity of natural-origin fall Chinook salmon in the lower Grande Ronde River MaSA, including lack of habitat quantity and diversity, excess fine sediment, degraded riparian conditions, low summer flows, high summer water temperatures, low concentrations of dissolved oxygen, and nutrients. These degraded habitat conditions are generally the result of combined past and current land use practices.

Lower Tucannon River MaSA. The Lower Tucannon River supports some spawning and rearing of fall Chinook salmon, although most of these fish are hatchery fish. Currently, there is a lack of evidence of natural-origin spawners in this MaSA. Factors limiting fall Chinook salmon abundance, productivity and spatial structure in the lower Tucannon River include sediment load, habitat quality and diversity, and channel stability. This major spawning rear also includes the tailrace reaches of lower Snake River dams. These tailrace reaches currently support limited spawning but contribute to species productivity and spatial structure. The MaSA lies at the downstream end of the population and ESA, and the loss of occupancy of naturally produced spawners in the Tucannon MaSA increased the distance between the Snake River Fall Chinook ESU and downstream ESUs in the Columbia Basin (ICTRT 2007). While the lack of occupancy in the lower Tucannon River MaSA does not create a gap among spawning aggregates within the population, the overall risk to the ESU may have increased somewhat as a result of the loss of natural connectivity between this population and downstream ESUs.

Estuary, plume, and ocean

Freshwater, estuary, plume, and ocean ecosystems are all connected biologically. Conditions in these inter-connected habitats affect Snake River fall Chinook salmon abundance, productivity, spatial structure and diversity. The management actions that take place in freshwater, particularly flow management of the FCRPS hydropower system, affect fish density in the estuary and ocean, as well as fish size and condition, timing of ocean entry, and even the growth and survival of fish during later fish life stages. Further, the conditions in the estuary and plume, and their effects on the condition and size of fall Chinook salmon as they leave the estuary and first enter the ocean, can be important determinants of subsequent survival and adult returns. For example, mean body size at ocean entry is correlated with adult returns.

In the estuary, combined impacts due to flow management by the FCRPS hydropower system and land use practices (including diking and filling) have led to reduced availability of in-channel and off-channel habitat for rearing fall Chinook salmon. They have also affected the thermal regime, caused changes in the food supply, and increased predation and competition. These impacts can stretch into the plume, where habitat functions have also been altered. Snake River fall Chinook salmon sub-yearlings and yearlings show different migration patterns through these estuary and plume environments. In the estuary, their behavior in, and use of, different habitats ranges from rapid migration to extended rearing. The yearlings often migrate through the area within about a week, while sub-yearling either migrate rapidly through the area or linger for up to several months in more shallow waters such as wetlands and shoreline areas. Thus, the health and diversity of different estuarine habitats not only contributes to species abundance and productivity, but also influences species diversity by supporting different life history strategies and characteristics.

Conditions in the ocean vary considerably between years, and the ocean ecosystem has a strong influence on the health and survival of the fish during their time in the ocean, and their condition upon returning to the Columbia River. This influence was illustrated in 2014, when strong fall Chinook salmon returns to the Columbia River were correlated with a single index, the northern “cold water” copepods. Studies indicate that the copepod condition had improved over the previous two years, such that nearly 80 percent of the variation in fall Chinook salmon counts at

Bonneville Dam could be explained by northern copepods alone (Peterson et al. 2014). Consequently, the conditions in each of these connected environments can significantly affect the abundance and productivity of Snake River fall Chinook salmon by affecting the numbers of fish that survive in the ocean and the spatial structure and diversity of the species, depending on whether ocean survival is better for fish from some major spawning areas than others.

5.2 Harvest

This section summarizes fishery-related mortality to Snake River fall Chinook salmon. It also identifies the primary fishery-related threats and priority limiting factors for the species. The Harvest Module (Appendix G) overviews the details of various fisheries, management processes, analyses, and other fisheries-related information in more detail. This information will inform future analysis of Snake River fall Chinook salmon status under ESA section 4(a)(1) listing factors B and D.

Harvest has the potential to affect abundance, productivity, and diversity of Snake River fall Chinook salmon by harvesting (killing) natural-origin adults and by producing selective pressure on migration timing, maturation timing, and size-at-age characteristics. The fish are harvested during fisheries that target harvestable hatchery and natural-origin fish. Harvest effects on natural Snake River fall Chinook salmon include mortality of fish that are caught and released, encounter fishing gear but are not landed, or are directly harvested. Indirect effects also might include genetic, growth, or reproductive changes when fishing rates are high and selective by size, age, or run timing.

Due to their patterns of ocean distribution and the timing of their spawning run up the Columbia River, Snake River fall Chinook salmon are subject to incidental harvest in a wide range of both ocean and inriver fisheries. Coastal fisheries in California, Oregon, Washington, British Columbia, and southeast Alaska have reported recoveries of tagged fish from the Snake River. The timing of the return and upriver spawning migration of Snake River fall Chinook salmon overlaps with the Hanford Reach upriver bright Chinook salmon returns, as well as several large hatchery runs returning to lower river release areas or to the major hatcheries adjacent to the lower mainstem Columbia River. In locations where the fish are harvested, it is infeasible to distinguish listed natural Snake River fall Chinook salmon from the large numbers of natural unlisted fish that are targeted for harvest. This difficulty in distinguishing the Snake River fall Chinook salmon run from other, healthier fish runs contributed to past high harvest rates. However, while the relatively high aggregate harvest impacts by ocean and in-river fisheries was one of the factors leading to the ESA listing of the species, harvest impacts declined after listing and have remained relatively constant in recent years (Good et al. 2005).

5.2.1 Exploitation Rates

No direct estimates of ocean harvest impacts on natural-origin Snake River fall Chinook salmon are available. However, ocean exploitation rates based on coded wire tag (CWT) results for subyearling releases of Lyons Ferry Hatchery fish are used as surrogates in fisheries management modeling. Total harvest mortalities for the combined ocean and inriver fisheries can be expressed in terms of exploitation rates, which provide a common currency for comparing ocean and inriver fishery impacts. Fisheries in the Columbia River are generally managed subject to harvest rate limits. Harvest rates are expressed as the proportion of the run returning to the river that is killed in river fisheries.

The Pacific Salmon Commission's Chinook Technical Committee (CTC) provides estimates of total exploitation rates for Snake River fall Chinook salmon based on an analysis of tagged subyearling Chinook released from Lyons Ferry Hatchery for catch years 1988 to 1994 and 2003 to 2010 (Table 5-2). There were too few tag recoveries during the intervening years to conduct the necessary analysis.

Table 5-2. Exploitation rate analysis of Lyons Ferry fingerlings CWTs by Pacific Salmon Commission Chinook Technical Committee modified by Snake River fall Chinook salmon Wild in-river harvest rates from run reconstruction, March 2015.

Catch Year	Total Exploitation Rate (%)	WA-OR-CA marine only	Columbia River only
1989	0.82	0.23	0.24
1990	0.75	0.19	0.29
1991	0.68	0.09	0.21
1992	0.57	0.11	0.15
1993-2002	na	na	na
2003	0.45	0.15	0.15
2004	0.37	0.10	0.16
2005	0.48	0.13	0.18
2006	0.51	0.15	0.18
2007	0.38	0.08	0.18
2008	0.47	0.12	0.20
2009	0.51	0.07	0.30
2010	0.45	0.15	0.19
2011	0.44	0.08	0.27
2012	0.51	0.14	0.26
2013-14	Na	na	na
Av. 1989-92	0.70	0.16	0.22
Av. 2003-12	0.46	0.12	0.21

In recent years, about 10 percent of the take has occurred in the Southeast Alaska fishery, about 22 percent in the Canadian fishery (primarily off the west coast of Vancouver Island), about 26 percent in the coastal fishery (primarily off Washington, and to a lesser degree off Oregon and Northern California), with the remaining 42 percent occurring in the non-Treaty and treaty Indian fisheries in the Columbia River (CTC 2102). In-river gillnet and sport fisheries are "shaped" in time and space to maximize the catch of harvestable hatchery and natural (Hanford Reach) stocks while minimizing impacts on the intermingled Snake River fall Chinook.

Reductions in ocean fishery impacts on Snake River fall Chinook salmon resulted from management measures designed to protect weakened or declining stocks specific to each set of fisheries. Fishery reductions have occurred through a series of agreements negotiated through the Pacific Salmon Treaty, which was first ratified in 1985. The Chinook Annex of the Pacific Salmon Treaty was renegotiated most recently, resulting in a new 10-year agreement covering the period from 2009 through 2018. Among other things, the Agreement results in harvest reductions of 15 percent in Southeast Alaskan fisheries and 30 percent in fisheries off the west coast of Vancouver Island.

As indicated above, fisheries in the Columbia River are managed subject to harvest rate limits. Harvest rates are expressed in terms of the proportion of the run returning to the river that is killed in the river fishery and therefore cannot be compared directly with the exploitation rate estimates shown in Table 5.2.

Table 5-3. Observed harvest rate in the Columbia River on Snake River fall Chinook salmon compared to the maximum allowable harvest rate limit under the 2008-2017 U.S. v Oregon Management Agreement (NMFS 2014b).

Year	Observed HR (%)*	Allowed HR (%)	Difference
1996	27.1%	31.3%	4.2%
1997	32.2%	31.3%	-0.9%
1998	26.7%	31.3%	4.6%
1999	30.4%	31.3%	0.9%
2000	28.7%	31.3%	2.6%
2001	21.2%	31.3%	10.1%
2002	28.0%	31.3%	3.3%
2003	21.7%	31.3%	9.6%
2004	20.7%	31.3%	10.6%
2005	25.3%	31.3%	6.0%
2006	27.0%	31.3%	4.3%
2007	22.6%	31.3%	8.7%

Year	Observed HR (%)*	Allowed HR (%)	Difference
2008	27.6%	31.3%	3.7%
2009	38.0%	38.0%	0.0%
2010	26.0%	33.3%	7.3%
2011	32.8%	45.0%	12.2%
2012	34.8%	45.0%	10.2%
2013	31.2%	45.0%	13.8%
1996-2000 Average	**27.9%**	**31.3**	**6.2%**

Fisheries in the Columbia River were managed for many years subject to an ESA-related harvest rate limit of 31.3 percent. The harvest management structure was changed with adoption of the most recent *U.S. v. Oregon* Agreement. Under the 2008-2017 *U.S. v. Oregon* Management Agreement, the harvest of Snake River fall Chinook salmon in the Columbia River may vary from year-to-year based on the abundance-based harvest rate schedule in Table 5-3. Allowable harvest on any given year depends on the abundance of unlisted upriver fall Chinook salmon and natural-origin Snake River fall Chinook. The allowable harvest rate ranges from 21.5 percent to 45.0 percent.

The harvest rate schedule in Table 5-4 modifies the past practice of managing fisheries subject to a fixed harvest rate, providing a management structure that is responsive to the status of the species. Under the new schedule, harvest may vary up or down depending on the overall abundance of unlisted upriver fall Chinook salmon and listed natural-origin Snake River fall Chinook. The harvest rate schedule is generally calibrated to provide higher harvest rates when abundance is high enough to accommodate the increased harvest and still meet the ICTRT recovery abundance threshold of 3,000 natural-origin fish to Lower Granite Dam. Conversely, when numbers are low, harvest rates are reduced to provide greater protection. As shown in Table 5.3 the actual harvest rates have been consistently well below the harvest rate limit.

Table 5-4. Abundance-based harvest rate schedule for Snake River fall Chinook salmon under the 2008-2017 *U.S. v. Oregon* Management Agreement (TAC 2008; copied from Harvest Module).

State/Tribal Proposed SR Fall Chinook Harvest Rate Schedule					
Expected URB River Mouth Run Size	**Expected River Mouth SR Wild Run Size [1]**	**Treaty Total Harvest Rate**	**Non-Treaty Harvest Rate**	**Total Harvest Rate**	**Expected Escapement of Snake R. Wild Past Fisheries**
< 60,000	Or < 1,000	20%	1.50%	21.50%	784
>60,000	And > 1,000	23%	4%	27.00%	730

State/Tribal Proposed SR Fall Chinook Harvest Rate Schedule

Expected URB River Mouth Run Size	Expected River Mouth SR Wild Run Size [1]	Treaty Total Harvest Rate	Non-Treaty Harvest Rate	Total Harvest Rate	Expected Escapement of Snake R. Wild Past Fisheries
>120,000	And > 2,000	23%	8.25%	31.25%	1,375
> 200,000	And > 5,000	25%	8.25%	33.25%	3,338
	And > 6,000	27%	11%	38.00%	3,720
	And > 8,000	30%	15%	45.00%	4,400

1. If the SR natural fall Chinook salmon forecast is less than level corresponding to an aggregate URB run size, the allowable mortality rate will be based on the SR natural fall Chinook salmon run size.

Notes:
Treaty Fisheries include: Zone 6 Ceremonial, subsistence, and commercial fisheries from August 1-December 31.
Non-Treaty Fisheries include: Commercial and recreational fisheries in Zones 1-5 and mainstem recreational fisheries from Bonneville Dam upstream to the confluence of the Snake River and commercial and recreation SAFE (Selective Areas Fisheries Evaluation) fisheries from August 1-December 31.
The Treaty Tribes and the States of Oregon and Washington may agree to a fishery for the Treaty Tribes below Bonneville Dam not to exceed the harvest rates provided for in this Agreement.
Fishery impacts in Hanford sport fisheries count in calculations of the percent of harvestable surplus achieved.
When expected river-mouth run sizes of naturally produced SR Fall Chinook equal or exceed 6,000, the states reserve the option to allocate some proportion of the non-treaty harvest rate to supplement fall Chinook salmon directed fisheries in the Snake River.

5.2.2 Indirect Effects

Harvest has the potential to affect migration timing, maturation timing and size-at-age. Based on the current timing and distribution of the fisheries with CWT recoveries, ocean harvest of Snake River fall Chinook salmon is assumed to impact both maturing and immature fish (Chinook Technical Committee 2007). As a result, the cumulative impact of ocean harvest is higher on components of the run maturing at older ages. Snake River fall Chinook salmon are also harvested by in-river fisheries directed at more abundant fall Chinook salmon runs. Age-specific exploitation rates of in-river fisheries also increase with age-at-return. Annual in-river exploitation rates are reported in two categories: jacks (primarily age-2s, some smaller age-3s) and adults (dominated by age-4 and age-5 returns).

These potential effects are not a limiting factor at this time, and they would result not just from harvest alone, but from collective effects of hydropower, hatchery, and harvest influence. Time series of size, growth, and age should be monitored.

5.2.3 Summary of Harvest Threats and Priority Limiting Factors

Threat: Fisheries.

Related priority limiting factors: Mortality.

Potential limiting factors to keep an eye on: Indirect selection for age, size, or run timing.

5.2.4 Effects of Harvest on Species Viability

Harvest has the potential to influence species abundance and productivity - the number, biomass, age, size, and fecundity of spawners - as well as the genetic characteristics and population structure of the ESU. Snake River fall Chinook salmon are harvested by both ocean and in-river fisheries, and harvest in these fisheries has the potential to produce selective pressure on migration timing, maturation timing, and size-at-age. Mortality due to harvest in the different fisheries is an impact that interacts with other factors to affect salmon abundance, productivity, and diversity. In many areas, the biological characteristics of contemporary population groups have been shaped by continued harvest patterns.

Today, fishery impacts on Snake River fall Chinook salmon viability from ocean and in-river fisheries are controlled through limits to protect this and other listed weak populations. Currently, the primary potential concern is for selective impacts of harvest on natural-origin Snake River fall Chinook salmon on maturation timing, reflected in the relative age composition of fish arriving on the spawning grounds.

5.3 Predation, Competition, and Other Ecological Interactions

This section summarizes the impacts on Snake River fall Chinook salmon from predation in the mainstem Columbia and Snake Rivers, and in the tributaries in which some fall Chinook salmon spawning occurs. It also discusses effects on the species from other ecological interactions, including changes in food web, prey availability, and competition. Mortalities due to these impacts affect species viability by influencing abundance, productivity, spatial structure, and diversity. The following discussions under each topic summarize related impacts and identify the primary related threats and priority limiting factors for Snake River fall Chinook salmon. This information will inform future analysis of Snake River fall Chinook salmon status under ESA section 4(a)(1) listing factors C, D and E.

5.3.1 Predation

Ecosystem alterations attributable to hydropower dams and modification of estuarine habitat have increased predation on Snake River fall Chinook salmon. Some of the predator species' abundance levels have increased dramatically, particularly in localized areas, with associated changes in predation (NMFS 2011b).

Avian Predation

In the estuary, the number and/or predation effectiveness of Caspian terns, double-crested cormorants, and a variety of gull species has increased because of habitat modification (LCREP 2006; Fresh et al. 2005; NMFS 2011b) and an influx of avian predators to the Columbia River Basin from other locations. Avian predators were estimated to have consumed 10 to 30 percent of the total estuarine salmonid smolt production of 1997 (LCREP 2004). Although Caspian tern predation has decreased because of management efforts to reduce the available island habitat, double-crested cormorant predation has increased (Roby et al. 2012). The 2010 season summary of Research, Monitoring, and Evaluation of Avian Predation on Salmonid Smolts in the Lower and Mid-Columbia River (Roby et al. 2011) estimates that terns nesting on East Sand Island near the mouth of the Columbia River consumed 5.3 million juvenile salmonids in 2010, and double-crested cormorants also nesting on East Sand Island consumed 19.2 million juvenile salmonids. Age-zero Chinook, which would include Snake River fall Chinook, made up a major portion of the cormorant colony salmon consumption. The fact that subyearlings, in general, are in shallow water and spend more time in the estuary than stream-type (age one plus) juveniles makes them more vulnerable to cormorants. However, tag studies are showing that interior Columbia subyearlings, which tend to be larger than lower river subyearlings, typically spend less than a week in the river from Bonneville Dam to the Columbia River mouth. Snake River fall Chinook salmon yearlings, which are spring migrants, spend approximately three to four days in the estuary (NMFS 2014c). Thus, Snake River fall Chinook salmon probably are less exposed to estuary predation than other subyearlings from the Willamette and Lower Columbia Rivers. Tern, cormorant, and gulls from colonies on islands in the Columbia River and the Lower Snake also prey on juvenile salmonids, but predation in the estuary is an order of magnitude greater. It is also significant that estuarine predation affects juveniles that have survived the migration corridor and may be more likely to return as adults.

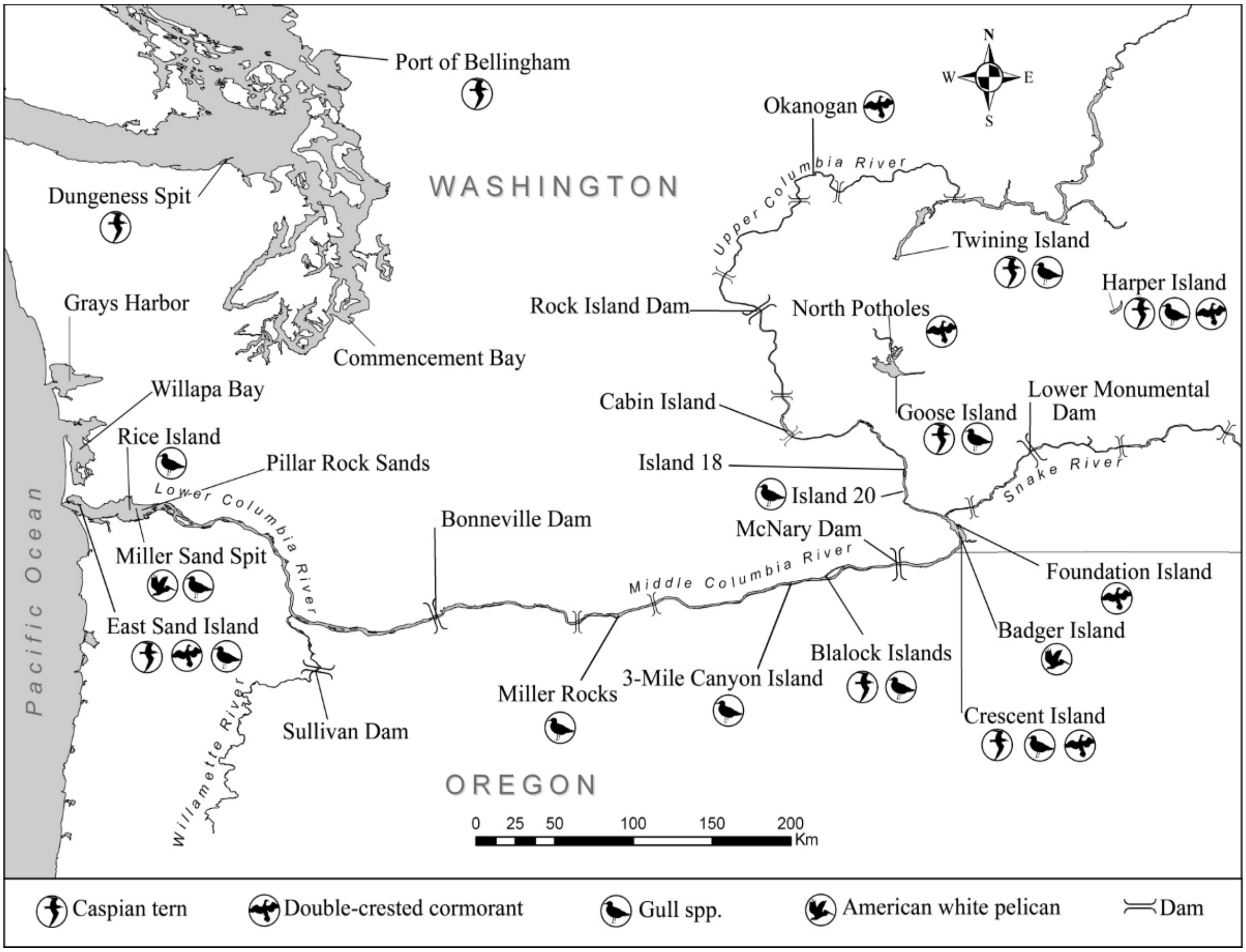

Figure 5-10. Study area in the Columbia River basin and coastal Washington showing the locations of active and former breeding colonies of piscivorous colonial waterbirds mentioned in this report (Roby et al. 2011).

Table 5-5. Predators to Snake River Chinook salmon and steelhead in the Columbia River.

PREDATOR	SPECIES	COLUMBIA RIVER LOCATION
Avian	Caspian Terns	Estuary and Crescent Island and Potholes Reservoir
Avian	Double-Crested Cormorants	Estuary and Foundation Island
Piscivores	Sturgeon, Northern pikeminnow, Walleye, Smallmouth Bass, and Channel Catfish	Total length; highest in dam impoundments and below Hells Canyon Dam Complex
Pinnipeds	Pacific harbor seals, Stellar sea lions, and California sea lions.	Below and in the forebay of Bonneville Dam

Pinnipeds

Marine mammals (pinnipeds) prey on winter and spring migrating adult salmon and steelhead in the lower Columbia River and as they attempt to pass over Bonneville Dam (USACE 2007); Snake River fall Chinook salmon for the most part are not migrating when marine mammals are most abundant and are likely much less affected than either spring or summer Chinook.

Non-native Fish Predation

Predation by non-salmonid fish is a significant concern (Table 5-5). Within the Columbia River basin, juvenile Pacific salmon could encounter no fewer than eight documented non-native predator and competitor fish species en-route to the estuary (Sanderson et al. 2009). Northern pikeminnows and non-native predatory species (e.g., smallmouth bass, walleye, channel catfish, etc.) congregate near dams or at hatchery release sites to feed on migrating smolts. The largest portion of salmon lost to fish predators is in the reservoirs. However, many of the studies that measured predation on juvenile salmonids have not determined the predator and prey population sizes needed to estimate an overall predation impact. On an individual population basis, the effects of predation by non-native fish species may be similar to that associated with passage through the hydro system (Sanderson et al. 2009).

Similarly, predation by nonnative fishes on outmigrating smolts is roughly equivalent to the productivity declines attributed to habitat loss and degradation (Beechie et al. 1994). Although it is difficult to make direct comparisons between adult and juvenile mortality with respect to population impacts, predation rates on juvenile outmigrants are also similar in magnitude to harvest-related mortality rates on adults (3 percent to 84 percent; McClure et al. 2003).

Beamesderfer and Nigro (1989) estimated that walleye annually consumed an average of 400,000 salmonids (250,000 to 2,000,000), or up to 2 percent of the salmonid run from 1983-

1986. Beamsderfer and Rieman 1988 found that of the total salmon consumed, northern pikeminnow consumed 78 percent of the salmon predated in the John Day Pool. Walleye only accounted for 13 percent. Abundance of walleye in the lower Columbia River appears highly variable, but losses of juveniles and smolts to walleye was estimated at up to 2 million fish per year, which compares to 4 million for pikeminnow (Tinus and Beamesderfer 1994).

Sculpins, suckers, and cyprinids (including northern pikeminnow) made up the majority of smallmouth bass diets in the John Day Reservoir; however, bass still ate a large number of salmonids, primarily young-of-the-year Chinook salmon that co-inhabit littoral areas in July and August (Poe et al. 1991). Downstream of Bonneville Dam, bass diets consisted of sculpins (46 percent), cyprinids (19 percent), suckers (16 percent), and salmonids (12 percent).

In the Yakima River, smallmouth bass appeared to have a preference for fall Chinook salmon, which made up to 47 percent of their diet in May; they consumed up to 35 percent of the outmigrants (Fritts and Pearsons 2004). In the Columbia River near Richland, Washington, salmonids made up nearly 60 percent of smallmouth diets (Tabor et al. 1993).

In the Snake River, Shively et al. (1991) and Nelle and Bennett (1999) found lower consumptive rates of juvenile salmonids in the areas they studied compared to the Columbia River studies mentioned above, this was likely due to the low abundance of subyearlings (Nelle 1999; Naughton et al. 2004). However, even though consumption rates are relatively low, the large number of individual predators can result in substantial losses of migrating juveniles. Predation may be a greater problem today due to increased juvenile fall Chinook salmon abundance, particularly if the predator population has increased in response. Subyearling emigrating during summer may be especially vulnerable to predation due to the higher feeding rates of predators at warmer temperatures. Current studies of smallmouth bass predation are ongoing in Hells Canyon and in the upper portion of Lower Granite Reservoir but inferences will be limited by sampling effort and the size of the study areas. Other predators of concern are channel catfish and walleye.

Fishing regulations in Oregon and Washington could potentially be used to control non-native fish predator populations. Fishing regulations currently limit the catch of smallmouth bass and walleye in the Columbia and Snake Rivers (Table 5-6). The state of Washington recently proposed regulatory changes to increase bag limits of non-native fish that are preying on juvenile salmonids.

Table 5-6. Fishing regulations for the Columbia Basin for smallmouth bass and walleye (from State fishing regulations).

Species	Oregon (Columbia River)	Washington	
		Columbia River	Snake River
Smallmouth bass	5 fish per day, no more than 3 of which can be > 15 inches.	From mouth to McNary Dam: 5 fish per day, no more than 3 of which can be > 15 inches. Upstream of McNary Dam: 10 fish per day, only 1 fish can be > 14 inches.	10 fish per day, only 1 fish can be > 14 inches.
Walleye	No minimum size or limit.	From mouth to Priest Rapids Dam: No minimum size, 10 fish per day of which 5 can be > 18 inches, and one can be > 24 inches. Upstream of Priest Rapids Dam: 5 fish per day, minimum size of 16 inches, and only 1 fish can be > 22 inches.	No minimum size, 10 fish per day of which 5 can be > 18 inches, and one can be > 24 inches.

Summary of Predation Threats and Priority Limiting Factors

Threat: Dam operation, reservoirs, alterations to estuary.

Related priority limiting factors: Increased predation by birds and non-native fish.

5.3.2 Other Ecological Interactions – food web, prey availability, and competition

The productivity of juvenile Snake River fall Chinook salmon depends in part on the food web that supports growth and survival and the interaction with predators and competitors. Juveniles exhibit a transitory rearing strategy whereby they use a continuum of riverine and reservoir habitats for rearing and migration. Because juveniles are generalists and opportunistic in their feeding, they are subject to changes in the prey communities that support them. The prey community varies between riverine and reservoir habitats. It is important to understand the capacity of the food web to support current and future levels of juvenile fall Chinook salmon abundances, and how the fish may be affected by changing prey resources resulting from invasion by nonnative species. Competition with both conspecifics and other native fishes will also affect juvenile fall Chinook salmon productivity. For example, the growth rate of fall Chinook salmon rearing in Lower Granite Reservoir has declined in recent years compared to that when the juvenile population was at low abundances in the 1990s (Connor et al. 2015).

Increased competition or changes in food resources may be contributing to this decline in growth rate.

The prey community has changed through time in the lower Snake River since its impoundment due to invasion by non-native species (ISAB 2011). Although Dorband (1980) noted the presence of the estuarine amphipod *Corophium* spp. in Lower Granite Reservoir soon after it was completed, Curet (1993) did not document this species in subyearling fall Chinook salmon diets in the early 1990s. Today, *Corophium* spp. composes a large portion of the subyearling diet at certain times. The cause for this is not known. *Neomysis mercedis*, an estuarine mysid native to the Columbia River estuary, also were not present in the lower Snake River as of about 15 years ago, but have expanded their range upstream and today they are very abundant in the Snake River. The ecological consequence of this species on juvenile fall Chinook salmon is not known because on one hand, it is a planktivore that may reduce the zooplankton population that juveniles feed on, but on the other hand it can be a relatively profitable prey due to its size and energy content (USGS, unpublished). Given their abundance, *Neomysis mercedis* has the potential to alter the food web in either a negative or positive way. Complicating this interaction is the recent invasion by the Siberian prawn *Exopalaemon modestus* (Haskell et al. 2006). This species has been increasing rapidly in the lower Snake River, but virtually nothing is known about its ecology and potential effects on the food web and Snake River fall Chinook salmon. Siberian prawns prey heavily on Neomysis and other invertebrates, which may have cascading effects through lower trophic levels of the food chain and ultimately on prey for juvenile fall Chinook salmon. Finally, non-native American shad *Alosa sapidissima* have the potential to consume a large portion of the zooplankton population (e.g., Haskell et al. 2013) if they become abundant in the Snake River, which may also affect prey availability for Snake River fall Chinook salmon.

Little is known about how competitive interactions affect juvenile fall Chinook salmon growth and productivity. The large increase in juvenile fall Chinook salmon abundance resulting from different recovery and mitigation actions may increase competition for food and space between conspecifics, other salmonids, and native fishes in lower Snake River reservoirs. The wider array of juvenile fishes inhabiting reservoirs may result in competition being more intense in those habitats, which may affect growth potential and the time fish are vulnerable to predators. To date, little is known about the densities of both fall Chinook salmon and other species in reservoir rearing habitats and the capacity of the existing habitat to support them.

Mainstem Snake and Columbia Rivers

Competition for food resources or rearing habitat among salmonids, and between salmonids and other fish species, may occur during downstream migration in the mainstem Snake and Columbia Rivers and in the estuary, depending on numbers of fish, available rearing habitat, and residence time (LCFRB 2004; NMFS 2011b).

Competition may occur on the spawning grounds between hatchery-origin and natural-origin spawners. NMFS has noted that “the apparent leveling off of natural returns [of Snake River fall

Chinook] in spite of the increases in total brood year spawners may indicate that density-dependent habitat effects are influencing production or that high hatchery proportions may be influencing natural production rates (Ford et al. 2010).” However, more study is needed. This is a critical uncertainty for Snake River fall Chinook salmon.

Competition can also occur between salmonids and non-native species. The effects of introduction of non-native species in the estuary, including 21 new invertebrates, plant species such as Eurasian water milfoil, and non-native fish such as shad, are poorly understood. The American shad in particular, because of the sheer tonnage of their biomass, may play a particularly important role in the degradation of the estuary ecosystem. Palmisano et al. (1993a, 1993b) concluded that increased numbers of shad likely compete with juvenile salmon and steelhead, resulting in reduced abundance and production of salmon and steelhead. A study to assess whether or not juvenile shad enhance growth rates of non-native predators (allowing them to prey on salmonids at earlier ages) is underway. Most recently, invasive Siberian shrimp appear to be increasing in abundance in the Snake and Columbia River reservoirs. This species is thought to favor similar prey items as fall Chinook salmon rearing in the Snake River reservoirs and is therefore, likely a direct competitor.

Competition may be a significant factor limiting viability of fall Chinook salmon, but additional research is needed to understand this critical uncertainty.

Snake River Tributary Streams

The extent of competition with other species in Snake River system tributary streams is generally unknown. Hatchery-produced B-run steelhead are released into the Clearwater River and may compete with Snake River fall Chinook salmon (Ecovista et al. 2003). The Nez Perce Tribe also releases coho salmon in the Clearwater River that may compete with Snake River fall Chinook salmon. These are important critical uncertainties to address in the RM&E plan.

Summary of Competition and Other Ecological Interactions Threats and Priority Limiting Factors

Threat: High proportion of hatchery fish on spawning grounds.

Related priority limiting factor: Competition for spawning areas, decreased production.

Threat: Increased abundance of non-native species.

Related priority limiting factor: Competition for space in spawning and rearing areas; competition for food; increased predation.

5.3.3 Effects of Predation, Competition, and Other Ecological Interactions on Species Viability

Predation, competition, and other ecological interactions affect the viability of Snake River fall Chinook salmon by reducing abundance, productivity, and diversity.

Predation. Predation rates by both fish and birds on subyearling Chinook salmon are a significant concern and have reduced survival during the smolt outmigration. Northern pikeminnow, smallmouth bass and avian predators selectively target subyearling Chinook salmon relative to larger yearling migrants. Consequently, mortality due to this predation influences species diversity, as well as abundance and productivity. Predation by sea lions and other marine mammals has less of an effect on species viability because most adults Snake River fall Chinook are not migrating through the lower Columbia River in the spring when the marine mammals are most abundant.

Competition and other ecological interactions. These factors are often interrelated. The capacity of the food web to support current and desired levels of juvenile fall Chinook salmon abundance can affect prey availability, as well as the level of interactions with predators and competitors. Abundance and productivity of juvenile Snake River fall Chinook salmon in a reach is influenced by the prey communities that support them, and this prey community varies between riverine and reservoir habitats. This prey community has changed through time in the lower Snake River since impoundment due to invasion of non-native species. The ecological consequences of this change is unclear. Competition for food or rearing habitats among fall Chinook salmon, and between this and other fish species may also occur in the mainstem migration corridor and estuary. Little is known about how competitive interactions affect juvenile fall Chinook salmon growth and productivity.

Competition between adults may also occur. Competition can occur on the spawning grounds between hatchery-origin and natural-origin fall Chinook salmon spawners, thus affecting natural-origin abundance and productivity. Currently, however, it is not clear whether or how density-dependent habitat effects, and competition with hatchery-origin fish for limited habitat, are influencing natural-origin production. It is also unclear whether competition between adult fall Chinook salmon and non-native species, such as shad, in the mainstem migration corridor and estuary is affecting species viability. Additional research is needed to understand the potential significance of this risk.

5.4 Hatcheries

Hatchery programs can affect all four VSP parameters, and in so doing can be a source of benefits or risks to natural-origin salmonid populations. This apparent paradox can be the source of considerable confusion in discussions of hatchery risk. Most simply put, hatcheries can benefit small populations but can become a risk to productivity and diversity in larger populations, in some cases becoming limiting factors. When natural-origin populations are chronically depressed, the presence of hatchery fish on the spawning grounds that are part of the same population can benefit salmonid viability by reducing extinction risk and conserving genetic variability that would otherwise be lost through genetic drift. On the other hand, as natural-origin spawners increase and extinction risk decreases, hatchery-influenced selection and ecological interactions - such as disease, competition for food and space, and predation - pose risks to natural-origin fish productivity.

Apart from the genetic and ecological risks, the presence of large numbers of unmarked hatchery fish on the spawning grounds can add uncertainty to our understanding of the status of the natural-origin population. Currently only 25 percent of Snake River fall Chinook salmon releases are unmarked; however, large numbers of hatchery fish on the spawning grounds adds uncertainty to estimates of natural-origin productivity even if they are 100 percent marked. In addition, hatcheries and hatchery management can also impose physical environmental changes in a variety of ways, such as increasing or decreasing stream flow, and creation of migration barriers.

In the sections below, we consider the effects of the Snake River fall Chinook salmon hatchery programs on the four VSP parameters. We then summarize the primary hatchery-related threats and priority limiting factors for Snake River fall Chinook salmon. In general, the hatchery programs have increased abundance and spatial structure, but the size of the programs relative to the level of natural-origin production and consequent high proportion of hatchery-origin fish on the spawning grounds raises concerns about natural-origin productivity and diversity. These concerns about the effects of hatchery operations on natural-origin fish productivity and diversity, and the large proportion of hatchery-origin fish on the spawning grounds have been cited in previous status reviews for the species (Waples et al. 1991 and NMFS 2011b). For a more comprehensive treatment of these and all other hatchery program issues, see the recent biological opinion on the Snake River fall Chinook salmon hatchery programs (NMFS 2012a).

5.4.1 Abundance

As described in Section 4, the proportion of natural-origin fish in the run over the last 10 years has been on average only 32 percent of the composite run. However, natural-origin fish numbers are currently in the thousands, which represents a dramatic improvement over the abundance levels in the 1990s. The increased abundance is partly a reflection of the growth of the hatchery programs in addition to improvements in harvest, hydropower and habitat management. In the 1990s, hatchery programs were limited to about 20 percent of their current levels due to concerns about inclusion of fish from other populations that were not part of the ESU.

There are several possible contributing causes to the increased abundance of Snake River fall Chinook salmon, including reduced harvest rates, improved in-river rearing and migration conditions, the development of life history adaptations to current conditions, and improved ocean conditions benefiting the relatively northern migration pattern (Cooney and Ford 2007). Undoubtedly, there are more natural-origin fish present now than before the hatchery programs began, but it is not possible to determine how much of this is due to a real growth in natural productivity rather than a consequence of more natural-origin fish being produced simply because the hatchery programs have artificially put more fish on the spawning grounds. As pointed out in the Biological Opinion (NMFS 2012a), now that the hatchery programs have reached their “mature” sizes, the relative contribution of the hatchery programs to abundance and other factors should be easier to determine.

5.4.2 Spatial Structure

The increased abundance of spawners has been accompanied by an expanded spatial distribution of spawners. It is not clear to what extent this represents the population radiating into new highly productive areas, which would be a positive indicator in terms of recovery, and to what extent it is a reflection of fish being forced into new areas as a result of competition for spawning sites because of the high abundance of the combination of hatchery-origin and natural-origin fish, or because of the particular location of hatchery release sites. Another possibility is an indirect effect caused by the ability of spawners to condition spawning gravel (Montgomery et al. 1999). In this case, even though the large number of fish may be forcing fish into non-optimal spawning areas, their spawning activity there may be increasing the value of these areas. Again, the concurrent increase in hatchery production and improvement in other factors affecting the population makes it impossible to clearly assess the effect of the hatchery programs on natural-origin spatial structure and distribution.

5.4.3 Productivity

Hatchery programs can influence productivity genetically and ecologically. As mentioned above, hatchery programs can increase productivity in very small populations by reducing extinction risk and decreasing genetic drift (the random loss of genetic diversity), but as populations grow and extinction risk and loss of genetic diversity become less serious concerns, the presence of naturally spawning hatchery fish shifts from a benefit to a risk through hatchery-influenced selection (also called domestication) and, in some cases, outbreeding depression. Ecologically, hatchery fish on the spawning grounds can potentially benefit productivity to some extent by conditioning spawning gravel and adding marine-derived nutrients to the ecosystem, but can depress productivity through competition and possibly predation. The larger the number of hatchery-origin fish relative to natural-origin fish, the greater the genetic and ecological risk.

5.4.3.1 Genetic effects

The current hatchery programs, although they have been responsible for substantial increases in abundance, have the potential to diminish Snake River fall Chinook salmon productivity through genetic change in several ways. The major concern by far, and because of this the only one we will discuss in this recovery plan, is loss of fitness through hatchery-influenced selection (also called domestication). Other concerns are discussed at length in the 2012 HGMP Biological Opinion (NMFS 2012a).

Hatchery-influenced selection is caused by the difference between hatchery and natural spawning and rearing environments in ways that cause fish with particular genotypes to be more successful in the hatchery environment than in the natural environment. The concern is that if returning hatchery fish contribute genetically to the natural population, the population will become less adapted to the natural environment, and thus less productive. The magnitude of fitness reduction resulting from hatchery-influenced selection depends on: (1) the extent to which the hatchery and natural environments differ in ways that cause genetic change (i.e.; differences in selective regime) that are different from those in the natural environment; (2) the extent of gene flow between hatchery-origin and natural-origin fish, both in the hatchery and on the spawning grounds; and (3) the length of time this has been going on. In assessing genetic risk or genetic impact, all three factors must be considered. Although there is a substantial and growing body of empirical literature documenting hatchery-influenced selection, demonstrating that fitness consequences can be large, the data and theory do not allow for precision in estimating the magnitude of fitness effects in any particular situation, or offer any guidance on the reversibility of the effects. An additional consideration in the case of Snake River fall Chinook salmon is that no empirical information of this sort is available for this population and almost all the data available is based on fish that are released as yearling smolts (spring Chinook, Coho, and steelhead). Snake River fall Chinook salmon production, both natural and hatchery, is a mix of yearling and subyearling smolts. The effects of hatchery-influenced selection may be less in fish with subyearling life histories.

With regard to the first factor above (the extent to which the hatchery and natural environments differ in ways that cause genetic change), for the most part, the Snake River fall Chinook salmon hatchery programs are typical hatchery programs in that they collect broodstock at a trap or as volunteers to the hatcheries, release smolts, and follow standard hatchery practices in doing so. Some aspects of fish culture in the programs may affect life history. Although this may have productivity consequences, these details will be dealt with under the Diversity discussion below. The dominant concern regarding hatchery-influenced selection in the Snake River fall Chinook salmon hatchery programs is the presumed extent of gene flow, based on the high proportion of natural spawners that are of hatchery-origin. In theory, the effect of large numbers of hatchery-origin fish spawning in the wild can be alleviated somewhat by inclusion of natural-origin fish in the hatchery broodstock. In recent years, however, the proportion of natural-origin fish in the broodstock has been under 10 percent, and the proportion of hatchery-origin fish on the spawning grounds has been over 70 percent (WDFW et al. 2011). A useful metric that puts these two gene flow rates (hatchery to natural and vice versa) in perspective is proportionate natural influence (PNI) (Mobrand et al. 2005; Paquet et al. 2011). Based on a mathematical model, a PNI value of 0.5 or above indicates natural selective forces dominating hatchery selective forces. No empirical data are available on the fitness effects expected under various levels of PNI, but the Hatchery Scientific Review Group (2009) has recommended that populations intended to reach viable status be managed at a PNI of 0.67 or higher in the long run. However, they recognized that lower values may be appropriate in certain conservation situations. The Snake River fall Chinook salmon population currently has a PNI of approximately 0.06, which is considerably below this level.

5.4.3.2 Ecological effects

As mentioned above, solely by virtue of their ability to increase the abundance of spawners, hatchery programs can theoretically increase productivity through delivery of marine-derived nutrients and through conditioning of spawning gravel. Assuming the Snake River fall Chinook salmon spawning population is much larger at present than it would be without hatchery programs, these two effects could be considerable. On the other hand, the river is considerably more eutrophic than it was historically, possibly decreasing the importance of marine-derived nutrients. Estimation of the magnitude of the net benefits would require detailed knowledge of the retention of the added nutrients in the freshwater ecosystem and the incremental improvement in spawning ground condition, and the relative importance of these effects compared to the potentially negative impacts of the hatchery fish.

The presence of large numbers of hatchery fish to the system may also be depressing productivity at the adult stage by increasing competition for spawning sites. Buhle et al. (2009) and Chilcote et al. (2011; 2013) found in other salmon populations that natural productivity is depressed as the proportion of hatchery-origin spawners increases. Competition for space and food can also potentially depress the survival of rearing and outmigrating juveniles. Although the potential for competition seems high because of the large numbers of hatchery fish released, the impact cannot be estimated without a detailed study of habitat usage and food web dynamics.

Another potential ecological concern at the juvenile life stage is predation. The extent of direct predation by hatchery-origin juveniles on natural-origin juveniles is likely to be insignificant because of the size differential and the fact that the hatchery fish for the most part are actively migrating. Indirect predation, predation by other species attracted by the large releases of hatchery juveniles, could be significant, but indirect predation effects have not been quantified.

5.4.4 Diversity

5.4.4.1 Subpopulation structure

A major diversity concern about the current hatchery programs for Snake River fall Chinook salmon is that they may be preventing development or maintenance of subpopulation structure by collecting broodstock primarily at Lower Granite Dam and the two hatcheries, and releasing their progeny without regard for where the parents originated or were released. Operation of the hatchery programs for Snake River fall Chinook salmon thus presumes that only a single panmictic (well-mixed) population is being managed[22]. However, the size and diversity of the primary geographical areas used by Snake River fall Chinook salmon for spawning and rearing (e.g., Lower Granite Dam and Hells Canyon Dam are 129 river miles apart, and spawning occurs in a range of habitat conditions), coupled with some limited information on homing fidelity (Garcia et al. 2004), supports the potential that a naturally reproducing population would have significant subpopulation structure. This subpopulation structure could factor significantly in the viability of the population. Also, a recent genetic study by Marshall and Small (2010) shows some evidence for an existing substructure.

5.4.4.2 Life history patterns

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[22] An NPT effort to develop a program component for the South Fork Clearwater is an exception.

Typically, the goal of mating protocols at salmon hatcheries is to mate fish randomly. Currently spawning protocols at both Snake River fall Chinook salmon hatcheries depart from this typical goal. Older, larger fish are being used preferentially both as a means of compensating for previous protocols resulting in overrepresentation of younger age classes, and as a means of trying to mimic natural spawning structures based on the work of Schroder et al. (2008) and Hankin et al. (2009). These protocols may be an improvement over a strategy of random mating, as fish definitely do not mate randomly in the wild, but it is too early to say what the diversity consequences will be.

Another strategy with uncertain diversity consequences is the release of 15 percent of the hatchery production as yearlings, rather than subyearlings, the dominant juvenile life history. This practice was adopted to achieve higher survivals of hatchery fish; survival rates to adulthood of yearling releases are routinely twice as high as those of subyearlings. Although the dominant life history pattern for these fish is subyearling outmigration, a portion of outmigrants, especially those emigrating from the Clearwater River, overwinter in reservoirs of the hydropower system and enter the ocean as yearlings (Connor et al. 2002; Connor et al. 2005). This may represent a response to relatively low stream temperatures accentuated by cool-water releases from Dworshak Dam. To the extent this response is selected for in an evolutionary sense (Williams et al. 2008), the high survival success of the yearling releases may change the life history more and at a faster rate than would naturally occur. Research is underway to understand the genetic basis of outmigration age in this population.

5.4.5 Critical Uncertainties Related to Hatcheries

As discussed above, there is considerable concern and uncertainty about the effect of the Snake River fall Chinook salmon hatchery programs on the population. In general, the critical uncertainties here are not very different from those that exist for many hatchery programs culturing listed species, because the Snake River fall Chinook salmon hatchery programs are not unusual in design or operation. Most supplementation programs involve a high proportion of hatchery production relative to natural production, and thus involve the same uncertainties about the effects of hatchery-influenced selection and ecological interactions. The major factor increasing uncertainty over the norm in the case of Snake River fall Chinook salmon is that the population is very difficult to study because of geographic extent, habitat, and logistics. These special and general uncertainties are more important in the case of Snake River fall Chinook salmon than in many other populations because the current population is the only extant population in the ESU, and therefore must reach a level of viability or high viability for the ESU to be recovered.

Below we list major uncertainties regarding the effects of the hatchery programs on Snake River fall Chinook salmon. These uncertainties are addressed in objectives 1, 3, and 12 in the RM&E strategy, which is explained in detail in Appendix B and summarized in Section 7.

1. Number of fish on the spawning grounds. Underlying much of the genetic and ecological concern about the effect of the hatchery programs is the perception that the hatchery production is quite large compared to the natural production, but the absolute number and hatchery/natural composition of spawners is uncertain. The population spawns primarily in the Snake and Clearwater Rivers and their tributaries upstream of the Lower Snake Dams, but also spawns in dam tailraces and some areas downstream of the Lower Snake dams. Redd counts are imprecise because in the larger rivers the water may be so deep that many of the redds are not visible. Carcasses are also very difficult to collect. Most of our information on abundance and hatchery/natural mix comes from monitoring at Lower Granite Dam, far below (~100 river miles[23]) where most of the spawning occurs. In addition to uncertainties about what happens between the dam and the spawning grounds, an unknown amount of fallback occurs at the dam. Updated escapement estimates incorporating an estimate of fallback based on reviewing past studies are being generated and fallback studies are being initiated under the current permits to reduce this uncertainty.
2. The hatchery-natural composition on the spawning grounds. Currently about 25 percent of the fish released by the hatcheries are unmarked, so hatchery-natural proportions must be estimated based in part on coded-wire tag expansions. Recent past estimates have also been based in part on a scale-pattern analysis that has been shown to be unreliable. In addition, there may be biases due to sampling rates at the dam. A reanalysis of data from previous years is underway to provide improved estimates of hatchery-natural composition of fish passing Lower Granite Dam. Additionally, a new parentage-based tagging approach has been implemented. Under this method, all adults spawned at the hatchery will be genotyped. Returning unmarked adults can then be traced back to hatchery parents. Fish that cannot be matched to hatchery parents are assumed to be of natural-origin.
3. Reproductive success in the wild of hatchery-origin spawners relative to natural-origin spawners, and consequent fitness loss caused by hatchery-natural interbreeding. Research available to date demonstrates that hatchery-origin fish are usually less successful reproducing on the spawning grounds than natural-origin fish. Therefore, hatchery-natural composition in the broodstock and on the spawning grounds must be adjusted for relative reproductive success in order to be translated to gene flow. This population poses two serious challenges in this regard: First, as previously mentioned, there are reasons to expect that fish with subyearling smolt life histories, such as Snake River fall Chinook, might experience less fitness loss due to the hatchery environment than fish with yearling smolt life histories, but there is very little information on relative reproductive success of hatchery fish with subyearling life histories. Second, because of logistical difficulties, an *in situ* study of relative reproductive success like those done on other populations may not be likely in this population, and no promising alternative approach has been proposed.

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[23] Distance between Lower Granite Dam and Pittsburgh Landing

4. Natural productivity of the population overall and major population segments. The population occupies well over 200 stream miles of large river habitat in the mainstem Snake River and in the Clearwater River drainage. As previously mentioned, the total number of spawners is not precisely known, and the situation is worse for specific areas because many redds are not visible, and carcass recoveries are difficult in most of the spawning areas. Juvenile sampling is also very difficult. Understanding area-specific productivity is important in the evaluation of potential for subpopulation structure.
5. Correlation between hatchery-origin spawner abundance and productivity.
6. Density dependent juvenile survival mechanisms relationship to productivity. Investigate the nature of potential mechanisms (e.g., interactions in the initial natal rearing areas or during the downstream migration phase).
7. Existing subpopulation structure and potential for subpopulation structure development. Determine if major spawning area genetic substructure is consistent with or trending towards levels associated with a naturally functioning population. Subpopulation structure requires geographically separated regions of sustainable production and adequate restriction of gene flow (i.e., homing fidelity of adults) between them. At this point there is no understanding of whether production centers of this sort exist, nor what kinds of modifications to the hatchery programs might keep gene flow sufficiently low to allow the structure to be maintained.
8. Correlation between size of hatchery releases and juvenile survival.
9. Diversity consequences of non-random mating strategies.
10. Diversity consequences of the proportion of yearling fish released.

5.4.6 Summary of Hatchery Threats and Priority Limiting Factors

Threat: High proportion of hatchery fish as juveniles.

Related priority limiting factors: Potential for competition with wild fish in rearing areas for food and other resources.

Threat: High proportion of hatchery fish as adults.

Related priority limiting factors: Genetic change, loss of fitness; disease transmission; competition for resources, including spawning areas; higher mortality from incidental harvest.

5.5 Toxic Pollutants

Throughout their migration corridor and in some rearing and spawning rearing areas, Snake River fall Chinook salmon are exposed to chemical contaminants from agricultural, municipal, industrial, and urban land uses. Exposure to these toxins can affect species abundance, productivity, and diversity by disrupting behavior and growth, reducing disease resistance, and potentially causing increased mortality. This section summarizes toxic water quality impairments for Snake River fall Chinook salmon and discusses potential effects on Snake River fall Chinook salmon from exposure to these contaminants. It also identifies the primary related threats and priority limiting factors for the ESU. This information will inform future analysis of Snake River fall Chinook salmon status under ESA section 4(a)(1) listing factors D and E.

Snake River fall Chinook salmon can be exposed to contaminants carried by runoff from agricultural land uses along the Snake and Columbia Rivers and tributaries. Irrigated agriculture began on lands adjacent to the Snake River around 1880 and developed in a band several miles wide on either side of the river. It remains a predominant land use. Agricultural runoff returns to the river and also recharges the aquifer. It can carry various contaminants from pesticides, fertilizers, and/or animal wastes. The Snake River also carries effluent from Boise, Idaho Falls, Twin Falls, and Lewiston, Idaho, as well as Clarkston, Washington, and the tri-cities of Kennewick, Pasco, and Richland, before its confluence with the Columbia River. These population centers are sources of contaminants associated with urban and industrial activity.

Snake River fall Chinook salmon are further exposed to contaminants during their migration through the Columbia River and estuary. The Columbia River, like the Snake River, passes through agricultural lands and receives urban and industrial runoff in both mainstem and tributary reaches. It also borders the Hanford Nuclear Reservation for approximately 50 river miles. In the estuary, the fish are at risk for exposure to contaminants, including toxicant inputs from large urban centers such as Portland, Oregon, and Vancouver, Washington. Snake River fall Chinook salmon subyearling migrants may be especially at risk because they can make extensive use of shallow, vegetated estuary habitats (Fresh et al. 2005).

The Environmental Protection Agency's *Columbia River Basin State of the River Report for Toxics* (EPA 2009) highlighted the threat of toxic contaminants to salmon recovery in the Columbia River basin. The report identified several classes of contaminants that may have adverse effects on Snake River fall Chinook salmon: mercury, dichlorodiphenyltrichloroethane (DDTs), polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and polycylic aromatic hydrocarbons (PAHs). These and other contaminants, including cooper, have received attention from NMFS because of their potential effects on listed salmonids (NMFS 2008b, 2010, 2011c). These contaminants may have adverse effects on Snake River Fall Chinook salmon. They are found at levels of concern in many locations throughout the Columbia and Snake River basin, and along the Snake River fall Chinook salmon migration corridor, although some contaminant levels are declining in some areas. The contaminants are persistent in the environment, contaminate food sources, increase in concentration in fish and birds, and pose risk to both humans and wildlife (EPA 2009).

The State of the River Report for Toxics also identified other contaminants of concern with potential effects on salmon (EPA 2009). These included metals such as arsenic and lead; radionuclides; combustion byproducts such as dioxin; and "contaminants of emerging concern" such as pharmaceuticals and personal care products. Additional information including geographically targeted studies on these contaminants is needed to evaluate their potential risk to threatened and endangered salmon.

Other recent studies have documented accumulation of persistent organic pollutants - including DDTs, PCBs, and PBDEs − in outmigrating juvenile Snake River fall Chinook salmon collected in the Lower Columbia River and estuary (Sloan et al. 2010; Johnson et al. 2013). However, comparable data on contaminant exposure and uptake in Snake River fall Chinook salmon are lacking for many critical habitats, including reaches of the Lower Snake and Mid-Columbia Rivers containing population centers (e.g. Hanford and the tri-cities of Kennewick, Pasco, and Richland) that are sources of contaminants associated with urban and industrial activity.

Recent NMFS Biological Opinions have addressed pesticide use and water quality criteria for toxic pollutants. In a 2008 Biological Opinion, NMFS concluded that, if applied improperly, several currently uses pesticides could jeopardize the continuing existence of Snake River fall Chinook salmon or damage critical habitat (NMFS 2008e).

The NMFS Biological Opinion on the Idaho water quality criteria for toxic pollutants (NMFS 2014d) found that approval of the proposed chronic water quality criterion for mercury would likely cause adverse modification to critical habitat or lethal and sub-lethal effects to Snake River fall Chinook salmon, and supports Idaho’s human health fish tissue criterion as a reasonable means of protecting Snake River fall Chinook salmon until a more protective water quality criterion can be established. This Biological Opinion also found that approval of the chronic water quality criteria for arsenic, copper, cyanide, and selenium, as well as calculation of metals toxicity levels using the 25 mg/l proposed hardness floor, would result in jeopardy for the Snake River Fall Chinook Salmon ESU. According to the Opinion, the chronic mercury, arsenic, and selenium criteria would not protect salmon against adverse effects on growth, reproduction, and survival mediated through the food chain contamination and uptake of these metals in the diet. The acute and chronic coper criteria could have adverse behavioral effects on growth, reproduction, and survival mediated through food chain contamination and uptake of these metals in the diet. The acute and chronic copper criteria could have adverse behavioral effects from loss of sense of small. The cyanide acute criterion could lead to lethality under cold winter temperatures, while the cyanide chronic criterion is close to threshold for adverse effects on swimming ability and reproduction.

The NMFS Biological Opinion on the Oregon water quality criteria for toxic pollutants (NMFS 2012b) similarly found that the proposed criteria for arsenic, copper, and selenium would not be protective of Snake River fall Chinook salmon. This Biological Opinion additionally found that adoption of the proposed criteria for aluminum, ammonia, lindane, cadmium, dieldrin, endosulfan-alpha, endosulfan-beta, endrin, nickel pentachloraphenol, silver, tributyltyin, and zinc could jeopardize the recovery of Snake River fall Chinook salmon, based on the potential of these contaminants to contribute to mortality at the population level.

NMFS' conclusions in these Biological Opinions do not necessarily indicate that waters in critical habitat are currently impaired by these compounds; instead they indicate that the proposed criteria would not prevent such impairment from occurring. Adoption of the reasonable and prudent alternatives proposed in these two Biological Opinions on Oregon and Idaho water quality standards should provide additional protection for Snake River fall Chinook salmon against the potential adverse effects of these toxic compounds.

In summary, our understanding of the effects on aquatic life impacts of many contaminants, alone or in combination with other chemicals (potential for synergistic effects) is incomplete. For example, in addition to the contaminant groups mentioned above, Snake River fall Chinook salmon may also be exposed to "contaminants of emerging concern" such as pharmaceuticals and personal care products, that are unregulated and whose effects on fish are uncertain. Even for those contaminant classes whose effects are better characterized, our understanding of their interactions with other stressors, food-web mediated effects, and effects in complex mixtures is limited, and this lack of knowledge may lead us to underestimate the risks associated with currently permitted concentrations of these substances.

5.5.1 Summary of Toxic Pollutant-related Threats and Priority Limiting Factors

Threats: Agricultural runoff, legacy mining contaminants, urban and industrial runoff, effluent, and wastes; Reservoirs.

Related priority limiting factors: Contaminants such as DDTs, PCBs, PBDEs, metals, mercury, methylmercury (MeHG), radionuclides, dioxin, etc., causing mortality, disease, reduced fitness.

5.5.2 Effects of Toxic Pollutants on Species Viability

Exposure to toxic pollutants could be affecting species viability; however, our current understanding of the effects on aquatic life impacts of many contaminants, alone or in combination with other chemicals (potential for synergistic effects) is incomplete. Several pesticides and contaminants (mercury, PAHs, PCBs, PBDEs, DDTs, copper, and others) may have adverse effects on Snake River fall Chinook salmon abundance, productivity, and diversity, as they are found at levels of concern in many locations throughout the Snake River basin and along the Snake River fall Chinook salmon migration corridor. Additional information, including geographically targeted studies, on these contaminants is needed to evaluate their potential risk to Snake River fall Chinook salmon and other ESA-listed species.

6. Recovery Strategy: Site-Specific Management Actions and Adaptive Management Framework

6.1 Recovery Strategy for the Snake River fall Chinook salmon ESU and Major Population Group

This recovery strategy is designed to rebuild the Snake River fall Chinook salmon ESU to a level where it can be self-sustaining in the wild over the long term and can be delisted under the ESA. It aims to meet the recovery goals and objectives provided in Section 3 by protecting recent improvements in the species' status, and by closing the remaining gaps between the species' present biological status described in Section 4 and the viability objectives in Section 3. The recovery strategy addresses the threats and priority limiting factors described in Section 5 through the management strategies and associated site-specific actions defined here in Section 6. The recovery strategy is also designed to be consistent with goals identified in Section 3 for the number of Snake River fall Chinook salmon needed in the Snake River system to help maintain tribal, commercial, and sport fisheries on a sustaining basis, and for reintroducing Snake River fall Chinook salmon above the Hells Canyon Complex. NMFS developed this recovery strategy to achieve ESA recovery in a manner consistent with these other goals in the shortest practicable time frame.

The Snake River fall Chinook salmon ESU has unique characteristics that pose challenges for both scientific understanding and successful management. As discussed earlier, and in successive NMFS status reviews, the ESU has lost a significant amount of important habitat upstream of the Hells Canyon Complex of dams on the Snake River, resulting in extirpation of one of two historical populations. Fish from the one extant population must pass eight large mainstem Snake and Columbia River dams and survive other effects of the FCRPS hydropower system as they travel to the ocean and back again. Natural-origin fall Chinook salmon productivity and diversity has also been affected by high aggregate harvest impacts from ocean and in-river fisheries, as well as by past and present hatchery operations and increasing proportions of hatchery-origin fish on the spawning grounds. While the one extant population in the ESU is rated as Viable (low risk of extinction within 100 years), the population needs to achieve a level of Highly Viable (very low risk) for ESU viability and delisting. Reaching this level requires improvements across all four viable salmonid population (VSP) parameters.

As described in Section 3.1, the recovery objectives for this ESU are to establish population-level combinations of abundance and productivity and of spatial structure and diversity such that the ESU persists and is resilient in the face of year-to-year variations in environmental influences. Another key objective is to address the threats or underlying causes of decline. This requires that, in order for the species to be de-listed, the primary threats to the species are ameliorated and regulatory mechanisms are in place to prevent a recurring problem and future need to re-list it.

The general recovery strategy for achieving the ESU recovery objectives centers on improving the status of the extant Lower Mainstem Snake population. The recovery strategy takes a life cycle approach to achieve the recovery objectives. It focuses on protecting and restoring VSP characteristics and the ecosystems on which the population depends throughout its life cycle. Thus, the recovery strategy provides the building blocks to recover the one remaining population to a status of highly viable, and the ESU to a level where it is self-sustaining and viable.

At the same time, the recovery strategy actively pursues the potential for reestablishing a second population in historical habitat upstream of the Hells Canyon Complex. Reestablishing a second upstream population would increase the species' geographic distribution and abundance, and further reduce risks associated with potential catastrophic events; however, it is not an easy task. While many of the actions for the Lower Mainstem Snake population, particularly those addressing passage and migration habitat, rearing habitat, and predation in the mainstem Snake and Columbia Rivers, will also create conditions that benefit a potential second population above Hells Canyon, habitat conditions in the area upstream of the Hells Canyon Complex are severely degraded. These conditions will need to improve substantially before any reintroduction effort can succeed. In addition, providing safe and effective downstream passage for migrating smolts remains a substantial technical challenge that will need to be overcome. It will take decades to restore Snake River fall Chinook salmon above the Hells Canyon Complex. Currently, the Hells Canyon Fisheries Resource Group, which represents affected tribes, states, and federal fish and wildlife agencies, is beginning to draft a plan to restore anadromous fish passage and eventually provide fisheries above the Hells Canyon Complex. This plan could inform future steps to reestablish passage and sustainable fish runs above the Hells Canyon Complex.

Fortunately, the remaining Lower Mainstem Snake population is well distributed over a large area and has demonstrated substantial increases in natural-origin returns since the extremely low spawning levels at the time of listing in the early 1990s. Thus, as presented in Section 3, it is likely possible to recover the ESU with only one population, if we are confident that the population is highly viable. This will not preclude efforts to restore a second population above the Hells Canyon Complex.

6.1.1 Recovery Strategy for the Lower Mainstem Snake River fall Chinook salmon population (Lower Mainstem Snake population)

Life Cycle Approach to Protection and Further Improvements in ESU Viability

Abundance of natural-origin Snake River fall Chinook salmon in the remaining extant population has increased substantially since listing. We attribute this increase in natural-origin abundance to a combination of actions that improved survival through the hydropower system, reduced harvest in ocean and mainstem fisheries, lowered predation rates, and increased natural production in remaining habitats through hatchery supplementation. Nevertheless, while natural-origin spawning levels are improved and the population is well distributed across four of its five major spawning areas, uncertainty remains about whether the abundance trends will persist and whether there are patterns of diversity that will sustain natural production across a range of changing environmental conditions.

A major focus of the recovery strategy for this population is to confirm the driving factors for the recent abundance increase and to validate or update management provisions to sustain long-term population viability through an adaptive management framework. Currently, the combined effects, and the relative effects, of actions in the different threat categories are not well understood. Consequently, in addition to providing actions in individual sectors, (i.e. habitat, hydropower, harvest, predation and other ecological interactions, and hatcheries) this recovery strategy calls for use of multi-stage life cycle models and other RM&E tools to improve our understanding of the combined and relative effects of limiting factors and recovery actions across the life cycle. This information will inform decisions about the most effective management strategies and direct future RM&E priorities to improve decision making. Accordingly, our ability to evaluate the combined and relative effects of actions across the life cycle will continue to improve. This improved understanding will help us better target actions with the most potential to further improve ESU viability and will be important for an adaptive management approach to recovery.

The recovery strategy for the Lower Mainstem Snake population addresses effects across the life cycle. The strategy first recommends continuing ongoing actions to protect the gains this species has made by addressing effects from hydropower, habitat, hatcheries, harvest, predation or competition, toxic pollutants, and other concerns. It also identifies opportunities in each of these sectors for potential additional improvements in viability. Evaluation and planning for many of the potential additional actions that could improve viability is already underway. In some cases, it is not. In the site-specific actions, Section 6.3, we clarify those potential additional actions that would further improve ESU viability and are already being assessed and planned for, but not yet implemented[24]. Also, the actions table (Table 6-1) identifies ongoing actions and suggests timing for potential additional site-specific actions. Implementing the adaptive management framework, overviewed in Section 6.4, will be important for evaluating the status of the population, the effectiveness of the actions, and making adjustments to actions accordingly.

We expect the site-specific actions recommended in this plan to be adequate for recovery. However, as part of implementation, a strategic framework will be designed for evaluating the status of the ESU, and for developing additional contingency actions if the species does not make progress toward recovery as we expect and/ or if it has a significant decline. In the event such additional contingency actions are needed, a life cycle approach to identifying the key opportunities for improving viability in the life cycle is called for in the recovery plan. This need is addressed further in Sections 6.4 (Contingency Processes and Actions for Recovery) and 6.5 (Potential Effectiveness of Management Actions and Need for Life Cycle Evaluations).

Associated Research, Monitoring, and Evaluation Actions

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[24] See footnote 8, in Section 2.6.1, regarding the state of Oregon's position that additional or alternative actions to the FCRPS BiOp should be taken in mainstem operations of the FCRPS for ESA-listed salmon and steelhead.

The actions associated with each management strategy often have corresponding RM&E needs that are particularly important. In many cases, these needs are already being addressed by ongoing RM&E, but there are gaps. Section 7 provides monitoring objectives and identifies and describes specific RM&E monitoring questions associated with each of the objectives. A more detailed description of RM&E is provided in Appendix B. There, the plan identifies the type of monitoring needed (e.g., status and trend or implementation), monitoring questions, approaches (monitoring methods), analyses, status of monitoring associated with each monitoring question, and identification of gaps in monitoring.

Strategy for Mainstem Snake and Columbia River Habitat, Estuarine Habitat and Tributary Habitat, Including Hydropower

Current mainstem Snake and Columbia River hydropower programs and operations and habitat restoration efforts are the result of agreements developed through the FCRPS collaborative process and the Hells Canyon Project FERC relicensing agreement. The Reasonable and Prudent Alternative for the 2014 FCRPS BiOp (NMFS 2014c) takes a comprehensive approach that includes existing operations and additional changes that are likely to improve viability. Actions identified through the Hells Canyon relicensing agreement process also address the species' needs. These existing processes represent the centerpiece of the mainstem hydropower and habitat recovery strategy for Snake River fall Chinook salmon.

It is a high priority to evaluate the mechanisms that appear to have led to the relatively recent increases in survival related to passage through the hydropower system and lower Columbia River mainstem. A better understanding of those mechanisms should identify key actions to maintain those improvements, as well as elucidate the potential for further viability improvement through further adaptations. Ongoing RM&E is evaluating management options that could further increase viability associated with rearing and migration through the mainstem Columbia and Snake River corridors. An ongoing evaluation of the efficacy of juvenile collection and transport will likely result in modifications to the current juvenile transport strategies.

There are potential opportunities for gaining additional improvements in ESU viability from actions addressing limiting factors in both mainstem and reservoir reaches extending downstream from the Hells Canyon Complex through the Snake and Columbia Rivers to the estuary. There are improvements that can be gained through addressing temperature issues that affect adult passage at Lower Granite Dam. Additional opportunities to increase viability may include modifying Hells Canyon Complex operations to further minimize stranding and entrapment in upstream reaches and to improve water quality. Also, there may be opportunities to reduce predation on juvenile fall Chinook salmon in the Lower Granite reservoir reach above Lower Granite Dam by reducing predator levels or altering shallow water habitats that attract predators.

Habitat protection and restoration actions are designed to protect and expand current spawning, rearing and migrating habitats in mainstem, estuarine, and tributary reaches. Ongoing juvenile monitoring programs have detected density-dependent patterns in growth, survival, and timing associated with the recent increases in fall Chinook salmon spawning levels above Lower Granite Dam (Connor et al. 2013). Studies are underway to evaluate how those patterns are influenced by environmental conditions, including exposure to predation and management operations, and to gain a better understanding of the potential impacts of climate change during freshwater and ocean life stages (see RM&E Section 7 and RM&E Strategy Appendix B). Further, while mainstem Snake River reaches contain most of the current and potential spawning habitat for the extant population, the strategy incorporates measures to expand natural production in the lower mainstem sections of the tributary major spawning areas. It also incorporates measures identified in the Estuary Module to protect and improve habitats used by Snake River fall Chinook salmon in the Columbia River below Bonneville Dam.

State of Oregon Position regarding Hydropower Operations

It is the state of Oregon’s position that additional or alternative actions to the FCRPS BiOp 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’ FCRPS BiOp. At this time, Oregon is a plaintiff in litigation against the FCRPS agencies and NMFS, challenging the adequacy of the measures contained in the current (2008 as supplemented in 2010 and 2014) FCRPS BiOps.

Strategy for Harvest Management

Snake River fall Chinook salmon are subject to harvest in ocean and in-river fisheries. Ocean fishery impacts on stocks, including Snake River fall Chinook salmon, are coordinated through the Pacific Salmon Commission and the U.S. regional fisheries management councils. In the Columbia River, mainstem harvest of Snake River fall Chinook salmon is managed through the *U.S. v. Oregon* Management Agreement for 2008-2017 and according to an abundance driven sliding-scale schedule. Regulations for recreational fisheries are developed by Idaho, Washington, and Oregon in their respective waters. The tribes also regulate tributary fisheries under their respective jurisdictions. The recovery strategy for harvest management includes implementing abundance-based harvest regimes according to the Pacific Salmon Treaty, *U.S. v. Oregon* Management Agreement, and fishery management agreements, and conducting annual assessments of the performance of these management regimes and periodic reassessments of the efficacy of the overall harvest management framework in contributing to achieving viability objectives.

Strategy for Predation, Competition, and other Ecological Interactions

The FCRPS BiOp and its Reasonable and Prudent Alternative identify a number of actions to reduce predation, competition, and other ecological interactions that affect recovery of Snake River fall Chinook salmon and other ESA-listed species. Additional actions in the Columbia River mainstem below Bonneville Dam are identified in the Estuary Module (Appendix F). The recovery strategy is to continue efforts to reduce or disperse bird colonies that prey on juvenile Snake River fall Chinook salmon in both the interior Columbia and the estuary. The strategy includes improving fishery management to address non-native fish predation, and evaluating plume and ocean conditions that influence predator fish populations and predation rates during the early ocean life stage. The recovery strategy also includes evaluating and addressing impacts of competition and density dependence on natural-origin Snake River fall Chinook salmon.

Strategy for Hatchery Management

Production goals, release sizes, release locations, release priorities, life stage and marking of released fish for Snake River fall Chinook salmon hatchery programs are all established through the *U.S. v. Oregon* management process. NMFS participates in this process and reviews these programs for ESA compliance through its ESA section 7 hatchery biological opinion (NMFS 2012a) on the HGMPs for the programs. The strategy for hatchery management is to continue to work through these processes to implement existing ongoing actions and additional actions that will improve ESU viability by reducing the impacts of hatchery-origin fish on natural-origin Snake River fall Chinook salmon.

The recent increases in natural-origin returns of the Lower Mainstem Snake River population have been accompanied by substantial increases in hatchery-origin returns. Thus, a high priority element of the recovery strategy involves evaluating and adapting the hatchery program in support of achieving the full range of ESA recovery objectives identified in Section 3 for the naturally spawning population, including productivity, diversity, and spatial structure parameters. Short-term studies are underway to determine the homing fidelity and dispersal patterns associated with the juvenile release locations comprising the current program. Preliminary evaluations by the NWFSC (Cooney, personal communication, 2015), indicate that, given current information on dispersal rates, moving juvenile release locations could feasibly result in significant natural production from natural-origin spawners in one or more major spawning areas (Natural Production Emphasis Areas). Shifts in release locations could include targeting a component of hatchery returns into tributary reaches where occupancy by natural-origin Snake River fall Chinook is currently low. It is important in the near term to explore a range of potential management actions that could achieve viability objectives for a single population through this approach. It is also important to further develop an RM&E approach to evaluate how shifts in release locations influence natural-origin returns to Natural Production Emphasis Areas as well as to other MaSAs.

Strategy for Addressing Present and Potential Future Threats that are not Well Understood, e.g., Toxic Pollutants

In addition to the threat-specific management actions and their related RM&E, the recovery strategy also includes elements aimed at factors that are not well understood but may potentially confound progress towards recovery objectives. These elements include gaining a better understanding of the potential for negative impacts of exotic species on Snake River fall Chinook salmon viability through competition or predation or alterations in the prey base, and the potential that exposure to toxic pollutants may negatively affect production.

6.1.2 Recovery Strategy for Middle Snake River population upstream of Hells Canyon Complex (extirpated)

The recovery strategy for the Middle Snake River population above the Hells Canyon Complex is to complete feasibility studies for upstream and downstream passage over the Hells Canyon Complex, restoration of historic habitats above the Hells Canyon Complex, and reintroduction of the species. These actions will be needed to achieve Viability Scenario A and will lend support to achieving broad sense goals for the ESU. The timing of the feasibility studies and implementation of their results will be determined through the ongoing Hells Canyon Complex relicensing proceedings.[25] In the meantime, actions that protect and restore passage, migration, and rearing habitat for the Lower Mainstem Snake River population below the Hells Canyon Complex would benefit a potential reintroduced population above Hells Canyon.

6.2 Prioritizing and Sequencing Site-Specific Actions

6.2.1 Adaptive Management Framework

This recovery plan uses an adaptive management framework that prioritizes implementation of site-specific actions based on the best available science, identifies monitoring to improve the science, and recommends updating actions based on new knowledge. The ESA section 4(f) requires site-specific actions “as may be necessary to achieve the plan’s goals for conservation and survival of the species.” Our overarching hypothesis is that the management actions recommended for the near- and mid-term identified in this plan will be effective in improving viability; however, uncertainties remain about their feasibility and effectiveness. Consequently, we include complementary RM&E actions to improve our understanding of the species status and management action effectiveness, and to help guide us in better defining opportunities to achieve recovery. We also employ a life cycle context to determine the best ways for closing the gap between the species’ status and achieving viability objectives.

The Snake River fall Chinook salmon ESU adaptive management framework includes the following steps:

1. Establish recovery goals and viability and threats criteria for delisting (Section 3).
2. Determine the species’ present status and the gaps between the present status and viability criteria (Section 4).
3. Assess the threats and limiting factors across the life cycle that are contributing to the gaps between present status and viability objectives (Section 5). Also, assess the threats in the context of variable ocean conditions and emerging climate change.

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[25] FERC (Federal Energy Regulatory Commission). 2007. Final Environmental Impact Statement: Hells Canyon Hydroelectric Project (FERC Project No. 1971-079). FERC, Washington, D.C., 8/1/2007.

4. Implement management strategies and actions (Section 6) that target the limiting factors and threats associated with each of the human-caused threats.
5. Implement RM&E actions (Section 7) to evaluate the status and trend of the species and the status and trend of limiting factors and threats, including action implementation and action effectiveness.
6. Identify contingency processes and actions to be implemented in the event of a significant decline in species status (Section 6.4). The site-specific recovery actions recommended in Section 6.3 are likely to be adequate for achieving recovery; however, we need to be prepared if the species does not continue to improve towards meeting recovery objectives in a timely manner and/or if there are significant declines in the species' status.
7. Review progress and identify best opportunities to improve viability. Regular major reviews of implementation progress, species response, and new information are needed. These progress reviews are addressed in the Implementation Section (Section 8).
8. Adjust actions according to progress reviews. The success of this recovery plan depends on an implementation structure that implements actions in response to the results of progress reviews.
9. Repeat the adaptive management cycle. Adaptive management should be a continuous loop of action implementation, monitoring and evaluation, new information, assessment of information and updated actions.

6.2.2 Prioritization Considerations

Our assessments of the species' current biological status (Section 4) and the limiting factors and threats that are contributing to this status (Section 5) indicate that protecting and restoring ecological processes throughout the entire life cycle is essential for conserving the ESU and the productive capacity of its habitat. Conserving existing habitat that supports core production and primary life history types, as well as quality migration habitats, is a critical priority. Given that they are primarily mainstem spawners, Snake River fall Chinook salmon spawning and rearing habitat can be dramatically affected by large-scale hydropower and water management actions. Furthermore, Snake River fall Chinook salmon are affected by substantial levels of ocean and river harvest and hatchery production. It is a priority for hydropower, fishery, and hatchery management actions to be consistent with recovery objectives.

This recovery plan includes two main categories of actions: the site-specific management actions (ongoing and potential additional actions) discussed in this section, and the RM&E actions described in RM&E Section 7 and Appendix B.

Considerations in Prioritizing Site-Specific Management Actions

Management actions include both ongoing actions, which are essential for conserving the species, and potential additional actions that may be needed to achieve and maintain a viability scenario. To assist in further discussion of and decisions regarding prioritization of management actions, we have categorized actions as follows:

Ongoing Management Actions

These actions have improved the extant population's status since listing and it is essential they continue as they are presently designed until or unless RM&E effectiveness monitoring or other information demonstrates issues with their effectiveness that warrant changes. These actions must be partnered with RM&E for evaluating their effectiveness, as described in the RM&E Section 7 and Appendix B. These ongoing efforts are part of programs already underway as described in Section 2.6, Recent History and Programs since Listing. However, many of these ongoing programs, including those reviewed by the FCRPS biological opinion (NMFS 2014c), the *U.S. v. Oregon* Agreement for 2008-2017 (U.S. District Court 2008), and the HGMP biological opinion (NMFS 2012a) are scheduled to be updated in 2018. Also, Hells Canyon operations, which are currently operating under interim agreements, could have final agreements through FERC relicensing negotiations by 2018. We anticipate that the ongoing actions described in this section will continue, although some may be updated, based on ongoing RM&E. RM&E associated with those programs should provide results that inform updates to management actions after 2018.

Potential Additional Management Actions

Potential additional actions are identified to bring the ESU closer to achieving ESA recovery. Many of these potential improvements have already been analyzed and funding and implementation is proceeding. Others are now being assessed through ongoing studies and there are commitments to build implementation of the actions into management programs. There are also cases where evaluations and implementation have not begun and the actions present new ideas. In all cases, these actions are not yet affecting the fish and influencing the species' viability. Additional actions should be implemented in the following sequence.

1. Actions most likely to provide the best and most timely opportunities for achieving ESU viability with the single extant population.
2. Actions to reestablish a population above the Hells Canyon Complex.
3. Actions that may not be necessary to achieve ESA viability but that could further enhance and secure viability of the extant population and the ESU. These potential actions warrant additional evaluations.

Considerations in Prioritizing Research, Monitoring, and Evaluation Actions

RM&E promotes understanding the status of the species and the effectiveness of existing management actions and explores the feasibility of, and the best opportunities for, additional management actions to improve and secure the species' viability. RM&E is also important for evaluating key uncertainties about potential but poorly understood threats. The full suite of RM&E objectives and associated key questions is provided in Section 7. The RM&E appendix provides detail on activities that are underway to address the RM&E objectives and key questions and also identifies the gaps in RM&E activities. Additional work is needed during implementation of this recovery plan to develop a strategic framework for prioritizing and sequencing RM&E activities.

6.2.3 Considerations in Sequencing Actions to Achieve Recovery

The site-specific management actions in this recovery plan promote achievement of multiple potential viability scenarios for Snake River fall Chinook salmon. Associated RM&E actions (see Section 7 and Appendix B) will also provide information needed to better define our course toward delisting. By 2018, we expect to have additional information that will inform the feasibility of potential scenarios, including Natural Production Emphasis Area scenarios, described in Section 3. In the meantime, as discussed in Section 6.2.2, this recovery plan's first step is to continue baseline, ongoing essential actions and associated RM&E for the extant population, while evaluating and preparing to implement potential additional management actions that provide the best and most timely opportunities for improving viability of the extant population. The next step is to implement actions in response to the evaluations, for example, actions to build permanent structures to address water temperature issues at Lower Granite Dam, or to further reduce juvenile collection and transport at Snake River collector projects. For the population above the Hells Canyon Complex, actions implemented through the relicensing process will include developing feasibility studies and actions to improve fish passage around the complex and improve habitat in the reach up to Swan Falls Dam.

The sequencing and rate at which additional actions are implemented are key variables that will influence how quickly the gaps are narrowed between the Snake River fall Chinook salmon ESU's present viability status and achieving VSP objectives. In this section (Tale 6-1) we have suggested general time frames – near-term and mid-term – for implementation of the additional management actions. The near term corresponds roughly to the next five years of implementation (2016-2020). This time frame is consistent with the period in which ongoing monitoring will yield significant new information and several ongoing processes will be reaching new decision points. The mid-term time frame corresponds generally to the succeeding twenty years. If delisting were not achieved within the 25-year time frame envisioned for implementation of this plan, it is possible that additional actions would need to be identified and implemented. Rather than speculating now on what those long-term actions might be, we would anticipate identifying them through adaptive management as additional information became available through RM&E and periodic plan reviews.

6.3 Site-Specific Management Actions

As mentioned above, this recovery plan contains two types of site-specific management actions: ongoing actions and potential additional actions to achieve ESU viability (See Section 6.2.2, above, for additional description of the two types of actions). The site-specific management actions address the threats and priority limiting factors described in Section 5. The actions are organized by two main subcategories: (1) actions for the extant Lower Mainstem Snake population and (2) actions for the extirpated population above the Hells Canyon Dam Complex. Actions are further organized under ten management strategies. Management strategies describe what needs to be done to protect and restore Snake River fall Chinook salmon, and the accompanying actions describe how to implement those strategies through site-specific actions. Together, the management strategies address hydropower; mainstem, tributary, and estuary habitat; harvest; predation, prey base, competition and other ecological interactions; hatcheries; and toxic pollutants. Since Snake River fall Chinook salmon are primarily mainstem spawners and significantly influenced by hydropower operations, mainstem habitat and hydropower factors are considered together. These site-specific actions are recommendations for recovery and do not predetermine the outcomes of regulatory determinations through sections 7, 10, and 4(d).

Where relevant, we have included a brief summary of the limiting factors and threats a group of actions is designed to address. These summaries are based on the material presented in Section 5.

Site-Specific Research, Monitoring, and Evaluation Actions

Research, monitoring, and evaluation (RM&E) is essential for evaluating the status of Snake River fall Chinook salmon and the effectiveness of actions to improve the species' status. The RM&E activities are also essential for addressing critical uncertainties that will help us better understand how best to achieve and maintain recovery of Snake River fall Chinook salmon. Section 7 summarizes the Snake River fall Chinook salmon RM&E framework, objectives, and key questions. Appendix B elaborates on the objectives and key questions and identifies existing activities that are addressing the RM&E objectives and questions as well as gaps that need to be filled.

An important step in implementation of this recovery plans will be to further prioritize and sequence the RM&E activities within a strategic framework, and to work on funding and implementing the activities in a manner that is coordinated across existing RM&E programs.

6.3.1 Site-Specific Management Actions for the Extant Lower Mainstem Snake River Population

6.3.1.1 Actions to Evaluate and Improve Viability across the Life Cycle

There is uncertainty regarding whether the recent increase in Snake River fall Chinook abundance will persist in coming years. It is also unclear whether existing patterns of diversity will sustain the Lower Mainstem Snake River population across a range of changing environmental conditions. Tools such as multi-stage life cycle models are needed to gain this understanding and help us target and prioritize recovery actions and RM&E accordingly.

Management Strategy 1: Develop tools, including life cycle models, for evaluating and understanding the relative effects of actions in different threat categories across the life cycle.

Continue Ongoing Actions:

1-1. Continue to conduct relevant actions under the life cycle modeling initiative being carried out through the FCRPS Adaptive Management Implementation Plan.

Implement Potential Additional Actions to Achieve ESU Viability:

1-2. Conduct multi-stage life cycle modeling to assess potential response of Snake River fall Chinook salmon to alternative management strategies and actions under alternative climate scenarios, and to determine the best opportunities for closing the gap between the species' status and achieving viability objectives.

1-3. Develop a multi-stage life cycle model that incorporates estimates of survival through various stages of salmon life cycle to assess changes in population viability.

1-4. Use life cycle model to assess the ESU as a whole, and interactions between the different spawning areas.

6.3.1.2 Actions to Maintain and Improve Mainstem Snake and Columbia River Habitat from Hells Canyon Complex to Bonneville Dam (including Hydropower Effects) and Lower Mainstem Snake River Tributary Habitats

Many efforts are ongoing to improve mainstem Snake and Columbia River hydropower programs and operations and restore habitats to support recovery of Snake River fall Chinook salmon. These efforts are implemented through existing processes, including the FCRPS Biological Opinion and the Hells Canyon Project FERC relicensing agreement. Potential opportunities exist to increase viability by further improving rearing and migration through the mainstem corridor. Opportunities also exist to further protect, improve, and expand spawning, rearing, and migration habitats in tributary reaches.

Threats: Hydropower projects and operations; reservoirs; predation; channel maintenance and dredging activities; and land uses adjacent to the mainstem and tributaries.

Limiting factors: Blocked habitat; inundated habitat; fish passage; reduced velocities; stranding and entrapment of juveniles; reduced water quality and altered thermal regime; reduced thermal refugia; low dissolved oxygen; total dissolved gas; altered flows (on a seasonal, daily, and hourly basis); interruption of geomorphological processes resulting in reduced turbidity, higher predation, and reduction in spawning gravels; habitat modification; and loss of channel structure.

Management Strategy 2: Maintain and enhance suitable spawning, incubation, rearing, and migration conditions by continuing ongoing actions and implementing additional actions in the Lower Mainstem Snake and Columbia Rivers and Lower Snake tributaries and tributaries.

Continue Ongoing Actions:

Mainstem Habitat

2-1. Continue to implement Idaho Power Company’s fall Chinook salmon spawning program to enhance and maintain suitable spawning and incubation conditions (IPC 1991).

2-2. Continue to implement cool-water releases from Dworshak Dam to maintain adequate migration conditions (for adults and juveniles) and juvenile rearing conditions (temperatures) in the lower Snake River (NMFS 2014c[26]).

2-3. Continue summer flow augmentation (Dworshak Reservoir, Brownlee Reservoir, and upper Snake River Bureau of Reclamation projects) to maintain adequate summer migration conditions (NMFS 2014c).

2-4. Continue summer spill at mainstem Lower Snake River and Lower Columbia River dams to maintain adequate passage conditions for substantial numbers of actively migrating fish (NMFS 2014c).

2-5. Continue management actions to reduce juvenile losses to predacious fish and birds (NMFS 2014c).

2-6. Continue interim operations at Lower Granite Dam to respond to adult passage blockages caused by warm surface waters entering the fish ladders (NMFS 2014c).

2-7. Complete fall Chinook salmon transportation study, scheduled for completion in 2017 (NMFS 2014c).

2-8. Continue to assess the behavior (including passage timing) and number of overwintering juveniles in the Lower Granite reservoir (NMFS 2014c).

2-9. Continue to implement measures identified in the Lower Snake River Programmatic Sediment Management Plan (PSMP) to reduce impacts of reservoir and river channel maintenance dredging and disposal on Snake River fall Chinook salmon.

  2-9.1. Continue to dispose of dredge material in a manner that does not create islands that could attract predator bird colonies.

  2-9.2. Continue in-water dredge sediment disposal in a manner that creates juvenile fall Chinook salmon habitat and reduces predator habitat.

Tributary Habitat

2-10. Continue to implement actions to protect, improve, and enhance spawning and rearing habitat conditions in tributary reaches.

Recovery actions in tributary habitats will maintain and improve spawning and rearing potential for Snake River fall Chinook salmon and help maintain cold water plumes at the mouths of tributaries that provide thermal refugia. These actions are described more specifically in three separate management unit plans that support recovery of the Snake River Spring and Summer Chinook Salmon ESU and Snake River Steelhead DPS. These management unit recovery plans for Snake River spring and summer Chinook salmon and steelhead in the Southeast Washington

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[26] NMFS 2014c: Endangered Species Act - Section 7(a)(2) Consultation, Supplemental Biological Opinion. Consultation on remand for operation of the Federal Columbia River Power System. National Marine Fisheries Service, Portland, Oregon, January 17, 2014.

Management Unit, Northeast Oregon Management Unit, and Idaho Management Unit were developed through a coordinated effort to create a comprehensive recovery plan for Snake River spring and summer Chinook salmon and Snake River steelhead. The three management unit plans will serve as appendices to the larger ESU/DPS recovery plan for Snake River spring/summer Chinook and steelhead, which is currently under development. Even though the actions in these management unit plans for Snake River spring/summer Chinook salmon and steelhead tend to be higher up in the tributaries than where Snake River fall Chinook salmon spawn and rear, the actions have cumulative beneficial effects on downstream habitats. The plans are available on the NMFS West Coast Region web site: http://www.westcoast.fisheries.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/snake_river/current_snake_river_recovery_plan_documents.html.

Implement Potential Additional Actions to Achieve ESU Viability:

Mainstem Habitat

2-11. Upon completion of the fall Chinook salmon transportation study, modify the Corps of Engineers' transportation program to enhance adult returns of migrating juvenile salmon, including consideration of terminating or modifying transport at one or more collector projects if warranted, depending on results (NMFS 2014c).

2-12. Install, if feasible, a passive integrated transponder (PIT) tag detector in the removable spillway weir at Lower Granite Dam to enhance understanding of smolt-to-adult returns and the contributions of alternative life history strategies (NMFS 2014c).

2-13. Based on results of actions to assess the behavior and number of overwintering juveniles in the Lower Granite reservoir, evaluate the potential to improve survival of juvenile fall Chinook salmon passing Lower Granite Dam in late fall and early spring, and depending on results, implement appropriate modifications to configurations (NMFS 2014c).

2-14. Implement structural and operational changes at Lower Granite Dam to more reliably address adult passage blockages caused by warm surface waters entering the fish ladders (NMFS 2014c).

2-15. Implement actions to improve the quality of water discharged from the Hells Canyon Complex (dissolved oxygen, total dissolved gas) - as called for in NMFS recommendations for the Hells Canyon FERC Relicensing (NMFS 2006b) (IDEQ and ODEQ 2004).

2-16. Develop and implement a gravel monitoring and management plan in the Hells Canyon reach of the Snake River (as called for in the Hells Canyon FEIS) (FERC 2007).

2-17. Determine the effects of water management strategies on mainstem rearing capacities at different flow levels and adapt, as appropriate, given consideration for requirements for other migrating species (e.g. sockeye, spring Chinook salmon, and steelhead).

2-18. Evaluate effects of winter dredging and of in-water dredge sediment disposal on predator- prey relationships and adapt management actions as appropriate.

2-19. Implement actions to improve water quality, including Clean Water Act Total Maximum Daily Loads (TMDLs) to improve water quality in the mainstem Snake and Columbia Rivers.[27]

Tributary Habitat

2-20. Complete and implement TMDLs to improve water quality in tributary habitats that affect Snake River fall Chinook salmon spawning and rearing habitats.

2-21. Improve tributary major spawning area (MaSA) habitat.

  2-21.1. Evaluate and prioritize opportunities to restore tributary side channel rearing habitats to increase natural production capacity for Snake River fall Chinook salmon in all MaSAs and associated tributary spawning areas.

  2-21.2. When carrying out actions to mitigate for declining flows by evaluating, protecting and restoring wetlands, floodplains, or other landscape features that store water (primarily to benefit spring Chinook salmon), consider downstream benefits to fall Chinook salmon.

  2-21.3. When carrying out actions to benefit spring Chinook by alleviating elevated temperatures and low stream flows through riparian restoration and managing water withdrawals, consider downstream benefits to fall Chinook salmon.

2-22. Target high priority opportunities to restore October spawning life history patterns.

  2-22.1. Evaluate potential spawning and rearing habitats in the lower reaches of the Selway, Lochsa, and South Fork Clearwater Rivers.

2-23. Evaluate whether water quantities and quality could be increased and whether sediment delivery could be reduced in the lower Grande Ronde River to improve spawning and rearing conditions and survival.

2-24. Evaluate the potential to reduce sediment impacts on lower Tucannon River mainstem historical spawning and rearing area.

6.3.1.3 Actions to Maintain and Improve Estuary (below Bonneville Dam), Plume, and Nearshore Ocean Habitat

The Estuary Module (NMFS 2011b[28]) identifies and prioritizes habitat-related management actions that, if implemented, would reduce the impacts of limiting factors that impede salmon and steelhead survival during their migration through and rearing in the estuary and plume

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[27] The Idaho and Oregon Departments of Environmental Quality (IDEQ and ODEQ) are jointly developing plans to implement (TMDLs) in mainstem segments of the Snake River and its tributaries. These plans indicate that without additional funding to address nutrients entering the Snake River from non-point sources, the nutrient standards will be met in 70 years (IDEQ and ODEQ 2004). NMFS supports the implementation of these TMDLs because they are likely to ultimately increase the likelihood of successful reintroduction of anadromous fish in the Middle Snake Mainstem, as well as provide substantial benefits to a host of resident species in future decades, thereby enhancing the historical habitat for anadromous fish. However, the TMDL time frame is not sufficient to address the adverse impacts stemming from low dissolved oxygen levels entering extant Snake River fall Chinook salmon critical habitat.

[28] NMFS 2011b: 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.

ecosystems. The module identifies the following threats and limiting factors as major or significant effects to ocean-type salmon, such as fall Chinook salmon:

Threats: Diking, filling, and other agricultural uses; pilings and other structures; FCRPS flow management and regulation; water withdrawals; dredging; fine sediment entrapment; reservoir-related temperature changes; industrial and urban practices; climate change; increased phytoplankton production; altered predator/prey relationships; ship ballast practices.

Related limiting factors: Reduced in-channel and off-channel habitat availability due to altered flow regime and changes in sediment/nutrient supplies; high water temperature; altered food web (reduced macrodetrital inputs); toxic contaminants; predation.

Management Strategy 3: Address lack of access to estuary habitat; altered food web; and altered flow regime by continuing ongoing actions and implementing potential additional actions identified in the Estuary Module (NMFS 2011b), FCRPS BiOp (NMFS 2014c) and this recovery plan.

Continue Ongoing Actions:

3-1. Protect recent gains in acquisitions of functioning habitat in the marshes and floodplains below Bonneville Dam.

3-2. Protect restored areas so that juvenile Snake River fall Chinook salmon can benefit from increased habitat capacity and quality.

Implement Additional Actions to Improve ESU Viability:

3-3. Continue to breach, lower, or relocate dikes and levees to establish or improve access to off-channel habitats.

3-4. Continue to protect remaining high-quality off channel habitat from degradation and restore degraded areas with high intrinsic potential for high quality habitat.

3-5. Continue to restore or mitigate contaminated sites.

3-6. Continue to identify and reduce terrestrially and marine-based industrial, commercial, and public sources of pollutants.

3-7. Further reduce predation on yearling migrants by implementing projects to redistribute part of the Caspian tern colony currently nesting on East Sand Island.

3-8. Further reduce predation on yearling migrants by implementing projects to reduce double-crested cormorant habitats and encourage dispersal to other locations.

6.3.1.4 Actions to Address Climate Change

Potential effects from climate change on Snake River fall Chinook salmon abundance, productivity, spatial structure, and diversity remain poorly understood. The species may be among those salmonids either least affected by, or most likely to adapt to, climate change effects on the mainstem and tributary habitat. However, it is also possible that changes such as increased water temperatures in the lower Snake River or in the ocean could affect viability.

Threat: Climate change: warmer air and water temperatures, changes in precipitation and flow patterns, and increased acidification in the Pacific Northwest and ocean.

Related limiting factors: Passage delay; gamete viability; pre-spawn mortality.

Management Strategy 4: Continue ongoing actions and implement potential additional actions that will conserve Snake River fall Chinook salmon in the face of emerging climate change.

In Mainstem Snake/Columbia Corridor:

4-1. Continue to implement cool water releases from Dworshak Dam to maintain adequate migration conditions (for adults and juveniles) and juvenile rearing conditions (temperatures) in the lower Snake River.

4-2. Maintain surface passage routes that reduce travel time through forebays.

4-3. Continue to reduce warm-water predators in reservoirs.

4-4. Monitor temperatures and flows to assess trends that may be related to climate change.

4-5. Continue interim operations at Lower Granite Dam to respond to adult passage blockages caused by warm surface waters entering the fish ladders and implement structural and operational changes to more reliably address adult passage blockages caused by warm surface waters entering the fish ladders.

In the Estuary:

4-6. Breach, lower, or relocate dikes and levees to establish or improve access to off-channel habitats.

6.3.1.5 Actions to Address Harvest

Harvest mortality and other effects on Snake River fall Chinook salmon viability from ocean and in-river fisheries are currently controlled through limits to protect Snake River fall Chinook salmon and other listed ESUs. The primary potential concern is for selective impacts of harvest on natural-origin Snake River fall Chinook salmon.

Threat: Fisheries.

Related Limiting Factors: Mortality.

Potential Limiting Factors: Indirect selection for age, size, or run timing.

Management Strategy 5: Implement harvest programs in a manner that protects and restores Snake River fall Chinook salmon.

Continue Ongoing Actions:

5-1. Implement abundance-based harvest regimes according to Pacific Salmon Treaty, *U.S. v. Oregon* Management Agreement, and fishery management frameworks authorized under the ESA (NMFS 2008b[29], 2008c[30], 2008f[31]).

5-2. Ensure accuracy of reported estimates of harvest of natural-origin Snake River fall Chinook salmon in both ocean and river fisheries as required by the existing biological opinions (NMFS 2008b, 2008c, 2008f).

Potential Additional Actions to Achieve ESU Viability:

5-3. Develop harvest management frameworks and complete ESA regulatory reviews for Snake Basin fisheries that directly or incidentally take Snake River fall Chinook salmon.

5-4. Update harvest management frameworks, as appropriate, to respond to potential changes in hatchery release strategies in 2018 and beyond.

5-5. Ensure that potential changes to downriver fisheries in response to the John Day mitigation program do not result in harvest of natural-origin Snake River fall Chinook salmon that is inconsistent with recovery objectives.

5-6. Consistent with results of the evaluations described in RM&E, update harvest management plans through negotiations with appropriate fishery management forums.

6.3.1.6 Actions to Address Predation, Prey Base, Competition, and other Ecological Interactions

Predation, particularly by fish and birds, is a significant concern for Snake River fall Chinook salmon and especially affects subyearling survival during outmigration. Competition and other ecological interactions, such as changes in the food web, also affect the viability of Snake River fall Chinook salmon by reducing abundance, productivity, and diversity.

Threats: Dam operations; reservoirs; alterations to estuary; high proportions of hatchery fish in spawning and rearing habitats; increased abundance of nonnative species.

Related Limiting Factors: Increased predation by birds and non-native fish; competition for space in spawning and rearing areas; decreased production; competition for food; increased predation.

Management Strategy 6: Continue ongoing actions and implement potential additional actions that address predation, prey base, competition and other ecological interactions.

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[29] NMFS (National Marine Fisheries Service). 2008b. Endangered Species Act Section 7 Consultation Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Consultation: consultation on remand for operation of the Federal Columbia River Power System and 19 Bureau of Reclamation Projects in the Columbia Basin. NMFS, Portland, Oregon. May 5. 2008

[30] NMFS (National Marine Fisheries Service).2008c. Endangered Species Act Section 7(a)(2) Consultation Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation. Consultation on the Approval of Revised Regimes under the Pacific Salmon Treaty and the Deferral of Management to Alaska of Certain Fisheries Included in those Regimes. NMFS, Northwest Region. December 22, 2008.

[31] NMFS (National Marine Fisheries Service). 2008f. Endangered Species Act Section 7 Consultation Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation. Consultation on Treaty Indian and Non-Indian Fisheries in the Columbia River Basin Subject to the 2008–2017 *U.S. v. Oregon* Management Agreement. NMFS, Northwest Region. May 5 2008.

Continue Ongoing Actions:

6-1. Continue efforts to reduce or disperse bird colonies that prey on juvenile Snake River fall Chinook salmon in both the interior Columbia and the estuary.

6-2. Continue pikeminnow bounty program.

Potential Additional Actions to Achieve ESU Viability:

6-3. Improve states of Oregon and Washington fishery management of non-native fish predator populations including pike minnow, smallmouth bass, channel catfish and walleye.

6-4. Evaluate plume/nearshore ocean conditions that influence predator fish populations and predation rates during the early ocean life stage.

6-5. Evaluate impacts of competition and density dependence on natural-origin Snake River fall Chinook salmon.

  6-5.1. Evaluate effect of spawner redd superimposition on juvenile productivity.

  6-5.2. Evaluate food availability and consumption by potential competitors in terms of effect on growth and survival of Snake River fall Chinook juveniles.

6-6. Take actions to prevent the rapidly expanding ranges of zebra mussel, quagga mussel, New Zealand mudsnail, Siberian prawns, and other invasive species from extending into Snake River fall Chinook salmon habitat and depleting available nutrients in the river.

6.3.1.7 Actions to Address Other Natural or Human Made Factors

Actions in this section address two threats: hatcheries and toxic pollutants. While hatchery programs have increased abundance and spatial structure of Snake River fall Chinook salmon, they remain a concern because of the high proportion of hatchery-origin fish on the spawning grounds, which raises concerns about the productivity and diversity of the natural-origin fish. Toxic pollutants are a concern because the fish are exposed to chemical contaminants in the migration corridor and in some rearing and spawning areas, and this exposure can have lethal or adverse sub-lethal effects.

6.3.1.7.1 Hatcheries

Threats: High proportion of hatchery fish as juveniles and as adults.

Related Limiting Factors: Genetic change; loss of fitness; potential for juvenile competition with wild fish in rearing areas for food and other resources; adult competition for resources, including spawning areas; higher mortality from incidental harvest; disease transmission.

Management Strategy 7: Continue ongoing actions and implement potential additional actions that reduce the impact of hatchery fish on Snake River fall Chinook salmon.

Continue Ongoing Actions:

7-1. Continue to implement best management practices at Snake River fall Chinook salmon hatcheries as reviewed in the ESA biological opinion on the HGMPS for those programs (NMFS 2012a[32]).

7-2. Continue current actions to minimize fish from outside the ESU spawning in the wild (NMFS 2012a).

7-3. Continue to improve estimates of natural- and hatchery-origin fish over Lower Granite Dam (NMFS 2012a).

  7-3.1. Re-estimate the proportion of natural- and hatchery-origin fish over Lower Granite Dam for the period 1991-2002 (and document the procedure used).

7-4. Continue to validate and improve estimates of hatchery/natural composition of adult fish on the spawning grounds, both overall and in specific major spawning areas (NMFS 2012a).

7-5. Continue to evaluate dispersal and homing fidelity of hatchery releases (NMFS 2012a).

7-6. Ensure that adult returns from new hatchery programs (e.g. the John Day mitigation program) do not stray above acceptable levels into the Snake River (NMFS 2012a).

Potential Additional Actions to Achieve ESU Viability:

7-7. Work through the *U.S. v. Oregon* co-managers forum to identify and assess potential management frameworks that would achieve delisting by 1) creating Natural Production Emphasis Areas (NPEAs) – i.e., major spawning areas that produce a substantial level of natural-origin adult spawners with a low proportion of hatchery-origin spawners; or 2) reducing hatchery-origin spawners in the population overall.

7-8. Based on existing and emerging data from ongoing RM&E, model feasibility (in terms of viability criteria) of frameworks that would result in achievement of VSP objectives for highly viable population status based on population performance in one or more NPEAs.

7-9. Identify data gaps that limit assessment of feasibility of NPEA management frameworks and implement appropriate RM&E measures to fill the gaps.

7-10. Develop appropriate metrics for evaluation of VSP status in NPEAs and other MaSAs.

7-11. Assess the expense, logistical difficulty, and consequences (e.g., to fisheries) of implementing NPEA frameworks.

6.3.1.7.2 Toxic Pollutants

Threats: Agricultural runoff, legacy mining contaminants, urban and industrial runoff, effluent, and wastes; accumulation of toxic pollutants in reservoirs.

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[32] NMFS (National Marine Fisheries Service). 2012a. Endangered Species Act (ESA) section 7(a)(2) Biological Opinion and Manguson-Stevens Fishery Conservation and Management Act Essential Fish Habitat (EFH) Consultation: Snake River Fall Chinook Salmon Hatchery Programs, ESA section 10(a)(1)(A) permits, numbers 16607 and 16615.October 9, 2012. NMFS Northwest Region.

Related limiting factors: Contaminants such as DDTs, PCBs, PBDEs, metals, mercury, MeHG, radionuclides, dioxin, etc., causing mortality, disease, reduced fitness.

Management Strategy 8: Reduce potential effects of toxic contaminants on Snake River fall Chinook.

- **8-1.** Develop actions to reduce toxic contaminants at the sources.
- **8-2.** Revise water and sediment quality criteria as needed to ensure they are protective of listed salmonids.
- **8-3.** Implement National Pollution Discharge Elimination System permit programs to address point source pollution.

6.3.2 Site-Specific Management Actions for the extirpated population above Hells Canyon Complex

Passage to historical habitat above the Hells Canyon Complex remains blocked and the mainstem habitat in the reach is too degraded to support anadromous fish. Some of these limiting factors are being addressed through the Hells Canyon Project FERC relicensing agreement.

Threats: Hydropower projects; reservoirs, land uses that alter river habitat: irrigated and dry land agriculture, livestock grazing, confined animal-feeding operations, mining, timber harvest.

Related Limiting Factors: Fish passage, blocked and inundated habitat, total dissolved gas levels, reduced velocities, excessive nutrients, sedimentation, toxic pollutants, low dissolved oxygen in water and gravel, and altered flows.

Management Strategy 9: Evaluate feasibility of adult and juvenile fish passage to and from spawning and rearing areas above the Hells Canyon Complex.

- **9-1.** Complete the Hells Canyon Federal Energy Regulatory Relicensing Proceedings and develop biological and engineering fish passage and migration feasibility studies.[33]

Management Strategy 10: Restore habitat conditions that can support Snake River fall Chinook salmon spawning and rearing above Hells Canyon Complex by encouraging local governments and stakeholders to implement actions to reduce nutrients and sediment to improve mainstem habitat.

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[33] Once completed, Idaho Power Company would be expected to implement FERC license articles and NMFS and USFWS biological opinion requirements (and potentially additional requirements in a settlement agreement) which together, should maintain or enhance survival and habitat function in extant (and potentially blocked historical habitat) and specify actions and timelines for assessing (and potentially implementing) actions to restore the passage to and from upstream spawning and rearing areas

10-1. Complete and implement plans to meet Total Maximum Daily Loads (TMDLs) to improve water quality in the mainstem Snake River to support adequate spawning and rearing habitat.

10-2. Continue to implement and develop incentive programs for land owners and water users that promote protecting and improving habitat conditions.

6.4 Contingency Processes and Actions for Recovery

As discussed in Section 6.2, this recovery plan depends on an adaptive management framework that implements site-specific management actions based on best available science, monitors to improve the science, and updates management actions based on new knowledge. We believe that the site-specific recovery actions recommended in Section 6.3, combined with improvements made through corresponding RM&E, should be adequate for achieving recovery. However, we need to be prepared if the species does not continue to improve towards meeting recovery objectives in a timely manner and/or if there are significant declines in the species' status. In the event there are significant declines, this recovery plan would depend on the 2010 FCRPS BiOp (NMFS 2010), which established a contingency process for significant declines in the Adaptive Management Implementation Plan (AMIP). The AMIP incorporates early warning indicators and sets of significant decline triggers. If a significant decline trigger is tripped, then processes are invoked within existing management frameworks to identify and implement rapid response actions, most of which would be short-term in duration, in the hydro, predation, harvest, and hatchery sectors.

A similarly structured contingency process should be established for developing actions if Snake River fall Chinook salmon does not continue to trend towards achieving long-term recovery objectives through implementation of the site-specific recovery actions. This recovery contingency process should set intermediate goals and time frames for the species to make meaningful progress toward delisting. As part of this process, additional actions should be developed that are contingency recovery actions, if needed, to address long-term trends toward recovery.

6.5 Potential Effectiveness of Management Actions and Need for Life Cycle Evaluations

Abundance of Snake River fall Chinook salmon natural-origin returns has increased substantially since listing. Thus, the working hypothesis is that the combination of management actions presently underway has been effective at improving abundance of the natural-origin population. In sum, these actions have improved survivals through the hydropower system, have reduced impacts from hydropower operations, reduced overall ocean and mainstem harvest, especially in relatively low return years, and increased natural production from hatchery supplementation.

However, as concluded in Section 4 (Current ESU Biological Status Assessment), there remains uncertainty about the status of the species' productivity and diversity. This remaining uncertainty contributes to the Lower Mainstem Snake River population's current overall status rating of Viable, with a low risk rating for abundance/productivity and a moderate risk rating for spatial structure/diversity. Currently, while natural-origin spawning levels are high, and recent productivity is also high, the levels are not high enough to account for the uncertainty buffer needed to achieve a rating of very low risk with high certainty. Uncertainty regarding potential impacts from hatchery-origin spawners restricts the population from attaining at least a low risk rating for spatial structure/diversity. These uncertainties leave NMFS with inadequate confidence that the ecosystem and the one remaining extant population have healed sufficiently so that the naturally produced ESU could be self-sustaining over the long term. These uncertainties need to be addressed and additional actions need to be implemented.

This recovery plan aims to address the uncertainties and targets specific actions to close the gap between the Lower Mainstem Snake River population's present viable status and the targeted status of Highly Viable. The biological status assessment in Section 4 evaluates the effectiveness of current actions for meeting viability and identifies remaining uncertainties. The potential additional actions to improve viability and adaptive management approach identified in this section address the uncertainties and recommend additional actions to improve viability. Most of the potential additional actions to improve viability, if implemented, could improve the species productivity and our confidence in evaluating it. The potential additional actions to improve ESU viability identified in Section 6.3.1.7.1 for hatcheries could also significantly improve the species' diversity. However, most of the additional improvements require more information and evaluation before their feasibility and the extent of their potential effectiveness can be confirmed.

Evaluations across the Life Cycle

The effectiveness of most of the ongoing management actions have been evaluated and continue to be evaluated through their associated RM&E as part of individual ESA section 7 consultations that were described in Section 2.6. These actions operate across the life cycle through different threat categories, i.e. hydropower and mainstem habitat, tributary habitat, harvest, hatcheries, estuary habitat and so on. However, the combined effects, and the relative effects of actions in different threat categories across the life cycle, are not well understood.

Multi-stage life cycle models that are under development for Snake River fall Chinook salmon should improve our understanding of the combined and relative effects of actions across the life cycle. These models incorporate empirical information and working hypotheses on survival and capacity relationships at different life stages. The models would provide a valuable framework for systematically assessing the potential response of Snake River fall Chinook salmon to alternative management strategies and actions under alternative climate scenarios. In addition to informing decisions about near-term management strategies, the fall Chinook salmon life cycle modeling can also be used to assess the status of the ESU as a whole, and interactions between different spawning areas. It can also be used to identify key RM&E priorities to improve future decision making. Accordingly, our ability to evaluate the combined and relative effects of actions across the life cycle will continue to improve.

Table 6-1. Summary of recommended site-specific recovery actions.

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Category Timing of Potential Additional Actions (near, mid, or long-term)[34]	Estimated Costs	Potential Implementing Entity(ies)	Comments
Management Strategy 1: Develop tools, including life cycle models, for evaluating and understanding the relative effects of actions in different threat categories across the life cycle.								
Ongoing Actions								
1-1	Continue to conduct relevant actions under the life cycle modeling initiative being carried out through the FCRPS Adaptive Management Implementation Plan.	All parameters	Improve ability to evaluate and understand the relative effects of actions in different threat categories across the life cycle.	Tools lacking to determine species response to actions at stages & across lifecycle	Category: Ongoing essential	Baseline action	BPA, NMFS, USFWS, USGS, co-managers	2008/2010 FCRPS BiOp (AMIP Section IIIa: Enhanced Life Cycle Monitoring)
Potential Additional Actions to Achieve ESU Viability								
1-2	Conduct multi-stage life cycle modeling to assess potential response of Snake River fall Chinook salmon to alternative management strategies and actions under alternative climate scenarios, and to determine the best opportunities for closing the gap between the species' status and achieving viability objectives.	All parameters	Improve ability to evaluate and understand the relative effects of actions in different threat categories across the life cycle.	Tools lacking to determine species response to actions at stages & across lifecycle	Category: Most likely to provide opportunities for achieving ESU viability. Timing: Near term	For actions 1-2, 1-3, and 1-4, $600,000[35]	NMFS, state and tribal co-managers, BPA, USFWS, USGS	
1-3	Develop multi-stage life cycle model that incorporates estimates of survival through various stages of salmon life cycle to assess changes in population viability.	All parameters	Improve ability to evaluate and understand the relative effects of actions in different threat categories across the life cycle.	Tools lacking to determine species response to actions at stages & across lifecycle	Category: Most likely to provide opportunities for achieving ESU viability. Timing: Near term	See action 1-2.	NMFS, state and tribal co-managers, BPA, USFWS, USGS	

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[34] The near-term time frame corresponds roughly with the next five years of implementation (2016-2020). The mid-term time frame corresponds generally to the succeeding twenty years.

[35] Assumes $150,000 per year for 4 years to fund a post-doctorate position to work with ongoing modelling efforts.

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Category Timing of Potential Additional Actions (near, mid, or long-term)[34]	Estimated Costs	Potential Implementing Entity(ies)	Comments
1-4	Use life cycle model to assess the ESU as a whole, and interactions between the different spawning areas.	All parameters	Improve ability to evaluate and understand the relative effects of actions in different threat categories across the life cycle.	Tools lacking to determine species response to actions at stages & across lifecycle	Category: Most likely to provide opportunities for achieving ESU viability. Timing: Near term	See action 1-2.	NMFS, state and tribal co-managers, BPA, USFWS, USGS	
Management Strategy 2: Maintain and enhance suitable spawning, incubation, rearing, and migration conditions by continuing ongoing actions and implementing additional actions in the mainstem and tributaries.								
Ongoing Actions — **Mainstem Habitat**								
2-1	Continue to implement Idaho Power Company's fall Chinook salmon spawning program to enhance and maintain suitable spawning and incubation conditions.	A, P & SS	Reduced spawning areas, dewatering of eggs, fitness of emerging fry. Reduced outflow & water quality: low dissolved oxygen, elevated TDG, potentially altered thermal regime	Hells Canyon Complex hydropower operations	Category: Ongoing essential	Baseline action	Idaho Power Company	FERC License
2-2	Continue to implement cool water releases from Dworshak Dam to maintain adequate migration conditions (for adults and juveniles) and juvenile rearing conditions (temperatures) in the lower Snake River.	All parameters	High temperatures Adults: delayed/ blocked migration, fallback, reduced spawning area. Juveniles: delayed migration, injuries stress, mortality	FCRPS reservoirs and dams	Category: Ongoing essential	Baseline action	COE	2008 FCRPS BiOp
2-3	Continue summer flow augmentation (at Dworshak Reservoir, Brownlee Reservoir, and upper Snake River Bureau of Reclamation projects) to maintain adequate summer migration conditions.	All parameters	Altered flows, High temperatures Adults: delayed/ blocked migration, fallback, reduced spawning area. Juveniles: delayed	FCRPS reservoirs and dams	Category: Ongoing essential	Baseline action	COE, BOR, Idaho Power Company	2008 FCRPS BiOp

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Category Timing of Potential Additional Actions (near, mid, or long-term)[34]	Estimated Costs	Potential Implementing Entity(ies)	Comments
			migration, injuries stress, mortality					
2-4	Continue summer spill at mainstem Lower Snake River and Lower Columbia River dams to maintain adequate passage conditions for substantial numbers of actively migrating fish.	All parameters	Altered flows; Adults: delayed/ blocked migration, fallback, reduced spawning area. Juveniles: delayed migration, injuries stress, mortality	FCRPS reservoirs and dams	Category: Ongoing essential	Baseline action	COE	2008 FCRPS BiOp
2-5	Continue management actions to reduce juvenile losses to predacious fish and birds.	A, P & D	Mortality, injury from predation	FCRPS reservoirs and dams	Category: Ongoing essential	Baseline action	COE, USFWS	2008 FCRPS BiOp
2-6	Continue interim operations at Lower Granite Dam to respond to adult passage blockages caused by warm surface waters entering the fish ladders. (Also see related action 2-13, below.)	All parameters	Altered thermal regime; Mortality, delayed/ blocked migration, fallback,	FCRPS reservoirs and dams	Category: Ongoing essential	Baseline action	COE	2008 FCRPS BiOp
2-7	Complete fall Chinook salmon transportation study, scheduled for completion in 2017.	A & P	Juveniles: slowed migration, mortality, stress, injury, predation, disrupted homing ability	FCRPS reservoirs and dams	Category: Ongoing essential	Baseline action	COE	2008 FCRPS BiOp
2-8	Continue to assess the behavior (including passage timing) and number of overwintering juveniles in the Lower Granite reservoir.	A, P, D	Altered thermal regime; slowed migration, mortality,	FCRPS reservoirs and dams	Category: Ongoing essential	Baseline action. May need to be expanded from baseline level of implementation.[36]	COE, BPA	2008 FCRPS BiOp

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[36] Estimating the number and passage timing of overwintering juveniles is an ongoing baseline action. Two methods have been developed for this assessment: a regression approach developed from one year of field data and a relatively simple expansion method that relies on extended operation of the juvenile fish bypass system at Lower Granite Dam. Under baseline activities, neither method has been

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Category Timing of Potential Additional Actions (near, mid, or long-term)[34]	Estimated Costs	Potential Implementing Entity(ies)	Comments
						Additional cost: $750,000[37]		
2-9	Continue to implement measures identified in the Lower Snake River Programmatic Sediment Management Plan (PSMP) to reduce impacts of reservoir and river channel maintenance dredging and disposal of Snake River fall Chinook salmon.	A, P & SS	Altered flow and sediment regimes; Increased predation, competition, loss of rearing area	Dam operations and reservoirs	Category: Ongoing essential	Baseline action	COE	Preferred alternative from Lower Snake River Programmatic Sediment Management Plan (PSMP) Final Environmental Impact Statement (EIS) (August 2014)
2-9.1	Continue to dispose of dredge material in a manner that does not create islands that could attract predator bird colonies.	A & P	Increased predation, competition	FCRPS system dams and reservoirs	Category: Ongoing essential	Baseline action	COE	PSMP EIS Preferred Alternative
2-9.2	Continue in-water dredge sediment disposal in a manner that creates juvenile fall Chinook salmon habitat and reduces predator habitat.	A, P, SS	Increased predation, competition, loss of rearing area	FCRPS system dams and reservoirs	Category: Ongoing essential	Baseline action	COE	2008 FCRPS BiOp; PSMP EIS Preferred Alternative
Ongoing Actions — Tributary Habitat								
2-10	Continue to implement actions to protect, improve, and enhance spawning and rearing habitat conditions in tributary reaches.	A, P, SS, D	Lack of habitat quantity and diversity, degraded water quality, excess fine sediment, degraded riparian area	Land uses that affect river corridor habitat conditions	Category: Ongoing essential	Baseline action	OR, ID, WA, NPT, local recovery planning groups	
Potential Additional Actions to Achieve ESU Viability – Mainstem Habitat								

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validated, nor is funding available to conduct all needed field work. To validate results, more data are needed over the entire time period that fish might be passing the dam. A three-year test period that includes operating the juvenile bypass system as late into December as possible and resuming bypass operations as early in March as possible would adequately inform a decision on the optimum duration of bypass operations in the future.

[37] Assumes $250,000 per season for three seasons to staff smolt monitoring facility, operate juvenile bypass system for two additional months per season, and provide for additional maintenance staff to offset lost in-water work time.

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Category Timing of Potential Additional Actions (near, mid, or long-term)[34]	Estimated Costs	Potential Implementing Entity(ies)	Comments
2-11	Upon completion of the fall Chinook salmon transportation study (see action 2-7), modify the Corps of Engineers' transportation program to enhance adult returns of migrating juvenile salmon, including consideration of terminating or modifying transport at one or more collector projects if warranted, depending on results.	A & P	Juveniles: slowed migration, mortality, stress, injury, predation, disrupted homing ability	FCRPS dams, operations, reservoirs	Category: Most likely to provide opportunities for achieving ESU viability. Timing: Near term	Baseline action	COE	2008 FCRPS BiOp
2-12	Install, if feasible, a passive integrated transponder (PIT) tag detector in the removable spillway weir at Lower Granite Dam to enhance understanding of smolt-to-adult returns and the contributions of alternative life history strategies.	All parameters	Juveniles: slowed migration, rise in mortality, injury, disrupted homing ability	FCRPS system dams and reservoirs	Category: Most likely to provide opportunities for achieving ESU viability. Timing: Near term	Baseline action	COE, BPA	2008 FCRPS BiOp
2-13	Based on results of action 2-8, evaluate the potential to improve survival of juvenile fall Chinook salmon passing Lower Granite Dam in late fall and early spring and, depending on results, implement appropriate modifications to configuration.	A, P & D	Altered thermal regime; slowed migration, mortality,	FCRPS system dams and reservoirs	Category: Warrants additional evaluation. Timing: Near term	To be determined (contingent on outcome of action 2-8).	COE, BPA	
2-14	Implement structural and operational changes at Lower Granite Dam to more reliably address adult passage blockages caused by warm	A, P & D	High temperatures Adults: delayed/ blocked migration, fallback, reduced spawning area.	FCRPS system dams and reservoirs	Category: Most likely to provide opportunities for achieving ESU viability.	Baseline action	COE, BPA	2008 FCRPS BiOp

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Category Timing of Potential Additional Actions (near, mid, or long-term)[34]	Estimated Costs	Potential Implementing Entity(ies)	Comments
	surface waters entering the fish ladders. (Also see related action 2-6, above.)				Timing: Near term			
2-15	Implement actions to improve the quality of water discharged from the Hells Canyon Complex (dissolved oxygen, total dissolved gas) – as called for in NMFS recommendations for the Hells Canyon FERC Relicensing.	A, P, SS	Reduced outflow, water quality: low dissolved oxygen, elevated TDG, potentially altered thermal regime	Hells Canyon Complex hydropower operations	Category: Most likely to provide opportunities for achieving ESU viability. Timing: Near term	Baseline action	Idaho Power	NMFS recommendations for the Hells Canyon FERC Relicensing (NMFS 2006).
2-16	Develop and implement a gravel monitoring and management plan in the Hells Canyon reach of the Snake River.	A, P, SS	Interruption of geomorphological processes, reduced gravel, habitat diversity	Hells Canyon Complex hydropower operations	Category: Warrants additional evaluation Timing: Near term	Baseline action	FERC, Idaho Power	Hells Canyon FEIS (FERC 2007)
2-17	Determine the effects of water management strategies on main-stem rearing capacities at different flow levels and adapt, as appropriate, given consideration for requirements for other migrating species (e.g., sockeye, spring Chinook salmon, and steelhead).	A, P, SS	Altered thermal regime; altered flows (seasonal, daily and hourly)	Hydro system and operations	Category: Warrants additional evaluation Timing: Mid term	$125,000[38] Any follow-up actions would depend on outcome of study and costs would be to be determined.	Idaho Power, BOR	
2-18	Evaluate effects of winter dredging and of in-water dredge sediment disposal on predator-prey relationships and adapt		Increased predation, competition, loss of rearing area	FCRPS system dams and reservoirs	Category: Warrants additional evaluation	Baseline action	COE	PSMP EIS Preferred Alternative

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[38] Cost estimate assumes that bathymetry and substrate data would be available (from Idaho Power Company). Cost is for running a 2D model (gradient and water velocity) for mainstem Snake from Hells Canyon to the Asotin (would need to determine what scenarios to model).

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Category Timing of Potential Additional Actions (near, mid, or long-term)[34]	Estimated Costs	Potential Implementing Entity(ies)	Comments
	management actions as appropriate.				Timing: Mid-term			
2-19	Implement actions to improve water quality, including Clean Water Act Total Maximum Daily Loads (TMDLs) to improve water quality in the mainstem Snake and Columbia Rivers.	A & P	Degraded water quality, including altered thermal regime, toxic pollutants,	FCRPS system dams and reservoirs	Category: Most likely to provide opportunities for achieving ESU viability. Timing: Near term	Baseline action	ID, OR, EPA	CWA TMDL Implementation Plans
Potential Additional Actions to Achieve ESU Viability – Tributary Habitat								
2-20	Complete and implement TMDLs to improve water quality in tributary habitats that affect Snake River fall Chinook salmon spawning and rearing habitats.	A, P, SS, D	Degraded water quality (high summer temps, toxic pollutants, nutrients, low dissolved oxygen).	Land uses that affect river corridor habitat conditions	Category: Most likely to provide opportunities for achieving ESU viability. Timing: Near term	Baseline action	ID, OR, EPA	CWA
2-21	Improve tributary habitat associated with major spawning areas (MaSAs).							
2-21.1	Evaluate and prioritize opportunities to restore tributary side channel rearing habitats to increase natural production capacity for fall Chinook salmon in all MaSAs and associated tributary spawning areas.	A, P, SS	Lack of habitat quantity and diversity (primary pools, large wood, glides, spawning gravels), excess fine sediment, degraded riparian	Land uses that affect river corridor habitat conditions	Category: Warrants additional evaluation. Timing: Mid term	$50,000[39]	WA, OR, ID, NPT	Addresses RM&E appendix gaps 4B and 4C.

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[39] Assumes action would be to conduct high-level survey (rather than full-scale habitat assessment) to identify, e.g., highly degraded areas that present opportunities for restoration. Could also utilize ongoing NWFSC habitat capacity work to extent possible. Opportunities primarily in Clearwater.

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Category Timing of Potential Additional Actions (near, mid, or long-term)[34]	Estimated Costs	Potential Implementing Entity(ies)	Comments
2-21.2	When carrying out actions to mitigate for declining tributary flows by evaluating, protecting, and restoring wetlands, floodplains, or other landscape features that store water (primarily to benefit spring Chinook), consider downstream benefits to fall Chinook.	A, P, SS, D	Low summer flow, degraded water quality (high summer temps, nutrients, etc.); reduced habitat quantity/ diversity, excess fine sediment	Water withdrawals and land uses that affect river corridor habitat conditions	Category: Warrants additional evaluation. Timing: Mid term	N/A[40]	WA, OR, ID, NPT	
2-21.3	When carrying out actions to benefit spring Chinook by alleviating elevated temperatures and low stream flows through riparian restoration and managing water withdrawals, consider downstresm benefits to fall Chinook salmon.	A, P, SS	Degraded riparian conditions, low summer flow, high summer water temps, reduced habitat quantity/ diversity	Land uses that affect river corridor, water withdrawals	Category: Warrants additional evaluation. Timing: Mid term	N/A [41]	WA, OR, ID, NPT	
2-22	Target high priority opportunities to restore October spawning life history patterns.	A, P, SS, D	Altered flows, thermal regime discourage fall spawning	Dworshak Dam operations; land uses that affect river habitat	Category: Most likely to provide opportunities for achieving ESU viability. Timing: Near term	$50,000[42]	NPT, ID, Idaho Power	

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[40] Such actions would be carried out primarily to benefit spring Chinook, particularly in Catherine Creek and the Grande Ronde River. Fall Chinook could gain some downstream benefit. Related to RM&E question 4A.

[41] Such actions would be carried out primarily to benefit spring Chinook. Fall Chinook could gain some downstream benefit but would not be the focus of the action.

[42] Assumes areas in South Fork Salmon, lower mainstem Wallowa (Upper Grande Ronde), and Upper Clearwater may have supported the October spawning life history pattern. Would need to restore spawning, rearing, migration habitats conducive to this life-history pattern. First step would be to evaluate temperature profiles (is spawning possible given October flow levels and temps; is rearing possible given winter/spring temp profiles? (Could also build off of capacity mapping efforts already underway.)

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Category Timing of Potential Additional Actions (near, mid, or long-term)[34]	Estimated Costs	Potential Implementing Entity(ies)	Comments
2-22.1	Evaluate potential spawning and rearing habitats in the lower reaches of the Selway, Lochsa, and South Fork Clearwater Rivers.	A, P, SS, D	-Degraded water quality: high temp, sediment, nutrients, pollutants. Altered Channel habitat	Land uses that affect river habitat, water withdrawals,	Category: Most likely to provide opportunities for achieving ESU viability. Timing: Near term	To be determined	NPT, ID, Idaho Power	
2-23	Evaluate whether water quantities and quality could be increased and whether sediment delivery could be reduced in the lower Grande Ronde River to improve spawning and rearing conditions and survival.	A, P, SS	Low summer flow, degraded water quality (high summer temps, nutrients, etc.); reduced habitat quantity/ diversity, excess fine sediment	Land uses that affect river habitat, water withdrawals,	Category: Warrants additional evaluation. Timing: Mid term	To be determined	OR, WA	
2-24	Evaluate the potential to reduce sediment impacts on lower Tucannon River mainstem historical spawning and rearing area.	A, P, SS	Altered sediment routing excess fine sediment, habitat diversity and channel stability.	Land uses that affect river habitat: cultivation and other ag practices	Category: Warrants additional evaluation. Timing: Mid term	To be determined	WA SRSRB	Current condition exceeds the SRSRB goal and therefore actions to reduce sediment in the lower Tucannon are a low priority at this time.
Management Strategy 3: Address lack of access to estuary habitat; altered food web; and altered flow regime by continuing ongoing actions and implementing potential additional actions identified in the Estuary Module, FCRPS BiOp and this recovery plan.								
Ongoing Actions								
3-1	Protect recent gains in acquisitions of functioning habitat in the marshes and floodplains below Bonneville Dam	A, P, SS	Reduced off-channel habitat	FCRPS flow management, land use practices that affect habitat -- diking, filling, etc.	Category: Ongoing essential	Baseline action. May need to be expanded from baseline level of implementation. If additional efforts	COE, BPA, OR, WA, local governments, tribes, NGOs, Lower Columbia Estuary	Estuary Module, CRE 9

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Category Timing of Potential Additional Actions (near, mid, or long-term)[34]	Estimated Costs	Potential Implementing Entity(ies)	Comments
						needed, costs to be determined.[43]	Partnership, et al.	
3-2	Protect restored areas so that juvenile Snake River fall Chinook salmon can benefit from increased habitat capacity and quality.	A, P, SS	Reduced off-channel habitat, reduced food	FCRPS flow management, land use practices that affect habitat -- diking, filling, etc.	Category: Ongoing essential	Baseline action. May need to be expanded from baseline level of implementation. If additional efforts needed, costs to be determined.[8]	COE, BPA, OR, WA, local governments, tribes, NGOs, Lower Columbia Estuary Partnership, et al.	Estuary Module, CRE 1, CRE 9
Potential Additional Actions to Achieve ESU Viability								
3-3	Continue to breach, lower or relocate dikes and levees to establish or improve access to off-channel habitats	A, P, SS	Reduced off-channel habitat, reduced food	Diking, filling, etc.	Category: Most likely to provide opportunities for achieving ESU viability. Timing: Near term	Baseline action. May need to be expanded from baseline level of implementation. If additional efforts needed, costs to be determined.[8]	COE, BPA, US FWS, OR, WA, local governments, Lower Columbia Fish Recovery Board, Lower Columbia Estuary Partnership, NGOs, et al.	FCRPS BiOp, Estuary Module CRE-10
3-4	Continue to protect remaining high-quality off channel habitat from degradation and restore degraded areas with high intrinsic potential for high quality habitat.	A, P, SS	Reduced off-channel habitat, reduced food	FCRPS flow management, land use practices that affect habitat -- diking, filling, etc.	Category: Most likely to provide opportunities for achieving ESU viability.	Baseline action. May need to be expanded from baseline level of implementation. If additional efforts	COE, BPA, US FWS, OR, WA, local governments, Lower Columbia Fish Recovery	FCRPS BiOp, Estuary Module CRE- 9

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[43] NOAA Fisheries' Columbia River Estuary Recovery Plan Module is incorporated by reference into this plan. The actions highlighted here are those expected to be particularly beneficial to fall Chinook salmon. The Estuary Module identified significant costs in addition to baseline costs for these actions (see Module, pp. 5-41—5-66). However, given the current risk status of this ESU and the ongoing implementation of estuary recovery actions under the 2008 FCRPS Biological Opinion and other baseline programs, it is likely that the level of effort needed in the estuary to achieve Snake River fall Chinook delisting will be lower than the level envisioned in the module. While it is possible that baseline actions in the estuary will need to be expanded to achieve delisting, it is not possible at this time to quantify the additional level of effort needed, or the costs associated with that additional level of effort. It is likely that additional efforts, and costs, would be significantly less than these identified in the module. This does not diminish the importance of improving salmon survival generally in the estuary through full implementation of actions in the Estuary Module, or the relevance of the cost estimates in the Estuary Module, for species that are currently at a higher risk status than Snake River fall Chinook.

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Category Timing of Potential Additional Actions (near, mid, or long-term)[34]	Estimated Costs	Potential Implementing Entity(ies)	Comments
					Timing: Near term	needed, costs to be determined.[8]	Board, Lower Columbia Estuary Partnership, NGOs, et al.	
3-5	Continue to restore or mitigate contaminated sites.	A, P, SS	Mortality, disease, reduced fitness from contaminates	Urban and industrial wastes	Category: Most likely to provide opportunities for achieving ESU viability. Timing: Near term	Baseline action. May need to be expanded from baseline level of implementation. If additional efforts needed, costs to be determined.[8]	EPA, USGS, OR, WA, Lower Columbia Estuary Partnership, et al.	FCRPS BiOp, Estuary Module CRE-22
3-6	Continue to identify and reduce terrestrially and marine-based industrial, commercial, and public sources of pollutants	A, P, SS	Mortality, disease, reduced fitness from contaminates	urban and industrial runoff, effluent, wastes	Category: Most likely to provide opportunities for achieving ESU viability. Timing: Near term	Baseline action. May need to be expanded from baseline level of implementation. If additional efforts needed, costs to be determined.[8]	EPA, OR, WA, local governments	FCRPS BiOp, Estuary Module CRE-21
3-7	Further reduce predation on yearling migrants by implementing projects to redistribute part of the Caspian tern colony currently nesting on East Sand Island.	A, P, SS	Mortality, injury from Increased predation by birds	FCRPS flow management	Category: Most likely to provide opportunities for achieving ESU viability. Timing: Near term	Baseline action. May need to be expanded from baseline level of implementation. If additional efforts needed, costs to be determined.[8]	COE, US FWS, USGS, ODFW, WDFW	FCRPS BiOp, Estuary Module CRE-16
3-8	Further reduce predation on yearling migrants by implementing projects to reduce double-crested cormorant habitats and encourage dispersal to other locations.	A, P, SS	Mortality, injury from increased predation by birds	FCRPS flow management	Category: Most likely to provide opportunities for achieving ESU viability.	Baseline action. May need to be expanded from baseline level of implementation. If additional efforts	COE, US FWS, USGS, ODFW, WDFW	FCRPS BiOp, Estuary Module, CRE-17

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Category Timing of Potential Additional Actions (near, mid, or long-term)[34]	Estimated Costs	Potential Implementing Entity(ies)	Comments
					Timing: Near term	needed, costs to be determined.[8]		
Management Strategy 4: Continue ongoing actions and implement potential additional actions that will conserve Snake River fall Chinook salmon in the face of emerging climate change.								
In Mainstem Snake/Columbia Corridor								
4-1	Continue to implement cool water releases from Dworshak Dam to maintain adequate migration conditions (for adults and juveniles) and juvenile rearing conditions (temperatures) in the lower Snake River. *(This action is the same as action 2-2 – it is repeated here since it applies to both strategies.)*	A, P, SS, D	High water temperatures, reduced spawning and rearing area	FCRPS reservoirs and dams, climate change	Category: Ongoing essential	Baseline action	COE	2008 FCRPS BiOp
4-2	Maintain surface passage routes that reduce travel time through forebays.	A, P, SS, D	Delayed migration, injuries stress, mortality	FCRPS reservoirs and dams, climate change	Category: Ongoing essential	Baseline action	COE	2008 FCRPS BiOp
4-3	Continue to reduce warm water predators in reservoirs (for example, as in action 5-3, above).	A, P, D	Mortality, delayed/ blocked migration, fallback,	FCRPS reservoirs and dams, climate change	Category: Ongoing essential	Baseline action		
4-4	Monitor temperatures and flows to assess trends that may be related to climate change.	A, P	Altered thermal and flow regimes; slowed migration, mortality	FCRPS reservoirs and dams, climate change	Category: Ongoing essential	Baseline action	Corps, BPA, ID Power/FERC, BOR, USGS	2008 FCRPS BiOp, FERC licenses and BiOps for Middle Snake
4-5	Continue interim operations at Lower Granite Dam to respond to adult passage blockages caused by warm surface waters entering the fish ladders and	A, P, D	Altered thermal regime; mortality, delayed/ blocked migration, fallback,	FCRPS reservoirs and dams, climate change	Category: Ongoing essential	Baseline action	COE	2008 FCRPS BiOp

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Category Timing of Potential Additional Actions (near, mid, or long-term)[34]	Estimated Costs	Potential Implementing Entity(ies)	Comments
	implement structural and operational changes to more reliably address adult passage blockages caused by warm surface waters entering the fish ladders. *(This action incorporates actions 2-6 and 2-13 above – repeated here because they apply to both strategies.)*							
In the estuary								
4-6	Breach, lower or relocate dikes and levees to establish or improve access to off-channel habitats. (This action is the same as action 3-3 – it is repeated here since it applies to both strategies.)	P, SS	Reduced off-channel habitat; food source change	Diking and other ag. practices	Category: Ongoing essential	Baseline action. May need to be expanded from baseline level of implementation. If additional efforts needed, costs to be determined	COE, BPA, US FWS, OR, WA, local governments, Lower Columbia Fish Recovery Board, Lower Columbia Estuary Partnership, NGOs, et al.	FCRPS BiOp, Estuary Module CRE-10
Management Strategy 5: Implement harvest programs in a manner that protects and restores Snake River fall Chinook salmon.								
Ongoing Actions								
5-1	Implement abundance-based harvest regimes according to Pacific Salmon Treaty, U.S. v. Oregon Management Agreement, and fishery management frameworks authorized under the ESA	A, P, D	Mortality Potential indirect selection for age, size, run timing	Fisheries	Category: Ongoing essential	Baseline action	US v. OR parties, Pacific Salmon Treaty parties	PST, US v OR, respective BiOps
5-2	Ensure accuracy of reported estimates of harvest of natural-origin Snake River fall Chinook salmon in both ocean and river	A, P, D	Mortality Potential indirect selection for age, size, run timing	Fisheries	Category: Ongoing essential	Baseline action	US v. OR parties, Pacific Salmon Treaty parties	PST, US v OR, respective BiOps

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Category Timing of Potential Additional Actions (near, mid, or long-term)[34]	Estimated Costs	Potential Implementing Entity(ies)	Comments
	fisheries as required by the existing biological opinions							
Potential Additional Actions to Achieve ESU Viability								
5-3	Develop harvest management frameworks and complete ESA regulatory reviews for Snake Basin fisheries that directly or incidentally take Snake River fall Chinook salmon	A, P, D	Mortality Potential indirect selection for age, size, run timing	Fisheries	Category: Most likely to provide opportunities for achieving ESU viability. Timing: Near term	Baseline action	US v. OR parties, Pacific Salmon Treaty parties	PST, US v OR, respective BiOps
5-4	Update harvest management frameworks, as appropriate, to respond to potential changes in hatchery release strategies in 2018 and beyond.	A, P, D	Mortality Potential indirect selection for age, size, run timing	Fisheries	Category: Most likely to provide opportunities for achieving ESU viability. Timing: Near term	Baseline action	US v. OR parties, Pacific Salmon Treaty parties	PST, US v OR, respective BiOps
5-5	Ensure that potential changes to downriver fisheries in response to the John Day mitigation program do not result in harvest of natural Snake River fall Chinook salmon that is inconsistent with recovery objectives	A, P, D	Mortality Potential indirect selection for age, size, run timing	Fisheries	Category: Most likely to provide opportunities for achieving ESU viability. Timing: Near term	Baseline action	US v. OR parties, Pacific Salmon Treaty parties	PST, US v OR, respective BiOps
5-6	Consistent with results of the evaluations described in RM&E update harvest management plans through negotiations with appropriate fishery management forums	A, P, D	Mortality Potential indirect selection for age, size, run timing	Fisheries	Category: Most likely to provide opportunities for achieving ESU viability. Timing: Near term	Baseline action	US v. OR parties, Pacific Salmon Treaty parties	PST, US v OR, respective BiOps
Management Strategy 6: Continue ongoing actions and implement potential additional actions that address predation, prey base, competition and other ecological interactions.								

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Category Timing of Potential Additional Actions (near, mid, or long-term)[34]	Estimated Costs	Potential Implementing Entity(ies)	Comments
Ongoing Actions								
6-1	Continue efforts to reduce or disperse bird colonies that prey on juvenile Snake River fall Chinook salmon in both the interior Columbia and the estuary.	A, P, SS, D	Mortality, injury due to increased predation by birds	Dam operations, reservoirs; alterations to estuary habitat	Category: Ongoing essential	Baseline action	COE, US FWS, USGS, ODFW, WDFW	2008 FCRPS BiOp In the estuary, this action overlaps with actions 3-7 and 3-8 above.
6-2	Continue pike minnow bounty program.	A, P	Mortality due to increased predation by non-native fish	FCRPS system, dam operations, reservoirs,	Category: Ongoing essential	Baseline action	BPA	2008 FCRPS BiOp
Potential Additional Actions to Achieve ESU Viability								
6-3	Improve states of Oregon and Washington fishery management of non-native fish predator populations including pike minnow, smallmouth bass, channel catfish and walleye.	A, P	Mortality, injury due to increased predation by non-native fish	Dam operations, reservoirs, land use alterations	Category: Warrants additional evaluation. Timing: Near term	To be determined	ODFW, WDFW	
6-4	Evaluate plume/nearshore ocean conditions that influence predator fish populations and predation rates during the early ocean life stage.	A, P, D	Mortality due to increased predation by other native and non-native fish	FCRPS system, land and water management actions; high abundance of hatchery fish	Category: Warrants additional evaluation. Timing: Mid term	$300,000[44]	NWFSC	
6-5	Evaluate impacts of competition and density dependence on natural-origin Snake River fall Chinook salmon.	A, P	Competition for space in spawning and rearing areas; competition for food	Increased abundance of non-native species	Category: Warrants additional evaluation. Timing: Mid term		USGS, USFWS	

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[44] Assumes that current trawl survey does not reflect fish predator field on salmonids and that sampling would be required nearshore and around jetties during Snake River fall Chinook outmigration. Effective sampling would require hook and line, SCUBA spearing, or possibly a small purse seine. Most predators are likely to be bottom-associated (rockfish, lingcod, cabezon, halibut, and perhaps arrowtooth flounder), which would require sampling on a smaller scale than with trawl surveys. If sampling offshore in the plume, might require sampling near the bottom with a trawl but more likely with longlines. Knowing predation rates, gut evacuation rates, and predator population sizes, would be possible to estimate consumption relative to salmon outmigration.

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Category Timing of Potential Additional Actions (near, mid, or long-term)[34]	Estimated Costs	Potential Implementing Entity(ies)	Comments
6-5.1	Evaluate effect of spawner redd superimposition on juvenile productivity		Competition for space in spawning and rearing areas		Category: Warrants additional evaluation. Timing: Mid term	$500,000[45]	BPA, USGS, USFWS	Could be implemented as expansion/reprogram of current shallow and deep water redd surveys conducted under BPA-funded project 199102900.
6-5.2	Evaluate food availability and consumption by potential competitors in terms of effect on growth and survival of Snake River fall Chinook juveniles.		Competition for space in spawning and rearing areas; competition for food		Category: Warrants additional evaluation. Timing: Mid term	$2.5 million[46]	BPA, USGS, USFWS	Could be implemented as expansion/reprogram of currently funded work related to predation under project 200203200 funded by BPA.
6-6	Take actions to prevent the rapidly expanding ranges of zebra mussel, quagga mussel, New Zealand mud snail, Siberian prawns and other invasive species from extending into Snake River fall Chinook salmon habitat and depleting available nutrients in rivers.	A, P, SS, D	Mortality and disease; reduced food, degraded water quality and habitat quality	Land and water management	Category: Warrants additional evaluation. Timing: Mid term	To be determined	ID, WA, OR	In the estuary, this action overlaps with actions 3-7 and 3-8 above.
Management Strategy 7: Continue ongoing actions and implement potential additional actions that reduce the impact of hatchery fish on Snake River fall Chinook salmon.								
Ongoing Actions								
7-1	Continue to implement best management practices at Snake River fall Chinook	A, P, D	Genetic changes; loss of fitness; disease transfer; competition	High proportion of hatchery fish as juveniles and	Category: Ongoing essential	Baseline action	NMFS, NPT, WDFW, IDFG, ODFW	BiOp

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[45] Assumes $100,000 per year for five years for field work required to quantify redd superimposition and conduct an analysis of its effects on juvenile abundance.

[46] Assumes $500,000 per year for 5 years to fund a 3-person crew to collect and analyze data.

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Category Timing of Potential Additional Actions (near, mid, or long-term)[34]	Estimated Costs	Potential Implementing Entity(ies)	Comments
	salmon hatcheries as reviewed in the ESA biological opinion on the HGMPS for those programs.		for spawning areas and other resource; higher mortality from incidental harvest	adults				
7-2	Continue current actions to minimize fish from outside the ESU spawning in the wild.	P, D	Genetic changes; loss of fitness; disease transfer; competition for spawning areas and other resource	Straying of out-of-ESU hatchery fish to spawning grounds	Category: Ongoing essential	Baseline action	NMFS, NPT, WDFW, IDFG, ODFW	BiOp
7-3	Continue to improve estimates of natural- and hatchery-origin fish over Lower Granite Dam.	A, P, D	Genetic changes; loss of fitness; disease transfer; competition for spawning areas and other resource	High proportion of hatchery fish; Straying of hatchery fish to spawning grounds	Category: Ongoing essential	Baseline action. Needs to be expanded from baseline level for full implementation – see action 7-3.1.	WDFW, IDFG, NPT, ID Power (IPC), USFWS, NMFS	
7-3.1	Re-estimate the proportion of natural- and hatchery-origin fish over Lower Granite Dam for the period 1991-2002 (and document the procedure used).	A, P, D	Genetic changes; loss of fitness; disease transfer; competition for spawning areas and other resource	High proportion of hatchery fish; Straying of hatchery fish to spawning grounds	Category: Most likely to provide opportunities for achieving ESU viability. Timing: Near term	$75,000[47]	USGS	
7-4	Continue to validate and improve estimates of hatchery/natural composition of adult fish on the spawning grounds, both overall and in specific major spawning areas.	P, D	Genetic changes; loss of fitness; disease transfer; competition for spawning areas and other resource	High proportion of adult hatchery fish; straying of hatchery fish to spawning grounds	Category: Ongoing essential	Baseline action. Needs to be expanded from baseline level for full implementation.	WDFW, Nez Perce Tribe, USFWS, Idaho Power Company	

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[47] Support for one analyst and coordination with the existing run reconstruction group.

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Category Timing of Potential Additional Actions (near, mid, or long-term)[34]	Estimated Costs	Potential Implementing Entity(ies)	Comments
						Additional cost: $370,000[48]		
7-5	Continue to evaluate dispersal and homing fidelity of hatchery releases.	A, P	Potential for competition with wild fish for food, other resources in rearing areas	High proportion of hatchery fish as juveniles	Category: Ongoing essential	Baseline action. May need to be repeated to obtain adequate information, depending on recovery scenario. Additional costs to be determined.	Nez Perce Tribe, WDFW, USGS	
7-6	Ensure that adult returns from new hatchery programs (e.g., the John Day mitigation program) do not stray above acceptable levels into the Snake River	A, P, D	Genetic changes, loss of fitness, disease transfer, competition, higher mortality from incidental harvest	High proportion of hatchery fish as adults; straying of hatchery fish to spawning grounds	Category: Ongoing essential	Baseline action	ODFW	
Potential Additional Actions to Achieve ESU Viability								
7-7	Work through the U.S. v. OR co-manager forum to identify and assess potential management frameworks that would achieve delisting by (1) creating natural production emphasis areas (NPEAs) – i.e., major spawning areas (MaSAs) that produce a substantial level of natural-origin adult spawners	P, SS, D	Genetic changes; loss of fitness; disease transfer; competition for spawning areas, food and other resource	High proportion of hatchery fish as juveniles and adults in some areas; straying of hatchery fish to spawning grounds	Category: Most likely to provide opportunities for achieving ESU viability. Timing: near term	To be determined	US v. OR parties	

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[48] Current estimates are based on dam counts and additional information/assumptions regarding run composition. Developing an approach based on direct sampling is problematic but would provide better estimates. Cost assumes $100,000 for a study of techniques used in large rivers to survey fall Chinook salmon, and $270,000 to evaluate and test new methods based on the study ($70,000 for three years for project leader and $20,000 for 3 years for two field assistants).

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Category Timing of Potential Additional Actions (near, mid, or long-term)[34]	Estimated Costs	Potential Implementing Entity(ies)	Comments
	with a low proportion of hatchery-origin spawners or (2) reducing hatchery-origin spawners in the population overall.							
7-8	Based on existing and emerging data from ongoing RM&E, model feasibility (in terms of viability criteria) of frameworks that would result in achievement of VSP objectives for highly viable population status based on population performance in one or more NPEAs.	A, P, SS, D	Genetic changes; loss of fitness; disease transfer; competition for spawning areas, food and other resource	High proportion of hatchery fish as juveniles and adults in some areas; straying of hatchery fish to spawning grounds	Category: Most likely to provide opportunities for achieving ESU viability. Timing: near term	See costs for actions 1-2, 1-3, and 1-4.	See actions 1-2, 1-3, and 1-4	This action would be addressed under actions 1-2, 1-3, and1-4.
7-9	Identify data gaps that limit assessment of feasibility of NPEA management frameworks and implement appropriate RM&E measures to fill the gaps.	P & D	Lack of information to assess feasibility of implementing, and potential results of, NPEA management framework	High proportion of hatchery fish and juveniles and adults; carrying capacity, competition	Category: Most likely to provide opportunities for achieving ESU viability. Timing: near term	To be determined	Nez Perce Tribe, NMFS, USFWS, ODFW, WDFW, Idaho Power, BPA	
7-10	Develop appropriate metrics for evaluation of VSP status in NPEAs and other MaSAs	P, SS & D	Lack of tools to evaluate VSP status	High proportions of hatchery fish as adults and juveniles in some areas; carrying capacity; competition	Category: Most likely to provide opportunities for achieving ESU viability. Timing: near term	N/A[49]		
7-11	Assess the expense, logistical difficulty, and consequences (e.g., to fisheries) of implementing NPEA	P, SS, D	Lack of information to complete assessment	Competition; high proportion of hatchery fish as adults and	Category: Most likely to provide opportunities for achieving ESU	To be determined	BPA, Nez Perce Tribe, NMFS, USFWS, ODFW, WDFW, Idaho	

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[49] Task would be completed with existing staff resources.

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Category Timing of Potential Additional Actions (near, mid, or long-term)[34]	Estimated Costs	Potential Implementing Entity(ies)	Comments
	frameworks			juveniles; higher mortality due to incidental harvest	viability. Timing: near term		Power	
Strategy 8: Reduce potential effects of toxic contaminants on Snake River fall Chinook.								
8-1	Develop actions to reduce toxic contaminants at the sources.	A, P	Contaminants causing mortality, disease, reduced fitness	Ag runoff, legacy mining, urban & industrial runoff, effluent, wastes	Category: Most likely to provide opportunities for achieving ESU viability. Timing: mid-term	To be determined	EPA and state water quality agencies in OR, WA, ID	
8-2	Revise water and sediment quality criteria as needed to ensure they are protective of listed salmonids.	A, P	Contaminants causing mortality, disease, reduced fitness	Ag runoff, legacy mining, urban & industrial runoff, effluent, wastes	Category: Most likely to provide opportunities for achieving ESU viability. Timing: mid-term	Baseline action	EPA and state water quality agencies in OR, WA, ID	Clean Water Act
8-3	Implement National Pollution Discharge Elimination System permit programs to address point source pollution.	A, P	Contaminants causing mortality, disease, reduced fitness	Mining, urban & industrial runoff, effluent, wastes	Category: Most likely to provide opportunities for achieving ESU viability. Timing: near term	Baseline action	EPA and state water quality agencies in OR, WA, ID	Clean Water Act
Management Strategy 9: Evaluate feasibility of adult and juvenile fish passage to and from spawning and rearing areas above the Hells Canyon Complex.								
9-1	Complete the Hells Canyon Federal Energy Regulatory Relicensing Proceedings and develop biological and engineering fish passage and migration feasibility studies.	A, P, SS, D	Fish passage to historical upstream habitats	Hydropower projects	Category: Action to reestablish a population above Hells Canyon Dam Complex Timing: near term	Baseline action	FERC, Idaho Power Company	

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Category Timing of Potential Additional Actions (near, mid, or long-term)[34]	Estimated Costs	Potential Implementing Entity(ies)	Comments
Management Strategy 10: Restore habitat conditions that can support Snake River fall Chinook spawning and rearing above Hells Canyon Complex by encouraging local governments and stakeholders to implement actions to reduce nutrients and sediment to improve mainstem habitat.								
10-1	Complete and implement plans to meet Total Maximum Daily Loads (TMDLs) to improve water quality in the mainstem Snake River to support adequate spawning and rearing habitat.	A, P, SS, D	Excessive nutrients, sedimentation, toxic pollutants low dissolved oxygen; reduced hyporheic conditions in reservoirs	Reservoirs; Land uses that affect river habitat	Category: Action to reestablish a population above Hells Canyon Dam Complex Timing: near term	Baseline action	State water quality agencies in OR, WA, ID	Clean Water Act
10-2	Continue to implement and develop incentive programs for land owners and water users that promote protecting and improving habitat conditions.	A, P, SS, D	Excessive nutrients, sedimentation, toxic pollutants low dissolved oxygen	Land uses that affect river habitat	Category: Action to reestablish a population above Hells Canyon Dam Complex Timing: near term	To be determined	OR, WA, ID, NGOs	

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7. Research, Monitoring, and Evaluation

This section summarizes the RM&E plan and the role of RM&E in adaptive management for Snake River fall Chinook salmon. The detailed RM&E plan is described in Appendix B. This section summarizes the RM&E recommended for assessing the status and trends in population viability and for evaluating the success of management actions implemented to address threats and recovery of Snake River fall Chinook salmon. It also describes current efforts and additional RM&E needs. Although logistical and monetary limitations exist, the RM&E plan will focus on the common goal of assessing success in recovery.

This RM&E plan is based in part on principles and concepts laid out in the NMFS document *Guidance for Monitoring Recovery of Pacific Northwest Salmon and Steelhead Listed Under the Federal Endangered Species Act* (January 2011) and *Adaptive Management for ESA-Listed Salmon and Steelhead Recovery: Decision Framework and Monitoring Guidance* (May 1, 2007). These guidance documents provide a listing status decision framework, which is a series of decision-questions that address the status and change in status of a salmonid ESU, and the risks posed by threats to the ESU (Figure 7-1). In addition, the RM&E plan borrows from other RM&E plans that were developed for other Columbia Basin regions and includes information from the Columbia Basin Anadromous Salmonid Monitoring Strategy (CBFWA 2010).

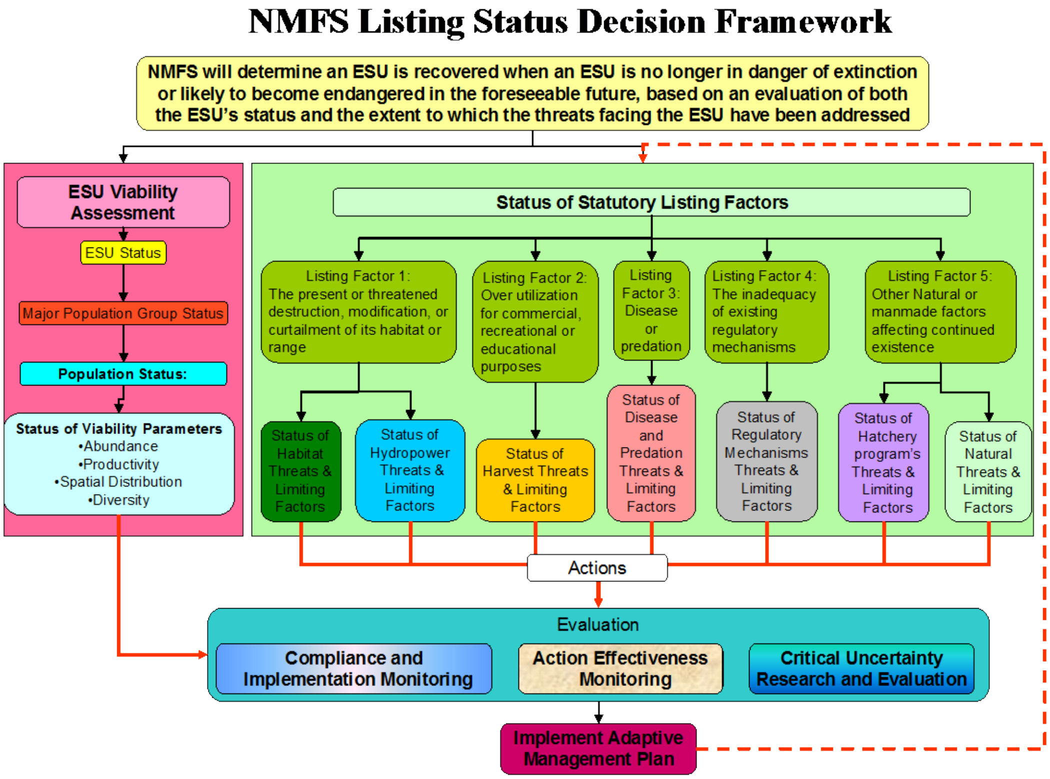

Figure 7-1. Flow diagram outlining the decision framework used by NOAA Fisheries to assess the status of biological viability criteria and limiting factors criteria.

7.1 Types of Monitoring Efforts

Several types of monitoring are needed to support adaptive management and to allow managers to make sound decisions:

- **Status and Trend Monitoring.** Status monitoring describes the current state or condition of the population and their limiting factors at any given time. Trend monitoring tracks these conditions to provide a measure of the increasing, decreasing, or steady state of a status measure through time. Status and trend monitoring includes the collection of standardized information used to describe broad-scale trends over time. This information is the basis for evaluating the cumulative effects of actions on fish and their habitats.

- **Action Effectiveness Monitoring.** This type of monitoring addresses cause-and-effect. That is, action effectiveness monitoring is designed to determine whether a given action or suite of actions achieved the desired effect or goal. This type of monitoring is research oriented and therefore requires elements of experimental design (e.g., controls or reference conditions) that are not critical to other types of monitoring. Consequently, action effectiveness monitoring is usually designed on a case-by-case basis. Action effectiveness monitoring provides funding entities with information on benefit/cost ratios and resource managers with information on what actions or types of actions improved environmental and biological conditions.

- **Implementation and Compliance Monitoring**. Implementation and compliance monitoring determines if actions were carried out as planned and meet established benchmarks. This is generally carried out as an administrative review and does not require any parameter measurements. Information recorded under this type of monitoring includes the types of actions implemented, how many were implemented, where they were implemented, and how much area or stream length was affected by the action. Success is determined by comparing field notes with what was specified in the plans or proposals (detailed descriptions of engineering and design criteria). Implementation monitoring sets the stage for action effectiveness monitoring by demonstrating that the restoration actions were implemented correctly and followed the proposed design.

- **Critical Uncertainties Research**. Research of critical uncertainties includes scientific investigations of critical assumptions and unknowns that constrain effective recovery plan implementation. Uncertainties include unavailable pieces of information required for informed decision making, as well as studies to establish or verify cause-and-effect and identification and analysis of limiting factors.

7.2 Monitoring Framework and Objectives

The desired outcome of this recovery plan is the long-term persistence of naturally produced Snake River fall Chinook salmon. In order to determine if the desired outcome has been achieved, answers to two general questions are needed.

- Is the status of the ESU trending toward recovery levels?
- Are the effects of the primary factors limiting the status of the ESU increasing, decreasing, or remaining stable?

Although these two general questions provide the basis for developing the RM&E plan, several specific objectives attend each of the two general questions. Below are listed the specific objectives.

1. Assess the status and trends in abundance and productivity of natural- and hatchery-origin fall Chinook salmon within the Lower Mainstem Snake River population.
2. Assess the status of the spatial structure of the Lower Mainstem Snake River fall Chinook salmon population based on current and historically used habitat.
3. Assess the status and trend in genetic and life history diversity of the Lower Mainstem Snake River fall Chinook salmon population.
4. Assess the status and trend of current and historically used adult holding, spawning, and juvenile rearing mainstem and tributary habitats used by Lower Mainstem Snake River fall Chinook salmon population.
5. Determine the effects of habitat limiting factors and associated management efforts in the major and minor spawning and rearing areas on the Lower Mainstem Snake River fall Chinook salmon population.
6. Determine the effects of federal hydropower operations and operational and structural improvements on the viability of Snake River fall Chinook salmon.
7. Determine the effects of ecological conditions in the estuary, plume, and near-shore ocean on the viability of Snake River fall Chinook salmon.
8. Determine the effects of physical and biological changes associated with climate change on the viability of Snake River fall Chinook salmon.
9. Determine the effects of harvest on the viability of Snake River fall Chinook salmon.
10. Determine the effect of disease, predation, prey base, competition, non-native species, and other ecological interactions on the viability of Snake River fall Chinook salmon.
11. Identify federal, state, tribal, and local regulatory mechanisms that conserve Snake River fall Chinook salmon and determine the adequacy of those regulatory mechanisms.
12. Determine the influence of hatchery supplementation programs on the viability of natural population of Snake River fall Chinook salmon.

13. Develop life cycle models to identify and assess potential factors that could limit the viability of Snake River fall Chinook salmon, including effects under current climate change projection scenarios.
14. Determine the influence of toxic contaminants on the viability of Snake River fall Chinook salmon.
15. Determine the feasibility of restoring passage and reintroduction of fall Chinook salmon populations in habitats upstream of the Hells Canyon Complex.

The following section identifies and describes specific RM&E monitoring questions associated with each of the monitoring objective listed above. A more detailed description of RM&E is provided in Appendix B. There, the plan identifies the type of monitoring needed (e.g., status and trend or implementation), monitoring questions, approaches (monitoring methods), analyses, status of monitoring associated with each monitoring question, and identification of gaps in monitoring.

7.3 Research, Monitoring, and Evaluation

As noted earlier, the overall goal of the RM&E plan is to determine if the status of the ESU is trending toward recovery levels and if the effects of the factors limiting the viability of the ESU are decreasing. Currently, there are several monitoring programs already in place that measure the status of the population and several of its limiting factors. This RM&E plan is designed to assess these current monitoring efforts and test new strategies for the conservation of Snake River fall Chinook salmon (see Appendix B). Current monitoring efforts include adult ladder counts, subsampling via adult trap, juvenile smolt indices and smolt condition, adult conversion rates, juvenile survival rates, assessments of avian predators, measurements of environmental parameters (e.g., project flow; spillway flow; forebay and tailrace total dissolved gas levels; forebay, tailrace, and scrollcase temperatures; and turbidity), juvenile dam passage performance evaluations, transportation evaluations, redd surveys, genetic sampling, tagging studies, and fishery assessments. There is also an extensive plan to assess the supplementation program (Addendum to the Snake River Fall Chinook HGMPs, 2011). These monitoring programs, as they relate to each objective, are described below. Where there are gaps in monitoring, this plan intends to fill those gaps by building upon the existing monitoring efforts.

Objective 1: Assess the status and trends in abundance and productivity of natural- and hatchery-origin fall Chinook salmon within the Lower Mainstem Snake River population.

The viability status of a population is determined by estimating the VSP parameters shown in Figure 7-1. The viability criteria are organized into two separate groupings: (1) natural-origin abundance and productivity and (2) spatial structure and diversity. Overall viability status at the population level is determined by the specific combination of ratings for those two groupings. Adult abundance is expressed as the most recent ten-year geometric mean natural-origin adult spawners. Natural return rates, or productivity, are estimated on a brood year basis as returns per spawner. Productivity is typically measured over a 20-year period. Estimating juvenile abundance at Lower Granite Dam will help to understand the influence of changes in density, environmental conditions, climate, harvest, supplementation, and other factors on productivity.

Monitoring Questions:

What are the long-term status and trends in escapement of natural- and hatchery-origin adults to the spawning areas upstream of Lower Granite Dam?

> This monitoring question focuses on generating annual estimates of natural- and hatchery-origin fall Chinook salmon that pass upstream of Lower Granite Dam to the spawning areas. Annual estimates of aggregate escapement into the spawning areas upstream from Lower Granite Dam are used to calculate standard metrics for recent average (geometric mean) adult escapement levels (total and natural origin), average hatchery proportions, and trends. Abundance is expressed as the most recent 5- and 10-year geometric mean natural-origin adult spawners. Trend in natural-origin spawners is calculated based on natural log transformed values. Standard metrics include the most recent 15-year trend and the trend since the time of listing. The inability to recover carcasses because of conditions prevalent in the large river spawning reaches used by Snake River fall Chinook salmon prevents direct estimation of area-specific hatchery and natural proportions.

What are the long-term status and trends in abundance of natural- and hatchery-origin juveniles at Lower Granite Dam?

> When coupled with results from the other monitoring questions under this objective, estimates of juvenile abundance at Lower Granite Dam aid in understanding the influence of changes in density, environmental conditions, climate, harvest, supplementation, and other factors on productivity.

What is the current estimate of intrinsic productivity for the Snake River Fall Chinook salmon population?

> In addition to providing a tool for estimating intrinsic productivity, development of a multi-stage model will also produce insights into potential density-dependent effects as a function of environmental conditions and provide a framework for evaluating the potential combined effects of management actions across life stages. Once fitted, the model will be used to assess “what if” scenarios. For example, changes in productivity resulting from changes in climate, harvest, and hatchery operations will be predicted.

Objective 2: Assess the status of the spatial structure of the Lower Mainstem Snake River fall Chinook salmon population based on current and historically used habitat.

The major spawning areas of the Snake River basin fall Chinook salmon ESU identified by the ICTRT include the Upper Mainstem Snake River MaSA (mainstem Snake River, Hells Canyon to Salmon River confluence), Lower Mainstem Snake River MaSA (Salmon River confluence to upper end of Lower Granite Reservoir), Lower Grande Ronde River MaSA, Lower Clearwater River MaSA, and Lower Tucannon River MaSA. Based on redd counts, most spawners are associated with the Clearwater River and the upper and lower reaches of the Snake River mainstem. Attempts are also being made to restore the minor spawning aggregate in the lower Selway River, and to establish a minor spawning aggregate in the South Fork Clearwater River. Using estimated spawning escapement over Lower Granite Dam as a starting point, estimates of adult and/or juvenile abundance at other life stages (e.g., outmigrating smolts or returning adults at the Columbia River mouth, pre-harvest adult recruitment) can be derived using additional information on stage-specific survival rates. Specific approaches and analyses are not detailed for the Tucannon River under Objective 1 (or any other objective unless noted), but those described could be adapted for application to that spawning area.

Monitoring Questions:

What are the long-term status and trends in estimates of spawning natural-origin adults in different spawning areas?

> It is highly unlikely that the proportion of hatchery-origin spawners is equal among the spawning areas as fidelity to the point of acclimation and release of hatchery adults and the numbers of hatchery smolts released varies among sites (Garcia et al. 2004; Connor 2014). Thus, the geographical distribution of redds does not accurately reflect the spatial distribution of natural-origin spawners. To fully inform managers of the status of the population relative to spatially explicit de-listing criteria, it will be necessary to estimate the spatial distribution of natural-origin spawners using an approach that accounts for the spatial distribution of hatchery-origin spawners. Appendix B identifies two approaches that could be used to estimate the annual number of natural-origin adults that escaped to the individual spawning areas.

How are estimates of the spawning distribution of natural-origin adults validated?

> The estimates of the spatial distribution of natural-origin spawners can be validated using otolith microchemistry (Hegg et al. 2013). Otolith microchemistry has the potential to become the primary process of tracking the spatial distribution of natural-origin spawners provided adequate samples of adults are trapped at Lower Granite Dam. It cannot be applied retrospectively.

Objective 3: Assess the status and trend in genetic and life history diversity of the Lower Mainstem Snake River fall Chinook salmon population.

Snake River fall Chinook salmon production may be influenced by local habitat conditions, releases of hatchery fish, hydropower operations, climate change, and many other natural and man-made factors. These influences may be expressed as changes in the pattern or overall level of diversity at both the genomic and life history levels. Therefore, monitoring diversity at both levels and understanding its implications for long-term population sustainability and productivity is critical. The hatchery programs have considerable potential to affect genetic and life history diversity, but can also affect the population in a variety of other ways. Thus, effects of the hatchery program are explicitly considered as a separate objective (Objective 12). However, there will obviously be considerable overlap between activities associated with this objective and those associated with Objective 12. Many genetic monitoring methods will be identical or nearly so to those used for status monitoring of many other populations, but some methods will be customized because of logistical constraints imposed by population biology or management. In addition, some measures may address concerns specific to this population. A case in point is monitoring genetic diversity among major spawning areas. Currently, our ability to measure several important aspects of genetic change is very limited, but significant advances are expected within the next few years. Monitoring of life history diversity could be extended to other traits in the future as their importance becomes evident, but currently interest in life history diversity is limited to juvenile outmigration age. Understanding the relative contribution of environmental factors and genetic mechanisms to the relative proportions of juveniles exhibiting subyearling or yearling ocean entry is important for evaluating current diversity status as well as for determining how management operations or actions may affect the population. Smolt sampling indicates that most of the natural-origin juveniles from the Snake River drainage migrate seaward early and enter the ocean as subyearlings, whereas most of the natural-origin juveniles in the Clearwater River drainage migrate late and enter the ocean as yearlings.

Monitoring questions:

What is the status of genetic diversity in the Lower Mainstem Snake River fall Chinook salmon population?

> Answering this monitoring question will help to determine if and how the genetic composition of the aggregate natural run is changing over time in terms of basic diversity metrics, initial level of differentiation among major spawning areas and how it changes, and how the population may be changing genetically at key life history traits. The suite of measures thus allows for the standard whole genome assessment of diversity, but also allows for assessing life-history changes at the genetic level. It also addresses a key issue specific to recovery of this population, which is subpopulation structure. Note, however, that this objective does not include evaluation of all the genetic effects of the hatchery program. Specifically, it does not include the genetic impact to productivity through hatchery-influenced selection. That is covered under objective 12.

What is the status and trend in the age-at-ocean entry of natural- and hatchery-origin adults that escape to the spawning grounds?

> Answering this question will provide information for evaluating the status and trend of the population relative to diversity criteria (e.g., the proportion of the natural population that enters the ocean at age-0 is stable or increasing).

What are the relative contributions of the subyearling and overwintering life history patterns to natural production?

> Understanding the relative contribution of environmental factors and genetic mechanisms to the relative proportions of juveniles exhibiting each of the basic life-history pathways is important for evaluating current diversity status as well as for determining how management operations or actions might affect the population. In addition to estimates of the contributions of the alternative pathways to adult returns, information on the production of subyearling and yearling outmigrants and their life stage survivals provides valuable insights. Estimating outmigrant smolt production by pathway and geographic area (e.g., Snake River upper and lower reaches versus lower Clearwater River) requires added monitoring and analysis. Smolt sampling indicates that most of the natural-origin juveniles from the Snake River drainage migrate seaward early and enter the ocean as subyearlings, whereas most of the natural-origin juveniles in the Clearwater River drainage migrate late and enter the ocean as yearlings.

Objective 4: Assess the status and trend of current and historically used adult holding, spawning, and juvenile rearing mainstem and tributary habitats used by Lower Mainstem Snake River fall Chinook salmon population.

Each of the spawning areas (see Objective 2) functions as a holding and rearing area. In addition, Lower Granite Reservoir is likely a holding area for returning adults prior to spawning, and fry and parr rear along the reservoir shorelines. Every juvenile spends some time feeding and growing within the reservoir before migrating seaward. An important part of this objective is to determine whether cool-water releases from Dworshak Dam maintain adequate migration conditions for adults destined for spawning areas upstream of Lower Granite Dam. Pursuing that question would also be compatible with proposals to alleviate both elevated temperatures and low stream flows in affected streams such as the Tucannon River during autumn by increasing shade through riparian restoration and managing water withdrawals to maintain as high a flow as possible. Assessment of spawning and rearing carrying capacity is also an important component of this objective.

Monitoring Questions:

What is the current understanding of adult fall Chinook salmon holding habitat quantity and quality within major and minor spawning areas?

> The answer to this monitoring question would establish if cool-water releases from Dworshak Dam maintain adequate migration conditions for adults destined for spawning areas upstream of Lower Granite Dam. Pursuing that answer would also be compatible with proposals to alleviate both elevated temperatures and low stream flows in affected streams such as the Tucannon River during autumn by increasing shade through riparian restoration and managing water withdrawals to maintain as high a flow as possible. Activities associated with this monitoring question would include the evaluation of potential restorative actions identified early in the recovery plan including: (1) changes in structures or operations at Lower Granite Dam to address adult passage blockages caused by warm surface waters entering the fish ladders and (2) other actions to reduce September water temperatures for adult migration and passage at Lower Granite Dam.

What is the status and trend in fall Chinook salmon spawning and incubation habitat quantity and quality within major and minor spawning areas?

> Answering this question would provide information on the carrying capacity of spawning habitat. It would also address Key Information Needs, including: (1) whether the Hells Canyon Complex could be operated to further benefit fall Chinook salmon egg incubation, (2) whether spawning and rearing conditions and survival could be improved by increasing water quantity and quality while reducing sediment delivery in the lower Grande Ronde River, and (3) what are the high priority opportunities to restore adaptive spawn timing patterns in the lower reaches of the Selway and South Fork Clearwater Rivers.

What is the status and trend in fall Chinook salmon rearing habitat quantity and quality within major and minor spawning areas?

> Answering this question will provide a standardized assessment of rearing habitat in the major and minor spawning areas that is currently lacking especially in the Grande Ronde, Selway, South Fork Clearwater, and Tucannon Rivers. Such a program could be coupled with a standard modeling framework to establish the present status of habitat threats and limiting factors (Figure 7-1).

Objective 5: Determine the effects of habitat limiting factors and associated management efforts in the major and minor spawning and rearing areas on the Lower Mainstem Snake River fall Chinook salmon population.

The abundance, survival, and productivity of Snake River fall Chinook salmon are affected by the quantity and quality of spawning and rearing habitat. As described in Section 5 of the Recovery Plan, spawning and rearing habitat is currently affected by reduced outflow and water quality, low dissolved oxygen levels in late summer and fall, elevated total dissolved gas (TDG) levels in winter and spring, and altered thermal regime. As a result, there could be lower survival for fall Chinook salmon due to delayed emergence and higher mortality for rearing juveniles and gas bubble disease. Also, altered flows (on a seasonal, daily, and hourly basis) result in altered migration patterns, and juvenile fish stranding and entrapment. Interruption of geomorphological processes (entrapment of sediment) results in potential reductions in spawning gravels and reduced turbidity that increases predation. Lower Granite Dam forebay and ladder temperatures may influence ladder ascension and fall back rates of migrating adult salmon. An important priority under this objective will be the documentation of historical and current mean levels and annual variation in pre-spawning survival and egg viability. That information will dictate how much effort is needed to evaluate the factors affecting pre-spawning mortality. In addition, a full evaluation of spawner to pre-smolt survival will inform restorative actions such as gravel monitoring and management in the Hells Canyon reach of the Snake River and the identification and evaluation of potential measures to increase juvenile survival in the mainstem Snake River major spawning areas.

Monitoring Questions:

How do environmental and behavioral factors influence pre-spawning survival and egg viability?

> Current thermal regimes in Lower Granite Reservoir and some spawning areas may be reducing pre-spawning survival and egg viability. Evaluations of structures or operations at Lower Granite Dam are needed to address adult passage blockages caused by warm surface waters entering the fish ladders. In addition evaluation of actions to reduce September water temperatures for adult migration and passage at Lower Granite Dam and actions to improve the quality of water discharged (dissolved oxygen) from the Hells Canyon Complex as called for in NMFS recommendations for the Hells Canyon FERC Relicensing are needed (NMFS 2006b). Thus, the first priorities under this monitoring question will be the documentation of historical and current mean levels and annual variation in pre-spawning survival and egg viability. That information will dictate how much effort is needed to evaluate the factors affecting pre-spawning mortality. If warranted, a full evaluation of whether current September and October temperatures significantly affect pre-spawning survival rates and gamete viability would provide information on existing protective actions including cool-water releases at Dworshak Dam, as well as the effectiveness of the actions described above.

What is the current understanding of factors limiting spawner to pre-smolt productivity?

> A full evaluation of spawner-to-pre-smolt survival would inform restorative actions including a gravel monitoring and management plan in the Hells Canyon reach of the Snake River (FERC 2007) and the identification and evaluation of potential measures to increase juvenile survival in the mainstem Snake River major spawning areas.

How do environmental and behavioral factors during rearing and early seaward migration influence growth, emigration size, survival, emigration, and age-at-seaward entry?

> Answering this question will inform Limiting Factor 5 under the NMFS Listing Status Decision Framework (Figure 7-1) by helping to determine how hatchery supplementation and natural environmental variability influence important phenotypic traits of the population. In turn, annual measures of those traits will be useful as covariates when developing life cycle models under Objective 13. The information generated along with the life cycle modeling assessments will provide important insights into how survivals during this life stage have changed relative to those prevalent at the time of listing.

Have management actions directed at mainstem and tributary habitat conditions improved adult to pre-smolt productivity of Snake River Fall Chinook salmon?

> Current activities identified in Section 6 of the recovery plan include reservoir management operations targeting mainstem flow and temperatures and Hells Canyon operations to stabilize flow conditions during spawning, prevent redd dewatering losses, and to avoid juvenile entrapment. Answering this question will determine if these activities improve adult and pre-smolt productivity.

Objective 6: Determine the effects of federal hydropower operations and operational and structural improvements on the viability of Snake River fall Chinook salmon.

Spawning and rearing habitat for both extant and historic populations of Snake River fall Chinook salmon lies upstream of mainstem Columbia River and Snake River hydroelectric projects. As a result, emigrating juveniles and returning adults must migrate past up to eight mainstem dams. Migrants are affected by mainstem dams both directly (e.g., injuries or mortalities occurring at a particular dam and reservoir) and indirectly (e.g., altered flows or water quality parameters that are also strongly influenced by upstream water storage project operations and agricultural, municipal, and industrial water management activities). Monitoring is essential for assessing the effect of management actions at the mainstem dams (or at upstream water storage projects) on passage conditions, and the migration timing and survival of migrating juvenile and adult fall Chinook salmon.

Monitoring Questions:

What is the timing and duration of juvenile and adult fall Chinook salmon passage through the mainstem hydropower projects?

> Answering this question will provide information on the effect of management actions at the mainstem dams (or at upstream water storage projects) on the migration timing of migrating juvenile and adult fall Chinook salmon and thereby inform managers about the efficacy of management actions taken to date and the "current" status of hydropower threats and limiting factors (Figure 7-1).

What is the effect of hydropower operations (including transportation) on naturally produced Snake River fall Chinook salmon emigrants using subyearling and freshwater overwintering migration pathways?

> Since the early 1990's, there have been a series of changes to hydropower operations aimed at improving the survival of out-migrating fall Chinook salmon. Identifying survival rates associated with current hydropower operations and contrasting those with rates that were prevalent at the time of listing is a high priority. Answering this question will help to evaluate the efficacy of recent structural and operational improvements, and the "current" status of hydropower threats and limiting factors (Figure 7-1). Additionally, since 2010, between 30 and 56 percent of "hatchery" and 41 and 61 percent of "wild" subyearling Chinook smolts were collected at Snake River dams and transported via barge or by truck to below Bonneville Dam (FPC 2013, Annual Report, Appendix G, Table G.9). Assessing the seasonal efficacy of transportation will provide managers with substantially better information on which to base future transport decisions. The information gained from this effort should also provide insights on the potential for additional survival improvements.

What is the effect of Columbia River hydropower operations on returning adult Snake River Fall Chinook salmon as they migrate upstream to natal spawning reaches?

> Answering this question will provide estimates of adult mortality associated with hydropower operations and support an assessment of the status of hydropower threats and limiting factors (Figure 7-1).

What are the effects of Columbia River hydropower operations on flow, temperature, total dissolved gas levels, and turbidity in the Snake and Columbia River mainstems?

> Answering this question will provide the data to populate models, inform project operations on an hourly, daily, or seasonal basis, and assess whether operations and structures are achieving management goals, including those established directly for fish and water quality standards.

Objective 7: Determine the effects of ecological conditions in the estuary, plume, and near-shore ocean on the viability of Snake River fall Chinook salmon.

Regardless of the age at ocean entry, Snake River fall Chinook salmon will use the estuary, plume, and near-shore ocean environments for rearing and migration. Thus, factors that affect these environments will have some effect on the viability of fall Chinook salmon. For example, diking and other structural alterations, combined with flow management, have reduced access to rearing habitat and production of macrodetritus (the base of the food web) and prey for juvenile fall Chinook salmon in the estuary. Large releases of hatchery fish may compete with natural-origin fish for food and space in the estuary when they overlap in space and time. In addition, fall Chinook salmon are lost to fish, bird, and marine mammal predators in the estuary. Finally, climate variability may affect growth and survival within the estuary, plume, and near-shore ocean environments. Thus, it is important to monitor these conditions to understand if they are affecting the status of the species.

Monitoring Questions:

What are the effects of habitat conditions in the estuary on growth, condition, and survival of juvenile Snake River fall Chinook salmon?

> Subyearling Snake River fall Chinook salmon use shallow-water habitats downstream of Bonneville Dam (Roegner et al. 2013) and derive direct benefits from these areas (e.g., food and water quality adequate for growth and the ongoing physiological transition to salt water; refuge from predators). Less is known about yearling fall Chinook salmon. Based on preliminary data for spring/summer Chinook salmon, these larger juveniles also may forage in or near wetlands or consume insects and amphipods transported from shallow water habitats to the main channel. Additional data on feeding and prey selection, combined with information on the migration timing and residency of juvenile and adult Snake River fall Chinook salmon passing through the lower Columbia River and associated near-shore habitats, will help NMFS determine how habitat restoration actions downstream from Bonneville Dam contribute to the recovery of the ESU.

What are the effects of habitat conditions in the plume on growth, condition, and survival of juvenile Snake River fall Chinook salmon?

> The timing and magnitude of mainstem flows during June and July, when juvenile Snake River fall Chinook move from Interior spawning areas to the ocean, have been drastically altered by management of flows in the Columbia River basin for flood control and power production (Figure 5.1-2 in NMFS 2008d). There are close physical connections between the river, estuary, and ocean that can affect biological processes, but these relationships can be complex. Two sets of relationships that appear to affect juvenile survival and thus merit further investigation are: (1) connections between river flow and the distribution and abundance of forage fishes in the estuary and plume (bottom up processes) and (2)

> bird and fish predation on juvenile salmonids (top down control). With respect to the later, several studies (Pearcy 1992; Rechisky et al. 2009; Tomaro et al. 2012; Miller et al. 2013; Brosnan et al. 2014) suggest that there is significant mortality in the estuary and along the coast of the Long Beach Peninsula, Washington, and that predation, especially by birds, might be a major factor in these areaa.

When taking into account all the hatchery and wild fish in the estuary, plume, and near-shore ocean, is density dependence influencing the survival of Snake River fall Chinook salmon?

> The estuary has undergone significant changes—where historically there were marshes, wetlands, and side channels along the river that provided salmon with food and refuge, most of these shallow water habitats have been diked and filled for agricultural, industrial, and other uses (NMFS 2011b). Little is known about the potential for density dependence in the estuary between natural-origin salmonids and hatchery releases in this modified system (Bottom et al. 2011). The ISAB (2015) said that this information gap was critical because a key goal for habitat restoration is to reduce density dependent limitations by increasing capacity and productivity.
>
> The overlap of hatchery- and natural-origin Chinook once these fish reach coastal waters has the potential to reduce early marine survival during unfavorable conditions. Jacobson et al. (2013) noted that the quantity of prey is generally lowest during July when most subyearlings migrate to sea, suggesting the potential for competition.

Objective 8: Determine the effects of physical and biological changes associated with climate change on the viability of Snake River fall Chinook salmon.

Likely changes[50] in temperature, precipitation, wind patterns, and sea-level height due to climate change could have profound implications for survival and viability of Snake River fall Chinook salmon. All other threats and conditions remaining equal, changes in air temperature, river temperature, water quality, and river flows due to climate change could cause changes in fall Chinook salmon distribution, behavior, growth, timing, and survival. The magnitude and timing of these changes - and their effects on Snake River fall Chinook salmon viability - remain unclear. It is possible that the Snake River subyearling life history strategy will allow Snake River fall Chinook salmon to adapt to climate change effects on mainstem and tributary habitats.

The effects of climate change will largely depend on how Snake River fall Chinook salmon migration, spawning timing, emergence, and dispersal are affected by increased water

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[50] As discussed in the NOAA Fisheries Climate Science Strategy (Link et al. 2015), natural variability in the earth's climate systems occurs on short time scales as weather and annual to decadal climate variability. Climate change occurs on a multi-decadal scale. The climate we experience is a combination of natural variability and long-term change. Climate change is not detectable day-to-day or year-to-year. It is detectable in the long-term trends in daily and annual temperatures. In addition to affecting the average climate, these long-term trends may also change the frequency and magnitude of the processes responsible for natural variability, such as El Niño events. Monitoring the impacts of both climate variability and change on listed species is very important to developing effective management approaches across multiple time scales and the RM&E measures in this section are intended to address both.

temperatures. In the lower mainstem Columbia and Snake Rivers, increased water temperatures from August through October could cause adult Snake River fall Chinook salmon to delay passage, leading to increased mortality or reduced spawning success due to lethal temperatures, delay, fallback at the dams, depleted energy reserves, or increased susceptibility to disease. Increased water temperatures in the lower Snake River above Lower Granite Dam during September and October could also reduce spawning success or egg viability.

A delay in spawn timing could then trigger a delay in fry emergence; however, warm water temperatures could also increase incubation rates, so that fry emerge at a similar date as they do today, or even earlier. A change in fry emergence would likely also shift the timing of dispersal to nearshore areas and, later, downstream. Such a change could be either beneficial or detrimental depending on location, size, and prey availability. Climate change could also increase water temperatures in the lower Snake River and Lower Granite Reservoir to levels that cannot be suitably reduced by releases from Dworshak Reservoir, resulting in a loss or reduction in Snake River fall Chinook salmon yearlings, or reservoir-types, which are considered an important alternative life history strategy for the species.

Currently, the degree to which phenotypic or genetic adaptations by Snake River fall Chinook salmon may partially offset these potential effects is being studied but is poorly understood. A better understanding of the mechanisms by which climatic changes influence population productivity and diversity will be essential to avoid undesirable outcomes. Monitoring is critical to track and evaluate the effects of habitat alterations on abundance, productivity, distribution, and genetic and life history characteristics of the natural-origin population. Life cycle modeling will help assess habitat metrics (e.g. flow and temperature) across a diversity of ecological regimes and habitat types to evaluate responses to climate change.

The monitoring questions below address potential biological responses of Snake River fall Chinook salmon to climate change. This plan assumes that physical environmental variables associated with projected climate change will continue to be monitored and summarized to explore correlations with the biological factors described below. In some cases, there may be gaps in monitoring that require some additional effort, and these are described under the biological questions described below. For example, water temperatures throughout the mainstem migration corridor are currently monitored, but an expansion of temporal coverage may be necessary in some locations to track potential effects on yearlings that overwinter in reservoirs. Similarly, some expansion may be needed to ensure adequate temperature monitoring at the mouths of tributaries that function as cold-water refugia during the adult migration. A variety of physical and biological factors are monitored in the estuary and ocean, but in some cases continuation of these monitoring programs may be uncertain.

Monitoring Questions:

Is the phenotypic and genotypic diversity of the natural-origin population changing over time? Are the changes consistent or not with expectations regarding climate change?

> This question refers to a population's degree of adaptation to the existing diversity of environments it occupies, and its capacity to evolve and adapt to future environmental change due to climate change. Monitoring evaluates measurable key life history traits such as run timing, age structure, and behavior. It also monitors and evaluates differentiation among major spawning areas and how it changes.

Are relative contributions of the subyearling and overwintering life history patterns to natural production changing over time? Are the changes consistent or not with expectations regarding climate change?

> Understanding the relative contribution of environmental factors and genetic mechanisms to the relative proportions of juveniles exhibiting each of the basic life-history pathways is important for determining how climate change might affect the population. Information on the production of subyearling and yearling outmigrants, and their life stage survivals, provides valuable insights into changes in life history patterns and the contributions of the alternative pathways to adult returns. Currently, most natural-origin juveniles from the Snake River drainage migrate seaward early and enter the ocean as subyearlings, while most natural-origin juveniles in the Clearwater River drainage migrate late and enter the ocean as yearlings. Later emerging and migrating juveniles, such as those from the Clearwater drainage, may be especially at risk if water temperatures rise to 20 °C in the lower Snake River and Lower Granite reservoir, and predation also increases.

How are environmental and behavioral factors influencing emergence, growth, emigration size, emigration, and age-at-seaward entry? Are the changes consistent or not with expectations regarding climate change?

> Answering this question will help determine how environmental variability influences important phenotypic traits of the population. If fall Chinook salmon delay spawning because of warmer water temperatures, it could then trigger a delay in fry emergence; however, incubation rates could also increase due to warm water temperatures, so that fry emergence occurs near the same time, or even earlier, than it does today. A change in fry emergence could shift the timing of dispersal to nearshore areas and, later, downstream. Such a change could be either beneficial or detrimental depending on location, size and prey availability. The information generated to answer this question, along with the life cycle modeling assessments, will provide important insights into how survivals during this life stage are changing in response to climate change.

How are environmental and behavioral factors influencing pre-spawning survival and egg viability? Are the changes consistent or not with expectations regarding climate change?

> Current thermal regimes in Lower Granite Reservoir and some spawning areas may be reducing pre-spawning survival and egg viability. Increased water temperatures in the

> lower Snake River dam fish ladders during September and October may increase the risk that Snake River fall Chinook salmon delay passage, leading to increased mortality, reduced spawning success, or egg viability because of lethal temperatures. Gaining information on current levels and annual variation in pre-spawning survival and egg viability will help determine whether changes in September and October temperatures significantly affect pre-spawning survival rates and gamete viability, and how effective cold-water releases from Dworshak Reservoir and other measures are reducing the risks. Evaluations of structures or operations at Lower Granite Dam are also needed to address adult passage blockages caused by warm surface waters entering the fish ladders.

How is ocean productivity of Snake River fall Chinook salmon changing? Are the changes consistent or not with expectations regarding climate change?

> The scope and magnitude of any effect experienced by Snake River fall Chinook salmon in the ocean environment will be a function of how the climate actually changes (e.g., rate and magnitude) and how these changes ultimately affect physical and biological processes (Tolimieri and Levin 2004). In the ocean, salmon can potentially be affected by climate-driven changes in the ocean's physical (e.g., temperature, circulation, stratification, and upwelling), chemical (e.g., acidification, nutrient input, and oxygen content), and biological (e.g., primary production, species distributions, phenology, food web structure, community composition, and ecosystem functions/services) components and processes.
>
> Currently, most of the risk factors related to climate change are poorly understood. There is little direct information on if, and how, changes in physical factors would affect salmon. The consequences of climate change for Snake River fall Chinook salmon and other species depends on potentially complex shifts in prey availability, and abilities of salmon to change life history strategies and diets. Consequently, assessing the consequences of climate change will require use of tools, such as life cycle modeling, that can consider the interactions of individual effects as they multiply across life stages within generations and across generations within populations. Work should continue to develop and refine indicators of ocean conditions that are relevant to salmon performance, particularly early marine survival and adult returns. More information is also needed to determine the spatial and temporal distribution of Snake River fall Chinook salmon in the ocean.

Objective 9: Determine the effects of harvest on the viability of Snake River fall Chinook salmon.

Snake River fall Chinook salmon are caught in ocean fisheries from Alaska to northern California, and in river fisheries from the Columbia River mouth up to Hells Canyon Dam. In recent years, there has been increasing interest and harvest of Snake River fall Chinook salmon in fisheries upstream from Lower Granite Dam. Fisheries in the ocean and mainstem Columbia

River have been subject to ESA-related constraints since listing. Those constraints have required that fisheries in the ocean and Columbia River be reduced by thirty percent relative to what occurred from 1988 to 1993. In 2008, management of the in-river fisheries was modified to implement an abundance-based framework that allowed harvest to increase or decrease relative to the previous benchmark depending on the abundance of natural-origin Snake River fall Chinook salmon. Harvest reductions in ocean and in-river fisheries were implemented shortly after listing as interim measures recognizing that there was some uncertainty about whether harvest constraints would be sufficient to allow for long-term recovery. The harvest reductions, coupled with other survival improvements throughout the system, allowed for substantial improvement in the status of the species. Nonetheless, a robust monitoring and evaluation program is needed to insure that fisheries are being implemented as intended, and that ESA-approved harvest levels continue to be consistent with evolving information and the expectation of survival and recovery.

Monitoring Questions:

What is the cumulative exploitation rate on naturally produced Snake River fall Chinook salmon in ocean and in-river fisheries?

> Harvest of Snake River fall Chinook salmon in ocean and Columbia River fisheries has been constrained for more than twenty years by ESA consultation requirements. All ocean fisheries combined are required to reduce impacts by 30 percent relative to what occurred from 1988 to 1993. Fisheries in the Columbia River were also required to reduce impacts by 30 percent relative to a 1988 to 1993 base period until 2008 when management switched to an abundance-based harvest schedule. Although ocean and in-river fisheries are reviewed separately for compliance with the applicable standards, there has not been a recent comprehensive analysis of the cumulative effects of all harvest.

Are current harvest limits consistent with the expectation of survival and recovery of natural-origin Snake River fall Chinook salmon and are they robust to variations in ocean survival?

> Whether a particular harvest regime is adequately protective depends on the productivity of the stock and the survival rates that affect all stages of the life history. The current harvest regime has been coincident with significant increases in the abundance of hatchery and natural-origin fish, suggesting that it may be adequately protective. However, the observed growth is confounded by the large contribution of hatchery-origin fish from the supplementation program. It is unknown if the natural-origin fish can sustain themselves in the absence of hatchery fish. In addition, the observed population growth has occurred during a period of relatively high ocean survival, particularly in recent years. Thus, it is unknown if the natural-origin fish can sustain themselves through a broader range of ocean survival conditions.

What is an appropriate harvest regime for new fisheries upstream from Lower Granite Dam?

> Until recently, there has been little or no harvest of Snake River fall Chinook salmon in fisheries above Lower Granite Dam. At the time of listing, and for some time thereafter, the fish numbers were low and the priority was to protect and rebuild the population. Tribal fisheries targeting fall Chinook salmon were closed. Recreational fishers upstream of Lower Granite Dam focused on steelhead; although, there was some incidental catch of Chinook salmon. However, as the return of Snake River fall Chinook salmon has increased from hundreds to thousands to tens of thousands, particularly over the last five years, there has been increased interest in expanded harvest opportunity. With returns to Lower Granite Dam approaching 60,000 in the last couple of years, there is clearly more harvest opportunity. A new abundance-based harvest schedule should be developed that allows more or less harvest depending on the year-specific circumstances and is consistent with recovery objectives.

Objective 10: Determine the effects of disease, predation, prey base, competition, non-native species, and other ecological interactions on the viability of Snake River fall Chinook salmon.

The productivity of juvenile Snake River fall Chinook salmon depends in part on the food webs that support growth and survival, and on the interactions of juvenile fall Chinook salmon with predators and competitors. Because juvenile fall Chinook salmon exhibit a transitory rearing strategy, they encounter many different environments, each replete with predators, competitors, and varying prey items. The prey communities that support juvenile growth vary among riverine, reservoir, and estuarine habitats. It is important to understand the capacity of the food web to support current and future levels of juvenile fall Chinook salmon abundances, and how juvenile Chinook salmon may be affected by changing predator and prey resources resulting from invasion by nonnative species. Competition with both conspecifics and other native fishes will also affect juvenile fall Chinook salmon productivity. The wider array of juvenile fishes inhabiting reservoirs may result in competition being more intense in those habitats and that may affect growth potential and the time fish are vulnerable to predators. The high abundance of non-native predators like smallmouth bass and walleye in the Snake and Columbia Rivers may be an important agent of mortality on juvenile fall Chinook salmon. Subyearlings emigrating during summer may be especially vulnerable to predation because of the higher feeding rates of predators at warmer temperatures. It is therefore important to monitor changes in the prey items, competitors, and predators.

Monitoring Questions:

What is the capacity of prey resources to support juvenile fall Chinook salmon during rearing and migration?

Fish growth is dependent in part on both the quantity and quality of prey. Prey resources differ between riverine to reservoir habitats, and prey availability and energetic content change seasonally as invertebrate prey move through different life stages. The capacity of prey to support fish growth is also dependent on the number of fish competing for and relying on the prey. Recent work suggests that in the unimpounded reaches of the Snake River, juvenile fall Chinook salmon consume a higher energy content diet and exhibit higher growth than fish that disperse downstream and rear in a reservoir (Tiffan et al. 2014). Paradoxically, prey biomass is higher in the reservoir, but the functional availability of prey and the extent of competition for that prey are unclear. Snake and Columbia River reservoirs support many native and non-native resident fishes as well as migrating salmonids that use prey resources along with Snake River fall Chinook salmon. Whether there is sufficient food to support the growth of these fishes in reservoirs during rearing and migration has been a concern since the early 1990s (e.g., Curet 1993). This is significant considering the food web changes that have occurred recently (see next Monitoring Question), the increased number of fish depending on available prey, and density-dependent changes in fall Chinook salmon growth that is affected by prey resources (Connor et al. 2013).

How will alterations to the food web (e.g., invasive species) influence the growth opportunity of juvenile fall Chinook salmon?

The importance of food webs to salmon recovery has been largely ignored, but they are critically important to providing the resources necessary for growth and survival (Naiman et al. 2012). Food webs are not static but change over time due to a variety of factors including changes in productivity, invertebrate and fish community changes, and invasion by non-native species. This is particularly true in the Snake and Columbia Rivers where many invasive species have become established (Sanderson et al. 2009). In Lower Granite Reservoir, the proliferation of two non-native and one native species could affect the growth opportunity of juvenile fall Chinook salmon. Siberian prawns (native to east Asia) have become established in the Snake and Columbia Rivers but ecological consequence of this invasion is currently unknown (Haskell et al. 2006). The opossum shrimp, *Neomysis mercedis*, was absent 20 years ago but has become very abundant in the Snake River and at times composes 98 percent of the invertebrate biomass in Lower Granite Reservoir (Tiffan et al. 2014). *Neomysis* may be a competitor with fall Chinook salmon for zooplankton or be prey themselves, but their role in the food web and relation to fall Chinook salmon is poorly understood (Tiffan et al. 2014). Finally, the native sand roller was absent in Lower Granite Reservoir as of about 2003, but is now extremely abundant throughout the lower Snake River. Sand rollers have the potential to compete with fall Chinook salmon for food or act as a buffer against predation (see next Monitoring Questions). Changes to the food web of this magnitude in Lower Granite Reservoir and elsewhere should be cause for concern given that so little is known about their ecological effects, not only Snake River fall Chinook salmon, but on other species as well.

To what extent are competitive interactions influencing juvenile fall Chinook salmon growth and survival?

> Since the listing of Snake River fall Chinook salmon in 1992, recovery efforts have led to a large increase in the juvenile population to the point of density-dependent changes in growth (Connor et al. 2013). Although juvenile fall Chinook salmon growth has declined only slightly in riverine habitats, it has declined significantly in reservoir habitats. Fall Chinook salmon that disperse downstream from riverine habitats into Lower Granite Reservoir rear along shorelines also inhabited by many native and non-native resident fishes. The potential for competition for food and space is probably higher in reservoir than in riverine habitats and may explain growth differences, but this has not been confirmed. Slower growth in reservoir habitats may increase the time fall Chinook salmon are vulnerable to predation.

What is the status and trend of predation on juvenile fall Chinook salmon?

> Snake River fall Chinook salmon may be particularly vulnerable to predation because of their relatively small size and because their main-stem rearing habitats often overlap or are in close proximity to habitats used by predators (Curet 1993; Nelle 1999; Naughton et al. 2004). Smallmouth bass are abundant in the Snake River and are probably the main predator of fall Chinook salmon along with northern pikeminnow. Past studies of smallmouth bass predation in the Snake River documented relatively low consumption of juvenile fall Chinook salmon (0-11% of the diet; Anglea 1997, Nelle 1999, Naughton et al. 2004). However, these studies were conducted soon after ESA listing when fall Chinook salmon abundance was at an historic low, which may explain why consumption rates were relatively low. Both Zimmerman (1999) and Naughton et al. (2004) showed that fish can comprise a large portion of smallmouth bass diets. Considering that subyearlings probably now make up a larger portion of the forage fish population, it is plausible that they may be at greater risk of predation. Fall Chinook salmon produced in the Clearwater River may be at particular risk to predation when they enter the warmer waters of Lower Granite Reservoir in the summer. Past studies have documented fall Chinook salmon mortality in the lower Clearwater River and the area downstream of its confluence with the Snake River that is likely due to predation (Tiffan et al. 2012b). However, predation pressure on fall Chinook salmon could be reduced by increases in alternative prey.

Objective 11: Identify federal, state, tribal, and local regulatory mechanisms that conserve Snake River fall Chinook salmon and determine the adequacy of those regulatory mechanisms.

There are several federal, state, tribal, and local regulatory mechanisms that protect Snake River fall Chinook salmon and their habitat. Any delisting decision would need to be supported by evidence that the threats facing the species have been ameliorated and that regulatory mechanisms are in place to continue conserving the species and help prevent a recurring need to re-list the species. Therefore, monitoring the status and trend of existing regulatory mechanisms and their enforcement of existing regulations is needed. This will provide a foundation from which to build lasting agreements for conserving the species in the event of a delisting.

Monitoring Questions:

What regulatory mechanisms are in place to protect the species or to further reduce risk of the primary limiting factors associated with habitat, hydropower, harvest, disease and predation, and hatcheries?

> There are several regulatory mechanisms in place to protect the species and/or reduce the risk of the primary limiting factors associated with the abundance, productivity, diversity, and spatial structure of Snake River fall Chinook salmon. There are regulatory mechanisms associated with habitat and hydro (e.g., FERC licenses, the FCRPS Biological Opinion, and the Clean Water Act), harvest (e.g., regulations under U.S. v OR and the Pacific Salmon Treaty), and hatcheries (e.g., ESA HGMPs). A complete listing of the regulatory mechanisms, including those that depend on ESA implementation, would help determine if there are gaps in regulations and protection measures, and would also help with evaluating the need for additional regulations and agreements that would endure in the event of an ESA delisting.

Would regulatory protections (above and below the Hells Canyon Complex) endure if there were to be an ESA delisting?

> There are several regulatory programs, such as section 7 consultations and section 10 permits, and those associated with the ESA-listing of a species. In addition, other existing regulations may be more strongly enforced when they protect ESA-listed species. Once the species is delisted, however, ESA-driven regulatory programs would no longer be required to be enforced and the benefits of those regulatory programs could disappear. It is therefore important to know which regulations will endure after delisting and how enforcement of those regulations may change.

Objective 12: Determine the influence of hatchery supplementation programs on the viability of the natural population of Snake River fall Chinook salmon.

Hatchery production of Snake River fall Chinook salmon was initiated as mitigation for production losses associated with the construction of Snake and Columbia River hydroelectric dams. Following listing, the ongoing program was adapted to include a directed supplementation effort shifting a significant proportion of releases upstream of Lower Granite Dam. The goals of that effort were to increase the natural spawning population, sustain long-term preservation and genetic integrity of the population, keep ecological effects within acceptable limits, assist in recovery and delisting, and provide harvest opportunities for both tribal and non-tribal anglers. Monitoring the annual escapement of hatchery adults and their relative contribution to spawning across major spawning areas is a basic requirement for assessing natural production. Specifically, monitoring is needed to assess the direct demographic contributions and effects of the ongoing supplementation program on the natural population and to evaluate the effects of the program on genetic or life history characteristics of the natural population. Monitoring is also needed to assess the degree that naturally produced juveniles are influenced by or are interacting with supplementation smolts. That is, the presence of hatchery smolts in natural rearing and migration reaches may adversely affect natural production through increased competition for high quality rearing habitats or through increased exposure to or attraction of predators.

Monitoring questions:

How is supplementation affecting the natural production of Snake River fall Chinook salmon?

> As with other directed supplementation programs, the Snake River fall Chinook hatchery programs are based on a series of assumptions regarding the ability of a hatchery program to boost the production of adult returns relative to production from fish spawning in nature. Ultimately, the evaluation of the hatchery program to supplement natural production should be measured in terms of changes in natural-origin production – are the fish taken into the hatchery program resulting in a net increase in natural production in the population? As with most other supplementation evaluation efforts, evaluation of this important demographic objective breaks the overall question into two parts: (1) does a spawning pair in the supplementation program produce more returns to the spawning grounds than a corresponding spawning pair in nature and (2) is natural production from spawning in nature, including the hatchery supplementation returns, increased relative to what it would have been in the absence of supplementation? It is important to determine if supplementation is having a negative effect on productivity.

Is supplementation altering natural development of genetic or life history characteristics of the natural-origin Snake River fall Chinook salmon population?

> Evaluating the effects of the supplementation program on genetic or life history characteristics of the natural population is based on monitoring programs aimed at both the potential effects of fish culture practices and of the subsequent effects on natural production of supplementation returns to natural spawning areas. This question is related to Objective 3, as large hatchery programs have considerable potential to affect the genetic structure of populations with which they interact.

To what extent are ecological relationships affecting natural production of Snake River fall Chinook salmon impacted by hatchery production?

> Recent patterns in natural-origin adult returns and in juvenile production indices are consistent with relatively high density-dependent effects at current spawning levels. The presence of hatchery smolts in natural rearing and migration reaches may adversely affect natural production through increased competition for high quality rearing habitats or through increased exposure to or attraction of predators. However, the degree to which naturally produced juveniles are influenced by or interacting with direct release supplementation smolts is not understood.

Are out-of-basin strays altering the genetic profile of naturally produced Snake River fall Chinook salmon?

> Straying of out-of-basin hatchery production into the Lower Snake River is monitored as part of the trap sampling efforts described under Objective 1. In the early 1990s, substantial numbers of hatchery-origin fish from the Bonneville and Priest Rapids Hatchery programs were identified in broodstock taken at Ice Harbor Dam and Lower Granite Dam. Mark spawning at the Lyons Ferry Hatchery, along with screening to avoid use of returns from earlier brood year releases that had included out-of-basin fish, was employed to minimize the incorporation of those fish in the Snake River Egg Bank program (e.g., Bugert et al. 1990). A substantial portion of the returns were unmarked releases of Priest Rapids stock into the Umatilla River. After 1994, 100 percent of the Umatilla River releases were marked and the program was reduced substantially. The combination of reduced release sizes and the dramatic increase in Snake River fall Chinook salmon returns has led to much lower out-of-basin proportions in recent years.

Objective 13: Develop life cycle models to identify and assess potential factors that could limit the viability of Snake River fall Chinook salmon, including effects under current climate change projection scenarios.

Multi-stage life cycle models that are under development for Snake River fall Chinook salmon should improve our understanding of the combined and relative effects of actions across the life cycle. These models incorporate empirical information and working hypotheses on survival and capacity relationships at different life stages. The models would provide a valuable framework for systematically assessing the potential response of Snake River fall Chinook salmon to alternative management strategies and actions under alternative climate scenarios. In addition to informing decisions about near-term management strategies, fall Chinook salmon life cycle modeling can also be used in identifying key RM&E priorities to improve future decision making. The development of multi-stage, life cycle models will produce insights into potential density-dependent effects as a function of environmental conditions and provide a framework for evaluating the potential combined effects of management actions across life stages. Once fitted, the models will be used to assess “what if” scenarios. For example, changes in productivity resulting from changes in habitat, ocean conditions, harvest, and hatchery operations will be predicted.

Monitoring Questions:

What factors are currently most limiting on natural production for the Snake River Fall Chinook Salmon population?

> Answering this question will provide valuable information concerning key factors across the life cycle, including density-dependent effects, that are currently restricting natural production. The information will help direct recovery actions to effectively address the factors.

How do alternative life history pathways (e.g., subyearling and yearling emigration/ ocean entry variations) contribute to natural production under varying environmental conditions?

> Using a life cycle model to evaluate relationships of spatial or temporal patterns in life history diversity to environmental factors and genetic mechanisms would contribute to evaluating current diversity status as well as for determining how management operations or actions may affect the population.

Integrating across current life stage survival and capacity estimates, what are the short and long term risks relative to survival and recovery criteria?

> Answering this question will improve our understanding of the risks posed by combined and relative factors on Snake River fall Chinook salmon across the life cycle, and their significance relative to achieving a status of highly viable with very low risk for the Lower Mainstem Snake population.

How would natural production of Snake River Fall Chinook Salmon respond to future climate variations, including projected climate change scenarios?

> Life cycle modeling will provide a critical tool for systematically assessing the potential response of Snake River fall Chinook salmon to alternative management strategies and actions under alternative climate scenarios.

How would the population respond to alternative management actions across sectors (e.g., habitat, hydropower, harvest and hatcheries) either individually or in combination?

> Information gained through life cycle modeling will provide critical information about the effectiveness of actions taken in the different sectors, as well as the combined effects of management actions implemented across life stages. It will allow us to predict and measure the population's response to various actions across the life cycle in terms of changes in abundance, productivity, spatial structure, and diversity.

Objective 14: Determine the influence of toxic contaminants on the viability of Snake River fall Chinook salmon.

Recent studies have documented accumulation of persistent organic pollutants, including DDTs, PCBs, and PBDEs in migrating juvenile Snake River fall Chinook salmon collected in the Lower Columbia River and estuary (Sloan et al. 2010; Johnson et al. 2013). NMFS Biological Opinions on current use pesticides have also identified Snake River fall Chinook salmon as at risk because of application of several of these compounds to their critical habitat (NMFS 2008e, 2010, 2011c). The NMFS Biological Opinion on the Oregon Water Quality Criteria (NMFS 2012b) has also identified copper, ammonia, cadmium, and aluminum as threats to Snake River fall Chinook salmon at water quality criterion concentrations.

It is unknown to what extent Snake River fall Chinook salmon are exposed to other contaminants of emerging concern, such as pharmaceuticals and personal care products. Even for those contaminant classes whose effects are better characterized, understanding of their interactions with other stressors, food-web mediated effects, and effects in complex mixtures is limited. This lack of knowledge may lead to underestimating the risks associated with currently permitted concentrations of these toxicants. Therefore, it is important to monitor and assess contaminant exposure and bioaccumulation in Snake River fall Chinook salmon, especially from locations where monitoring is limited (e.g., lower Snake River and the middle Columbia River). It is also important to assess the effects of toxic pollutants on individuals, spawning aggregates, and the population.

Monitoring Questions:

What are contaminant exposure profiles in Snake River fall Chinook salmon?

> This question focuses on obtaining adequate information on exposure to and uptake of contaminants of concern in Snake River fall Chinook salmon. Contaminants of concern include persistent organic pollutants (PAHs, PCBs, DDTs, other organochlorine pesticides, and PBDEs); metals including copper, cadmium, aluminum, and possibly mercury; current use pesticides; and pharmaceuticals and personal care products. Other considerations include exposure for specific life stages: eggs and larvae, outmigrant juveniles, and returning adults.

What proportions of fish are exposed to or are accumulating concentrations of contaminants at above levels associated with toxic effects?

> This question focuses on assessing risk of chemical contaminants to Snake River fall Chinook salmon based on contaminant exposure profiles and available data on contaminant toxicity. Contaminants of concern include persistent organic pollutants (PAHs, PCBs, DDTs, and other organochlorine pesticides, and PBDEs), metals (copper, cadmium, aluminum, and possibly mercury), current use pesticides, and pharmaceuticals

> and personal care products. Other considerations include exposure for specific life stages: eggs and larvae, outmigrant juveniles, and returning adults.

What are the major areas where exposure is occurring and sources of exposure?

> This question focuses on obtaining adequate information on contaminant sources and areas of Snake River fall Chinook salmon critical habitat that are impaired by chemical contaminants. Contaminants of concern include persistent organic pollutants such as PCBs, DDTs, PBDEs, PAHs, as well as some metals such as copper, cadmium, aluminum, and possibly copper.

What are estimated population level effects of exposure, or to what extent would reduction in exposure contribute to population productivity for Snake River fall Chinook salmon?

> This question focuses on obtaining adequate information on exposure to and uptake of contaminants in Snake River fall Chinook salmon. Contaminants of concern include persistent organic pollutants such as PCBs, DDTs, PBDEs, and PAHs. Other considerations include exposure for specific life stages: eggs and larvae, outmigrant juveniles, and returning adults.

What is the effectiveness of actions undertaken to minimize exposure?

> This question focuses on obtaining information on the effectiveness of ongoing efforts (e.g., Portland Harbor cleanup) to reduce toxicant exposure and minimize toxicant-related injury in Snake River fall Chinook salmon.

Objective 15: Determine the feasibility of restoring passage and reintroduction of fall Chinook salmon populations in habitats upstream of the Hells Canyon Complex.

Before mainstem dam construction, significant fall Chinook salmon spawning occurred in the upper reaches of the Middle Snake River upstream of the present-day Hells Canyon Dam site. The most important areas were generally upstream of the confluence of the Snake River and the Boise River up to Auger Falls. Large groundwater inflows associated with discharge from the Eastern Snake River Plain Aquifer strongly influenced the thermal regime favoring ocean-type production of fall Chinook salmon. There are several large tributaries that enter into the middle Snake River, including the Bruneau River, Boise River, Owhyee River, Payette River, Weiser River, Malheur River, Burnt River, and Powder River. There are a few anecdotal accounts of the lower portions of these rivers being used for spawning by fall Chinook salmon, but these rivers were affected early by mining and dam construction and their historic significance relative to Snake River Fall Chinook salmon is unknown. Construction of Swan Falls Dam in 1901 created a barrier to fall Chinook salmon migration and limited spawning to areas downstream from Swan Falls Dam. The area referred to as the Marsing Reach, between Swan Falls Dam and the town of Marsing, was the primary spawning area in the middle Snake River after construction of Swan

Falls Dam but before construction of the Hells Canyon Complex, which ultimately eliminated access to the middle Snake River. Dam construction upstream of Swan Falls further fragmented the river into five reaches separated by dams. The largest riverine reaches are downstream from Bliss Dam and downstream from Swan Falls Dam. Habitat quality in all reaches are influenced by various land uses, especially irrigated agriculture both in terms of heavy sediment and nutrient loading from irrigation returns and altered hydrographs.

Monitoring Questions:

Are there suitable habitats for incubation, rearing, and adult holding available in reaches upstream from Hells Canyon under present-day conditions?

> This question focuses on identifying river segments upstream from Hells Canyon Dam that have the physical habitat attributes to support spawning and rearing of fall Chinook salmon. Considerations for suitable habitats include thermal regimes and associated life histories, availability of suitable spawning and incubation gravels, and suitable juvenile rearing and migration, and adult holding habitats.

For candidate reintroduction reaches, what are egg-to-emigrant survival rates associated with current and improved habitat conditions?

> Because of the predominate agricultural land use associated with the Middle Snake River, heavy sediment/nutrient loads known to impair salmonid spawning habitats are prevalent. Large macrophyte beds have developed throughout known historic spawning habitats. Macrophyte beds accumulate fine sediments that infiltrate salmon redds and degrade the quality of spawning habitats. Hydrographs have been altered because of agricultural storage reservoirs distributed throughout the Upper and Middle Snake River basins. Diversion of water for irrigation purposes has changed the hydrology such that spring freshets are no longer common, and limited flushing flows to clean gravels or scour macrophyte-dominated areas rarely occur.

Given downstream emigrant survival rates for naturally produced juveniles from the extant Lower Mainstem Snake River population, what levels of egg-to-emigrant, downstream passage, or transport survival would be required to establish sustained natural production in suitable reaches upstream from the Hells Canyon Complex and what reaches are best suited for reintroduction?

> Reintroduction will provide a demographic benefit to the Snake River ESU only if all life stages originating in the new, upstream spawning areas experience sufficient survival and avoid having adverse effects on the extant population downstream from Hells Canyon. The ability to parse out those components of survival associated with collection, transport, spawning, and rearing in the new areas, and downstream migration (or transport) is essential to evaluating potential for success. Anticipating what levels of

survival might be under present-day conditions is necessary to assess potential success of a reintroduction effort and prioritize factors that would need to be addressed to implement a successful program.

Is a collection and/or passage system feasible with survival levels necessary to sustain a population?

Construction of the Hells Canyon Complex initially included passage of anadromous fish including fall Chinook salmon with the hope of sustaining the natural production that was occurring upstream of the Complex. Although passage of adults using traps at the base of the dams and hauling them upstream of the dams was successful, efforts to pass juvenile fish through the large impoundment created by Brownlee Reservoir and collect them near Brownlee Dam were not. This failure ultimately led to discontinuing the passage effort and creating the present-day blockage at the Hells Canyon Complex. Dams upstream of the Hells Canyon Complex associated with other potential reaches do not have passage systems.

8. Implementation

Ultimately, the recovery of Snake River fall Chinook salmon will depend on the commitment and dedicated actions of the many entities and individuals who share responsibility for the species' future. Today we face a common challenge: to take the remaining steps needed to bring the species to a level where we are confident that it is viable and naturally self-sustaining. We also need to take remaining steps to ensure that there are adequate regulatory and other programs in place that will conserve the species in the event it is delisted.

There are multiple existing forums responsible for managing the species and its habitat throughout different phases of its life cycle. These existing forums include those established for *U.S. v. Oregon*, the FCRPS biological opinion, the FERC relicensing of the Hells Canyon Complex operations and mitigation program, the Lower Snake River Compensation Plan, the Pacific Salmon Treaty, and the Columbia Basin Fish Accords, as well as entities that coordinate and oversee implementation of tributary habitat actions (e.g., the Southeast Washington Salmon Recovery Funding Board, Oregon Watershed Enhancement Board, and Idaho Governor's Office of Species Conservation. The challenge is to provide coordinated information to these diverse forums so that they can individually and collectively consider the best management opportunities to protect and improve the species status across its life cycle and take actions accordingly. This section proposes a framework for achieving coordinated evaluation, reporting, and implementation of management actions.

Since NMFS listed Snake River fall Chinook salmon in 1992, there have been significant improvements in the species' status and in the working relationships and coordination among those responsible for managing the species. NMFS acknowledges the leadership, hard work and dedication of the tribes, states of Washington, Idaho, and Oregon, the U.S. Fish and Wildlife Service and other federal agencies, and stakeholders, including the Idaho Power Company, that have worked for many years on Snake River fall Chinook salmon conservation programs. Accordingly, this plan builds upon the successes of the partnerships and agreements forged since the species was listed. The plan depends on continued implementation of the ongoing management actions identified in Section 6 and the RM&E programs identified in Section 7. These management and RM&E actions are an essential foundation of this recovery plan.

Implementation of ongoing programs, however, is not sufficient to achieve recovery. As described in Section 4, the extant population is considered viable, but overall still at risk due primarily to concerns and uncertainty related to productivity and diversity. This recovery plan seeks to add value to the suite of ongoing management programs and actions by providing a structured process and a life cycle context for evaluating the collective and relative effectiveness of ongoing actions, for evaluating uncertainties regarding the condition of the species and its habitat, and for determining the additional management actions that will most benefit the species and lead to delisting.

As described in Section 3, there are alternative viability scenarios with the potential to achieve recovery and delisting. It is likely that a scenario with Natural Production Emphasis Areas has the potential to be the most timely path to delisting and to meet both ESA and mitigation objectives. Depending on the results of ongoing RM&E, it may be feasible to identify management actions necessary to achieve a scenario with Natural Production Emphasis Areas within the next few years. However, this depends on an active implementation approach where co-managers work together to evaluate potential suites of management actions and prepare to implement the actions as soon as possible once RM&E results informing feasibility are confirmed. We also note that actions taken to achieve scenarios with Natural Production Emphasis Areas would not foreclose the potential for implementing actions to achieve other viability scenarios.

This recovery plan depends on an adaptive management process as described in the Section 6 Recovery Strategy. While there is a robust set of recovery actions already ongoing, more information is needed about these actions' effectiveness, individually and collectively, to inform decisions regarding additional actions that will lead the species to recovery. Life cycle modeling is in development that will assist with evaluating projected trends towards recovery criteria under the combined effects of hydropower, habitat, harvest, hatchery and predation strategies throughout a range of ocean conditions. The modeling results will also help focus contingency actions if the species unexpectedly declines significantly and/or is not trending toward recovery as expected. Robust RM&E programs are underway, and meaningful new information is likely to emerge between 2015 and 2018, and beyond. A framework is important to ensure that emerging information is shared and considered, and that management actions and RM&E activities are either affirmed as priorities or adjusted accordingly.

This section proposes some additions to existing management structures with the objective of facilitating coordinated implementation of recovery actions across the forums and across the life cycle. This species has tangible potential to be delisted. The rate at which we achieve delisting depends at least in part on coordination across the many management entities that influence the species' survival.

8.1 Implementation Framework

This proposal builds on the conservation work carried out since listing, relies heavily on existing forums, and seeks to facilitate coordination among those forums to achieve recovery and continue conservation efforts beyond ESA delisting. The following proposed framework is put forth for discussion and will be revised based on input and review during the public comment period.

This proposed implementation framework includes two potentially new entities: a Snake River Fall Chinook Science Team and a Snake River Fall Chinook Salmon Policy Group. Possible roles for these groups are described below.

Proposed Snake River Fall Chinook Science Team

The Snake River Fall Chinook Science Team would be a relatively small, focused group with expertise in Snake River fall Chinook salmon convened by NMFS. This team would help guide implementation of the RM&E strategy and help coordinate and report on key RM&E results. It would also help guide continued evaluation of RM&E priorities as new information emerges. Based on RM&E results, including results from life cycle modeling, the team could recommend the types of management actions that would most benefit the species and report its findings and recommendations objectively and in a manner useful to all managers. NMFS would help facilitate the team and assist with communicating its work to various management groups and forums. Team members would include scientists who are experts on the species and familiar with existing RM&E strategies. This would likely include scientists from the Nez Perce Tribe and other Interior Columbia River and Snake River tribes, WDFW, USFWS, IDFG, ODFW, and NMFS.

Key tasks might include:

- Periodically reporting on and summarizing key RM&E findings and advising on next steps for RM&E priorities.
- Making recommendations for how to simplify and consolidate RM&E reporting.
- In 2018, summarizing reports on new information that has emerged through RM&E on the FCRPS BiOp, the HGMP BiOps, and other programs.
- Developing recommendations, based on new information, for potential additional restorative actions and potential adjustments to ongoing management actions.

Proposed Snake River Fall Chinook Salmon Policy Group

The Snake River Fall Chinook Salmon Policy Group would be composed of senior policy representatives from NMFS, the tribes, states, FCRPS agencies, and USFWS. Ideally, group members would overlap with policy representatives in the existing forums mentioned above (e.g., *U.S. v. Oregon*, FCRPS implementation, FERC relicensing for the Hells Canyon Complex operations and mitigation programs, the Lower Snake River Compensation Plan, the Pacific Salmon Treaty, the Columbia Basin Fish Accords, and groups such as the Southeast Washington Salmon Recovery Funding Board that implement tributary habitat actions). Group members would have access to member entity staff to help implement key tasks. The group would be convened by NMFS and likely meet several times initially to clarify their objectives and key tasks, and thereafter most likely meet approximately twice a year. The primary objective for this group would be to facilitate collective recovery plan implementation.

Key tasks might include:

- Discussing management options for evaluating and achieving viability scenarios.
- Developing and confirming contingency plans and actions in the event of significant declines.

- Developing intermediate targets for recovery that will show the species is trending toward recovery in the expected time frame.
- Developing a list of potential contingency actions that go beyond those recommended in the site-specific actions (e.g. those identified in the Contingency Processes and Actions for Recovery Section 6.4) in the event that the species does not trend toward recovery in expected time frames.
- Identifying and developing conservation agreements and regulatory processes that would endure and conserver the species beyond an ESA delisting.

In addition, it is likely that the following existing coordination forums would continue to play a role:

Snake River Fall Chinook Salmon Technical Coordination Group

The Snake River Fall Chinook Salmon Technical Coordination Group includes technical representatives from the states, tribes, federal agencies, and Idaho Power Company. They coordinate regularly on technical information and issues associated with fish passage and trapping facilities and dam operations, and on managing the suite of hatchery programs. They also share regular science and policy updates about the fish, the dams, the hatcheries, habitat issues, and so on.

Snake River Coordination Group

The Snake River Coordination Group, convened by NMFS, brings together representatives from the tribes, states, other federal agencies, and Snake River recovery management units to coordinate policy and technical issues across the four listed Snake River salmon and steelhead ESUs and DPS. This group provides organizational structure for communication and coordination on a tri-state and multi-tribal level across the Snake River recovery domain. The group could continue to provide cross-species communication and input to NMFS on recovery plan issues.

NMFS’ Role in Recovery Plan Implementation

NMFS anticipates playing a role in coordinating and implementing this recovery plan. NMFS will provide coordination, facilitation, and administrative support for the Science Team and the Policy Group, and participate in and report regularly to the Snake River Fall Chinook Technical Coordination Group. It will implement the actions in this recovery plan for which it has the authority and funding to do so, and will seek additional authorities and funding as appropriate and needed. NMFS will also report on the implementation of the management and RM&E actions in this Plan, and will prepare updated status review findings during five-year reviews, or sooner if new information warrants. Finally, NMFS will use this recovery plan to provide information and context for its other activities implementing the ESA, including implementation of ESA section 4(d), section 7 consultations, and section 10(a)(1)(A) permits.

8.2 Implementation Progress and Status Assessments

Evaluating a species for potential delisting requires an explicit analysis of population or demographic parameters (biological criteria) and also of threats under the five ESA listing factors in ESA section 4(a)(1) (listing factors (threats) criteria). Together these make up the "objective, measurable criteria" required under section 4(f)(1)(B). This plan summarizes the biological criteria and threats criteria that will be used to evaluate the Snake River Fall Chinook Salmon ESU for potential change in listing status or delisting.

Five-Year Reviews and ESU/DPS Status Assessments

The ESA requires that, at least every five years, the Secretary of Commerce shall conduct a review of all ESA-listed species and determine whether any species should (1) be removed from such list; (2) be changed in status from an endangered species to a threatened species; or (3) be changed in status from a threatened species to an endangered species. Accordingly, at five-year intervals, NMFS will conduct reviews of the listed Snake River salmon ESUs and steelhead DPSs. These reviews will consider information that has become available since the most recent listing determinations, information specifically related to the limiting factors and threats identified in recovery plans, and make recommendations whether there is substantial information to suggest that a change in listing status may be warranted. If an ESU or DPS may warrant a change in status, NMFS will conduct a more in-depth, ESA status review consistent with section 4(a) of the Act. Any formal status reviews will be based on the NMFS Listing Status Decision Framework and will be informed by the information obtained through implementation of monitoring, research, and evaluation programs in each management unit plan and the recovery modules.

Similarly, new information considered during five-year reviews may also compel more in-depth assessments of implementation and effectiveness monitoring and associated research to inform adaptive management decision at the management unit level.

Modifying or Updating the Recovery Plan

The ESA requires a review of all listed species at least once every five years. Guidance for these reviews, developed jointly by NMFS and the U.S. Fish and Wildlife Service, is on the NMFS website: http://www.nmfs.noaa.gov/pr/pdfs/laws/guidance_5_year_review.pdf. According to NMFS Interim Guidance (NMFS 2006a), immediately following the five-year species review, an approved recovery plan should be reviewed in conjunction with implementation monitoring, to determine whether or not the plan needs to be brought up to date.

NMFS' Recovery Guidance provides three types of plan modifications: (1) an update, (2) a revision, or (3) an addendum. An update involves relatively minor changes. An update may identify specific actions that have been initiated since the plan was completed, as well as changes in species status or background information that do not alter the overall direction of the recovery effort. An update does not suffice if substantive changes are being made in the recovery criteria or if any changes in the recovery strategy, criteria, or actions indicate a shift in the overall direction of recovery; in this case, a revision would be required. Updates can be made by NMFS' Interior Columbia Basin Office of the West Coast Region, which will seek input from the local stakeholder group prior to making any update. An update would not require a public review and comment period.

NMFS expects that updates will result from implementation of the adaptive management program for this Plan. Adaptive management depends on the flow of information from field staff to recovery managers and planners; hence, it requires frequent updates from monitoring and research on the effectiveness of recovery actions and the status and trends of the listed species. It may be most efficient to keep the recovery plan current by updating it frequently enough to forego the need for major revisions.

A revision is a substantial rewrite and is usually required if major changes are needed in the recovery strategy, objectives, criteria, or actions. A revision may also be required if new threats to the species are identified, when research identifies new life history traits or threats that have significant recovery ramifications, or when the current plan is not achieving its objectives. Revisions represent a major change to the recovery plan and must include a public review and comment period.

An addendum can be added to a recovery plan after the plan has been approved and can accommodate minor information updates or relatively simple additions such as implementation strategies, or participation plans, by approval of the Area Office or NMFS' West Coast Region's Regional Administrator. More significant addenda (for example, adding a species to a recovery plan) should undergo public review and comment before being attached to a recovery plan. Addenda are approved on a case-by-case basis because of the wide range of significance of different types of addenda. NMFS will seek input from stakeholders on minor addenda to this Plan.

9. Time and Cost Estimates

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

9.1 Time Estimates

The time to recover Snake River fall Chinook salmon depends on the continued implementation of ongoing actions and the timeliness of effective additional actions that close the gaps between its present status and viability. The species’ present status demonstrates a rapid improvement in abundance of the extant population. As described in the Section 4, the extant population is presently considered Viable; however, it needs to be improved to Highly Viable status to support delisting. Thus, further actions are needed to close the gap between the population’s present status and high viability. This plan identifies the actions needed to close the gap and achieve ESU viability.

This plan provides viability criteria scenarios for scenarios A and B, which illustrate conditions under which NMFS would propose to delist the species. Achieving Scenario A would most likely take at least 25 years, because it depends on establishing a viable population above the Hells Canyon Complex in addition to improving the extant population to highly viable status. Evaluations are presently underway to determine the feasibility of establishing this population and the actions that would need to be carried out. Scenario B, which relies on the single extant population, could conceivably be achieved in a shorter time frame; however, it would require reductions in current levels of hatchery releases within the areas where natural-origin fish are spawning. The plan also includes a placeholder for development of additional scenarios that would include Natural Production Emphasis Areas (NPEAs). NPEAs would provide a substantial portion of the natural-origin production, and no hatchery fish would be released into these areas. ESU viability objectives could be measured and evaluated from these NPEAs. A viability scenario that includes NPEAs could be designed to achieve recovery sooner than under Scenario A and also to maintain current levels of hatchery production, unlike Scenario B, which would require reduced hatchery production.

Several variables that affect time to recovery for this ESU include, but are not limited to: whether existing protective actions remain in place; the timing and effectiveness of additional actions; the species’ response to both ongoing and additional actions; the adequacy of RM&E activities to determine the status of natural-origin spawners and the effectiveness of management actions; and the impacts of ecological factors, such as ocean conditions and climate. Achieving recovery in the shortest possible time frame and keeping the species recovered, depends on a functioning and funded adaptive management implementation system as described in Sections 6 and 8. Finally, the time to recovery includes the need to have effective regulatory mechanisms, including binding agreements, in place so we have a high level of confidence that once the species is delisted, it would continue to be conserved and the threats would remain ameliorated so that the species would not likely need to be listed again in the foreseeable future.

By way of example, implementation of actions targeted to achieve either Scenario B or an outcome consistent with the placeholder Natural Production Emphasis Area scenario could conceivably begin as early as 2018. These actions would include an updated hatchery juvenile release strategy, combined with continued implementation of ongoing actions and appropriate additional actions that update hydrosystem, habitat, and harvest strategies consistent with Scenarios B or an NPEA scenario. If these actions are implemented in 2018, the progeny of the first fish to spawn under the new conditions would begin returning in 2022. The progeny of those spawners would begin returning in 2026. Bearing in mind that ocean conditions are highly variable and that a downturn in ocean conditions could complicate matters, the period of 2022 through 2030 would provide an opportunity to determine whether or not the updated management regimes are working as planned and moving Snake River fall Chinook salmon toward delisting.

9.2 Cost Estimates

This section provides five-year and total cost estimates as called for under ESA section 4(f)(1)(B) and NOAA Interim Recovery Planning Guidance, version 1.3 (June 2010). Based on the limiting factors and threats identified in this Plan, staff from NMFS West Coast Region and the Northwest Fisheries Science Center, in coordination with tribal, state, and other federal agency staff, identified ongoing and potential additional actions to recover ESA-listed Snake River fall Chinook salmon. This list of recovery actions (Table 6-1) was developed using the most up-to-date assessment of current Snake River fall Chinook salmon status and recovery needs, without consideration of cost or potential funding.

In order to prepare cost estimates for these recovery actions, NMFS staff worked with tribal, state, and NMFS and other federal agency staff familiar with the ongoing and potential additional recovery actions to estimate costs where information was sufficient to allow reasonable estimates to be made. The approach taken to estimate the total cost of each action used the scale described for each action, where available, together with unit costs for each action type, where applicable. For some actions, no scale estimate was available at this time, in which case either we have documented the assumptions used to develop estimates or no cost estimate was provided at this time.

Table 6-1 in this document provides the estimated costs for actions set forth in this recovery plan, where information was sufficient to provide these estimates. The table includes the action numbers, action descriptions, potential implementing entities, and estimated costs. In some cases, costs have yet to be determined. Those that can be estimated at this point are included in this table.

Potential implementing entities are agencies or organizations with authority, responsibility, or expressed interest to implement a specific recovery action. The listing of an entity in the table does not require them to implement the action(s) or to secure funding for implementing the action(s).

All costs identified in Table 6-1 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. Unless otherwise noted, the costs are direct, incremental costs, meaning that they are (1) out-of-pocket costs that a public or private interest would pay to initiate and complete a management action and (2) costs that are in addition to the baseline costs for existing program and activities. This approach is consistent with NMFS West Coast Region guidance on cost estimates for ESA recovery plans.

Categorizing Recovery Actions and Corresponding Cost Estimates

There are different categories of actions for purposes of cost estimates. The following types of actions do not have cost estimates provided:

Baseline actions: These are actions are categorized as part of ongoing, existing programs that will be carried out regardless of this Plan. No cost estimate is provided for these actions because they do not represent new costs that are a direct result of this Plan.

To Be Determined: These are actions that need costs to be developed, need unit costs, and/or need project scale estimates to be sufficiently detailed to support a cost estimate. These costs will be developed during the implementation phase and the Recovery Cost Summary Table will be updated accordingly.

Not Applicable: These actions are generally policy actions requiring staff time and do not have separate, direct costs associated with them.

As described in Section 2 and in Section 6, multiple entities have implemented significant programs that have benefitted Snake River fall Chinook salmon since the ESU was listed in 1992 and that have helped it achieve its present abundance levels. These programs are all part of the baseline costs. Our assumption is that most of the baseline actions will continue into the future. If they do not, it is likely that additional recovery actions would need to be identified to replace them and maintain species status and that those costs would have to be added to the costs of implementing this recovery plan.

Total Cost of Recovery

While this recovery plan contains an extensive list of actions to recover Snake River fall Chinook salmon, there are many uncertainties involved in predicting the course of recovery and in estimating total costs. Such uncertainties include biological and ecosystem responses to recovery actions, as well as long-term and future funding to implement needed actions through the species' life cycle. Thus, it is impracticable to estimate all projected actions and costs to reach recovery. Instead, it is most appropriate to focus on the first 25 years of action implementation, with the understanding that before the end of each five-year implementation period, specific actions and costs will be estimated for subsequent years. Rather than speculate on conditions that may or may not exist that far into the future, this 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 under the ESA is no longer required.

The total cost estimated for all actions during the five-year period from 2016-2020, where costs are available, is approximately $1.845 million. This represents the total of the estimated costs for all actions identified in Table 6-1 for implementation in the near-term,[51] as well as costs for expansion of several baseline actions where we have indicated a potential need for expansion for full implementation. The total estimated cost of recovery actions for Snake River fall Chinook salmon over the next 25 years is approximately $5.2 million. These costs do not include costs directly associated with implementation of other programs. As noted throughout this document, many Snake River fall Chinook salmon recovery actions are already ongoing, or will be implemented as baseline actions, meaning that they will be carried out regardless of this plan. We have not included cost estimates for those actions, because they do not represent new costs that are a direct result of this plan.[52] As also noted above, in Section 6.2.3, if delisting were not achieved within the 25-year time frame envisioned for implementation of this plan, it is possible that additional actions would need to be identified and implemented. Costs for those actions would be identified at that time.

These costs do not include costs associated with implementing actions and associated RM&E for the following baseline programs:

- Federal Columbia River Power System operations, structural improvements, transportation, research, and other actions to maintain and enhance spawning, incubation,

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[51] As noted above, in Section 6.2.3, the near-term time frame corresponds to the five-year period from 2016 through 2022.

[52] Plan costs also do not include costs for estuary actions. As noted in Table 6-1, NOAA Fisheries' Columbia River Estuary Recovery Plan Module is incorporated by reference into this plan. The estuary actions highlighted in Table 6-1 are those expected to be particularly beneficial to fall Chinook salmon. The Estuary Module identified significant costs in addition to baseline costs for these actions (see Module, pp. 5-41—5-66). However, given the current risk status of this ESU and the ongoing implementation of estuary recovery actions under the 2008 FCRPS Biological Opinion and other baseline programs, it is likely that the level of effort needed in the estuary to achieve Snake River fall Chinook delisting will be lower than the level envisioned in the module. While it is possible that baseline actions in the estuary will need to be expanded to achieve delisting, it is not possible at this time to quantify the additional level of effort needed, or the costs associated with that additional level of effort. It is likely that additional efforts, and costs, would be significantly less than these identified in the module. This does not diminish the importance of improving salmon survival generally in the estuary through full implementation of actions in the Estuary Module, or the relevance of the cost estimates in the Estuary Module, for species that are currently at a higher risk status than Snake River fall Chinook.

rearing and migration conditions for fall Chinook salmon, as specified in the FCRPS Biological Opinion (NMFS 2014c).

- Hatchery programs at Lyons Ferry Hatchery, the Fall Chinook Acclimation Ponds Program, Nez Perce Tribal Hatchery and Oxbow Hatchery that support Snake River fall Chinook salmon recovery. NMFS issued a biological opinion in 2012 that provides ESA compliance on Hatchery and Genetic Management Plans for these Snake River fall Chinook salmon hatchery programs (NMFS 2012a). The biological opinion also describes a detailed RM&E program.
- Idaho Power Company activities to maintain or improve spawning, incubating, and rearing conditions for fall Chinook downstream of the Hells Canyon Complex and to assess (and potentially provide) passage to and from blocked historical habitats upstream of the complex. The actions are currently being defined through the FERC relicensing process and will need to meet NMFS and USFWS biological opinion requirement.
- Activities conducted by multiple harvest-management jurisdictions to reduce harvest on Snake River fall Chinook salmon in ocean and in-river fisheries, as described in the Harvest Module (Appendix G) and in NMFS’ ESA biological opinion on the fishing regimes (NMFS 2008c).FCRPS and other actions to improve Snake River fall Chinook salmon survival and productivity in the Columbia River estuary and plume, including those to increase habitat access, food availability, water quality and flow conditions. These actions are described in the Estuary Module (Appendix F) and the FCRPS Biological Opinion (NMFS 2014b).
- Related tributary habitat actions for recovery of Snake River spring/summer Chinook salmon and steelhead, as described in the Snake River Spring/Summer Chinook Salmon and Steelhead Recovery Plan and associated Management Unit Plans for Northeast Oregon, Southeast Washington and Idaho (NMFS, In Prep).

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