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

November 2017

Photo: U.S. Fish &Wildlife

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Acronyms and Abbreviations

BiOp	Biological Opinion
BOR/USBR	U.S. Bureau of Reclamation
BPA	Bonneville Power Administration
COE/Corps	U.S. Army Corps of Engineers
Council	Northwest Power and Conservation Council
CWT	coded-wire-tagging
DDT	dichlorodiphenyltrichloroethane
DO	dissolved oxygen
DPS	distinct population segment
EPA	Environmental Protection Agency
ESA	Endangered Species Act
ESU	evolutionarily significant unit
FCRPS	Federal Columbia River Power System
FEIS	Final Environmental Impact Statement
FERC	Federal Energy Regulatory Commission
FR	Federal Register
HGMP	Hatchery and Genetics Management Plan
HSRG	Hatchery Scientific Review Group
ICTRT	Interior Columbia Technical Recovery Team
IDFG	Idaho Department of Fish and Game
IFIM	Instream Flow Incremental Methodology
IPC	Idaho Power Company
LCREP	Lower Columbia River Estuary Partnership
LSRCP	Lower Snake River Compensation Plan
MPG	major population group
MaSA	major spawning area
N/A	not applicable
NEPA	National Environmental Policy Act
NGO	non-governmental organization
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPCC	Northwest Power and Conservation Council
NPEA	Natural Production Emphasis Area
NPT	Nez Perce Tribe
NPTH	Nez Perce Tribal Hatchery
NWFSC	Northwest Fisheries Science Center
ODFW	Oregon Department of Fish and Wildlife
PAH	polycyclic aromatic hydrocarbons
PBDEs	polybrominated diphenyl ethers

PCB	polychlorinated biphenyls
PDO	Pacific Decadal Oscillation
PFMC	Pacific Fisheries Management Council
pHOS	proportion of hatchery-origin spawners
PIT	passive integrated transponder
PNI	proportionate natural influence (in hatchery broodstock)
pNOB	proportion of natural-origin broodstock
RM	river mile
RM&E	research, monitoring, and evaluation
R/S	Return-per spawner
SCA	Supplemental Comprehensive Analysis
SRSRB	Snake River Salmon Recovery Board
TAC	Technical Advisory Committee
TDG	total dissolved gas
TMDL	total maximum daily load
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

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	An approach to recovery in which actions are implemented to improve the status of a salmon or steelhead species by reducing adverse effects throughout the species life-cycle and in all threat categories. This is commonly referred to as an “all H” approach because the most common threat categories are hydropower, hatcheries, habitat, and harvest (as well as predation and other ecological interactions).
Anadromous fish	Species that are hatched in freshwater migrate to and mature in salt water, and return to freshwater to spawn.
Baseline action	Baseline actions are part of ongoing, existing programs and will be carried out regardless of a recovery plan. No cost estimate is provided for these actions because they do not represent new actions or new costs that are a direct result of a recovery plan.
Broad sense recovery goals	Goals defined outside the ESA recovery planning process, generally by fisheries managers (state and tribal entities) or stakeholders, and 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	The genetic and phenotypic (life history, behavioral, and morphological) variation within a population. Variation could include anadromous or resident life histories, 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.
Direct effects of harvest	Direct effects of harvest include mortality of fish that are targeted for harvest, as well as mortality of fish that are incidentally harvested and mortality of fish that are caught and released or injured by fishing gear but not landed.
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.
Exploitation rate	The proportion of a total run that is harvested by the combined fisheries.
Extinct	No longer in existence. No individuals of this species can be found.
Extirpated	No longer present in a given area (i.e., locally extinct). Other populations of this species exist elsewhere. See also, functionally extirpated.
Federal Columbia River Power System (FCRPS)	The Federal Columbia River Power System (FCRPS) comprises 31 federally owned multipurpose dams in the Columbia River and its tributaries (i.e., the Willamette River, Upper Snake River, etc.). The system is managed collaboratively by three federal agencies: the Bonneville Power Administration, the U.S. Army Corps of Engineers, and the Bureau of Reclamation. The FCRPS ESA section 7 consultation focuses on 14 of these projects: Bonneville, The Dalles, John Day, McNary, Chief Joseph, Albeni Falls, Libby, Ice Harbor, Lower Monumental, Little Goose, Lower Granite, and Dworshak Dams (operated and maintained by the Corps) and the Hungry Horse Project and Columbia Basin Project, which includes Grand Coulee Dam (operated by the USBR).

Fish ladder	A series of stair-step pools that enables adult salmon and steelhead to migrate upstream past a dam or other barrier. Swimming from pool to pool, adult salmon and steelhead work their way up the ladder to the top of the barrier, and then continue their migration upriver.
Floodplain	The floodplain is the area of land next to a river that experiences flooding during periods of high discharge. Especially in the lower 50 miles of the estuary, there is also a “surge plain,” created when the incoming tide moves a wedge of salt water upstream along the bottom, forcing fresh water to surge out over low-lying areas.
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, subspecies, or population that has been functionally extirpated from a given area; although a few individuals may occasionally be found, there are not enough fish or habitat in suitable condition to support a functional population.
Indirect effects of harvest	Indirect effects of harvest can occur when fishing rates are high and selective by age, size, or run timing and might include selective pressure on migration timing, maturation timing, and size characteristics as well as genetic, growth, or reproductive changes
Hells Canyon Complex	The Hells Canyon Complex is three-dam hydroelectric project on the Snake River. The project has a generating capacity of 1167 megawatts and is owned and operated by the Idaho Power Company. The lowest of the three dams, Hells Canyon (at RM247.6), was completed in 1967; Oxbow Dam, at RM272.5, was completed in 1961; and Brownlee Dam, at RM 284.6, was completed in 1958. The three dams block passage and affect streamflows for ESA-listed fish.
Implementation monitoring	Monitoring to determine whether an activity was performed and/or completed as planned.
Incidental harvest	The harvest or take of fish that are caught incidentally to a targeted species or stock.
Indicator	A variable used to forecast the value or change in the value of another variable.
Intrinsic potential	The estimated relative suitability of a habitat for spawning and rearing of anadromous salmonid species under historical conditions, as inferred from stream characteristics including channel size, gradient, and valley width.
Intrinsic productivity	A population’s maximum growth rate (productivity) when free of density dependent limitations (McElhany et al. 2000). The ICTRT (2007) defined intrinsic productivity as the ratio of natural-origin offspring (returns) to parent spawners at levels of abundance below carrying capacity. The productivity metric incorporated into ICTRT viability criteria requires that both parent and return estimates be expressed in terms of spawners.
Limiting factors	Physical, biological, or chemical conditions (e.g., inadequate spawning habitat, high water temperature, insufficient prey resources) and associated ecological processes that result in reductions in viable salmonid population (VSP) parameters (abundance, productivity, spatial structure, and diversity). Priority 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 or DPS that share similar genetic and spatial characteristics.
Major spawning area (MaSA)	A river system with one or more branches that contains sufficient spawning and rearing habitat to support at least 500 spawners.
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.
Morphology	The form and structure of an organism, with special emphasis on external features.
Natural-origin fish	Fish that spawned and reared in the wild, regardless of parental origin.
Natural Production Emphasis Area (NPEA)	One or more major spawning areas that would produce a substantial level of an ESU's natural-origin adult spawners and have a low proportion of hatchery-origin spawners.
Out-of-ESU hatchery program	A hatchery program that is not designated as part of the Snake River fall Chinook salmon ESU and that produces fish intended to return to areas outside of the Snake River basin.
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.
Plume	The layer of Columbia River water in the nearshore Pacific Ocean.
Productivity	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 productivity over an entire life cycle. The indicator for productivity is the average number of surviving offspring per parent, which 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 recovery plan. These goals may include both ESA recovery goals and broad sense recovery goals that go beyond the requirements of ESA delisting by addressing other legislative mandates or social, cultural, and ecological values.
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 recovery, 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 recovery plan or the management of natural resources affected by the recovery plan and its implementation.

Subyearling life history	Life-history pattern in which young fish emerge from redds and rear in natal habitat for a short time but migrate seaward during their first year of life.
Supplementation	Production and release of hatchery fish intended to spawn naturally to increase the abundance of the naturally spawning population.
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.
Thalweg	The line following the lowest elevation or points within a valley or watercourse. The thalweg usually provides the deepest and fastest water available in a river channel.
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 salmonid (genus *Oncorhynchus*) that has a negligible risk of extinction due to threats from demographic variation (random or directional), local environmental variation, and genetic diversity changes (random or directional) over a 100-year time frame.
VSP parameters	Abundance, productivity, spatial structure, and diversity. These describe characteristics of salmonid populations that are useful in evaluating population viability. See NOAA Technical Memorandum NMFS-NWFSC-42, Viable salmonid populations and the recovery of evolutionarily significant units (McElhany et al. 2000).
Within-ESU hatchery program	Hatchery program that is designated as part of the Snake River fall Chinook salmon ESU and that produces fish intended to return to the Snake River.
Yearling	Life-history pattern in which young fish emerge from redds and rear in freshwater habitat for a year before migrating seaward during their second year of life.

Executive Summary

Snake River Fall Chinook Salmon Recovery Plan

Introduction

This Endangered Species Act (ESA) recovery plan (Plan or recovery 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)[1] of Chinook salmon (*Oncorhynchus tshawytscha*), as a threatened species under the ESA on April 22, 1992 (57 FR 14653). NMFS revisited the listing in 2005 (in light of its subsequent Hatchery Listing Policy), and determined that the species should remain listed as "threatened" (70 FR 37160). In 2010 and 2016, NMFS conducted 5-Year reviews of the status of the species, and based on the best scientific information available at that time, determined that the "threatened" classification remained appropriate (NMFS 2011a, 2016a).

At one time the run numbered half a million strong. Historically, this mighty run of fall Chinook salmon traveled 300 miles up the Columbia River and then up to 600 more miles in the Snake River basin each year. They spawned in the mainstem Snake River from its confluence with the Columbia River upstream to Shoshone Falls, a 212-foot natural barrier to salmon migration near river mile (RM) 615, and in several major tributaries. The fish run began to decline toward the end of the late 1800s and continued to decline into the 1990s as a result of overfishing and other human activities ─ including construction of major dams on the Snake River that cut off access to primary spawning and rearing habitats. By the late 1980s, average runs of natural-origin fall Chinook salmon to the Snake River had dropped to approximately 100 adults annually. Only about 78 natural-origin adult fish returned in 1990 (Lavoy and Mendel 1996). The drastic decline in Snake River fall Chinook salmon led NMFS to list the species under the ESA in 1992 and spurred 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. While the collective actions have brought us a long way towards recovering the ESU, more effort is needed to ensure that the ESU can be naturally self-sustaining. Uncertainty remains regarding the status of the species' productivity and diversity, whether recent high abundance can be maintained, and

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[1] An Evolutionarily Significant Unit (ESU) is a group of Pacific salmon that is discrete from other groups or the same species and that represents an important component of the evolutionary legacy of the species. An ESA is treated as a species under the Endangered Species Act (56 FR 58612). NMFS' official nomenclature for this ESU is Snake River Fall-run Chinook salmon. In this Plan we generally refer to the ESU as Snake River fall Chinook salmon.

whether the ESU can be self-sustaining in the wild over the long term. This Plan identifies actions to address these uncertainties and to take the ESU the remaining distance so we are confident of its ability to be self-sustaining in the wild into the future.

The listed ESU includes all natural-origin fall-run Chinook salmon from the mainstem Snake River below Hells Canyon Dam at RM 247 (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 (Figure ES-1). Fall-run Chinook salmon from four artificial propagation programs are also considered part of the ESU: Lyons Ferry Hatchery Program, Fall Chinook Acclimation Ponds Program, Nez Perce Tribal Hatchery Program, and the Oxbow (Idaho Power Company) Hatchery Program (64 FR 50406).

Historically, Snake River fall Chinook salmon also spawned in the Middle Snake River and tributaries upstream of the rugged Hells Canyon area. The Middle Snake River, which now lies upstream of the three-dam Hells Canyon Complex, supported the majority of all Snake River fall Chinook salmon production until the area became inaccessible due to dam construction. Nine major tributaries to the Middle Snake River ─ Salmon Falls Creek and the Owyhee, Bruneau, Boise, Payette, Weiser, Malheur, Burnt, and Powder Rivers ─ were also accessible but most fall Chinook salmon spawned in the mainstem Snake River. The loss of this upstream habitat area restricted the species to the area downstream of Hells Canyon Dam, which represents approximately 20 percent of the species' historically available habitat (Dauble et al. 2003).

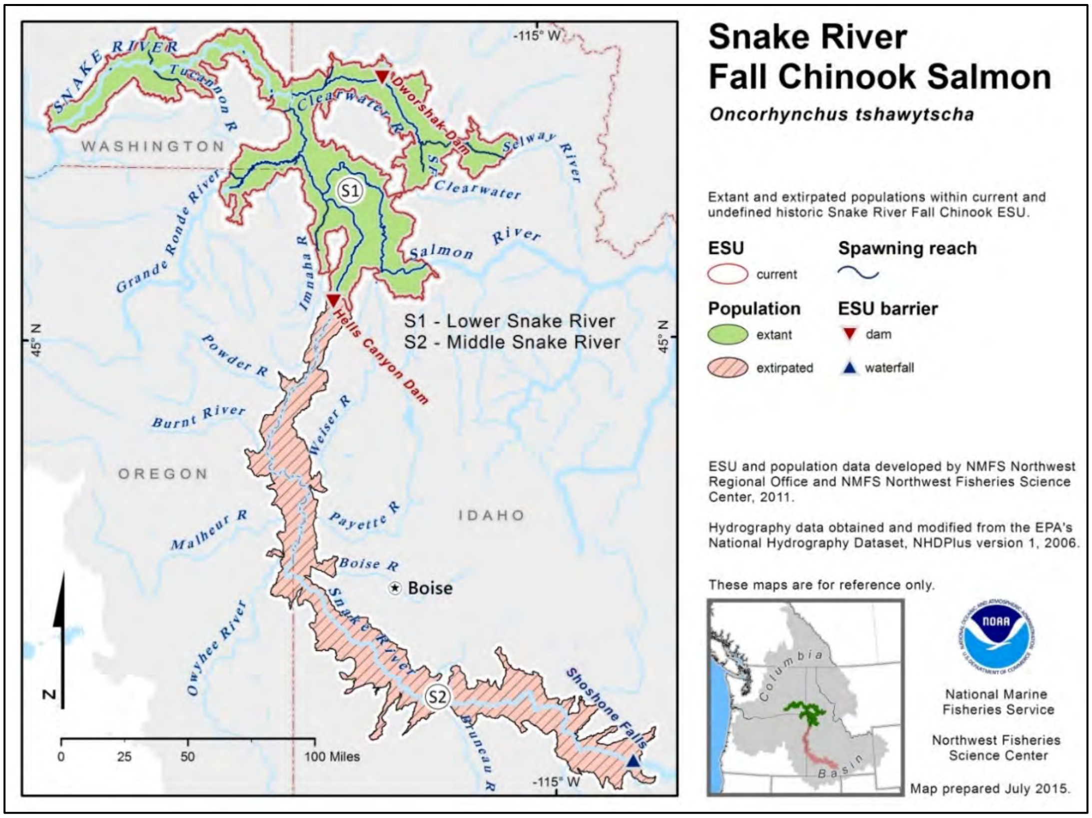

Figure ES-1. Snake River fall Chinook salmon current and historical spawning range.

About This Recovery Plan

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

The Plan also provides other information that can help frame Snake River fall Chinook salmon conservation, recovery, and research efforts. It summarizes the current status of the ESU, and describes the limiting factors and threats that affect the species status and recovery potential. It identifies alternative scenarios for recovery of the ESU, as well as a set of strategies and actions to address the limiting factors and threats and achieve recovery. It also describes an adaptive management framework, a plan 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 (USFWS 2015)*. 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 - *2017 Supplemental Recovery Plan Module for Snake River Salmon and Steelhead Mainstem Columbia River Hydropower Projects* (Hydro Module) (NMFS 2017a), 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, leading 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, and whether the species can be self-sustaining in the wild. 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 ensure that the Snake River fall Chinook salmon ESU is self-sustaining in the wild and no longer needs ESA protection.

Historical Context

Historically, most fall Chinook salmon spawned in areas of the Middle Snake River upstream of Hells Canyon, where relatively warm spring-fed water released from the Eastern Snake River Plain Aquifer created prime habitat conditions. These springs, including a large spring complex known as Thousand Springs (Figure ES-2), once contributed about 4,000 cubic feet per second of flow at an average temperature of approximately 60 °F (15.5 °C) to the Snake River mainstem and influenced water temperatures in the river for about 86 miles. The area from Auger Falls (RM 607) to near the mouth of the Burnt River (approximately RM 327) provided particularly productive 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.

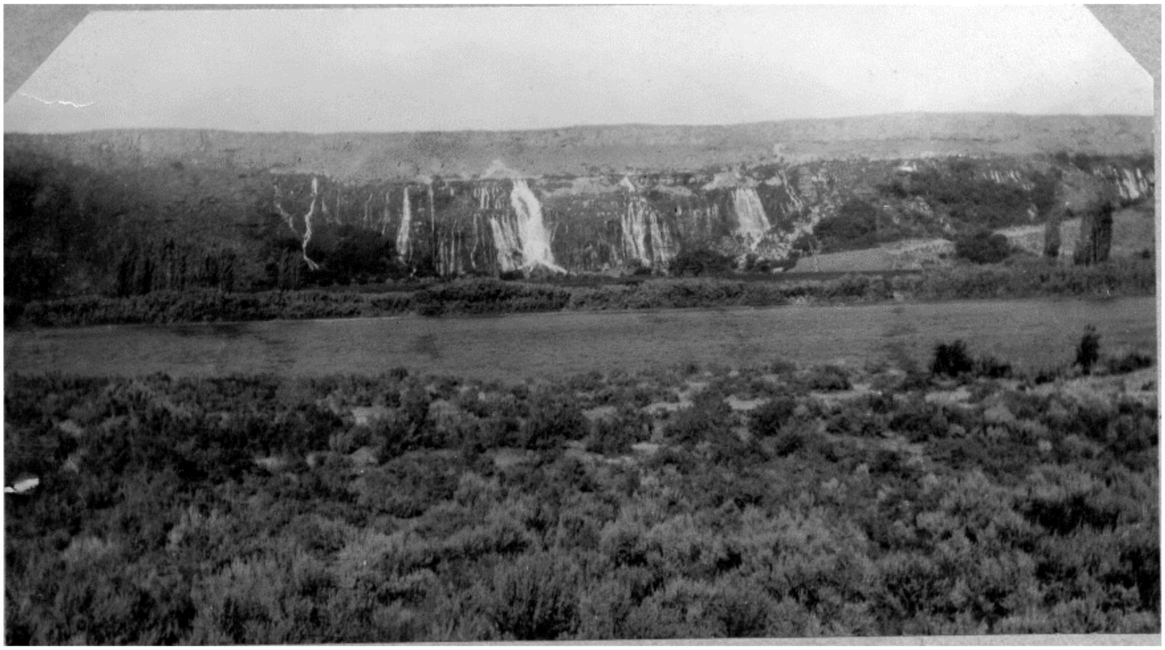

Figure ES-2. The area known as Thousand Springs (RM 584).

In 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 continued to decline into the 1990s as a result of overfishing and other human activities, including the construction of major dams (Table ES-1).

The species’ drastic decline led NMFS to list it under the ESA in 1992. NMFS’ status reviews leading to the original listing decision (57 FR 14653) and subsequent status reviews cite the loss of primary spawning and rearing areas upstream of the Hells Canyon Complex, the effects of lower Snake and Columbia River projects associated with the Federal Columbia River Power System (FCRPS), the increase in non-local hatchery contribution to adult escapement above Lower Granite Dam,[2] and the relatively high aggregate harvest impacts by ocean and in-river

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[2] Lower Granite Dam is one of four large dams on the lower Snake River. It is located at the upstream end of the four lower Snake River dams.

fisheries as the factors causing the steady and severe decline in abundance of Snake River fall Chinook salmon. The 1991 status review (Waples et al. 1991) and the most recent status reviews (ICTRT 2010; Ford et al. 2011; NWFSC 2015; NMFS 2011a, 2016a) also noted concerns about effects of hatchery operations and high proportions of hatchery-origin spawners on the species. The listing increased the pace and number of efforts to reverse the decline, and these efforts have contributed to increases in the ESU’s abundance and productivity. Actions 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. In addition, RM&E has provided critical information on the run and recovery efforts.

Table ES-1. Selected 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 targeting fall Chinook salmon.	Harvest peaks at nearly 80% of returning fall Chinook adults.	Abundance begins to decline.
1901-1902	Swan Falls Dam constructed on Snake River (RM 457.7). First full-scale hatchery constructed at Ontario, Oregon (1902); operated 1902-1909.	Access blocked to 157 miles of mainstem habitat.	Substantially reduced abundance and distribution in Middle Snake River.
1904-1925	Commercial harvest effort moves from lower Columbia, where harvest was controlled, to above Celilo Falls (1904). Fish wheels outlawed in Oregon (1928) and Washington (1935).		Abundance continues to decline.
1927	Lewiston Dam constructed on Clearwater River (RM 6).	Access to Clearwater River blocked (1927-73).	
1938-1947	Bonneville Dam completed on Columbia River (RM 146) in 1938.	During this period, harvest rate on returning fall Chinook adults in Columbia River ranges from 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 average annual adult return to Snake River.
1958-1967	Hells Canyon Dam Complex 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 population in Middle Snake River 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 miles of lower mainstem Snake River habitat.	Abundance declines further.
1964-1968	John Day Dam completed on Columbia River (RM 215.6) in 1968.		12,720 average annual adult return to Snake River.
1969-1976	Lower Snake River Compensation Plan starts egg bank program and begins producing hatchery fish to compensate for production lost due to habitat 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 average annual adult return; low of 100 adults (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 a major risk.
1990-1992	Current Idaho Power Company fall Chinook salmon program initiated (1991). Snake River fall Chinook salmon listed under the ESA as threatened (1992).		Broodstock scarce; hatchery production levels very low. 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 biological opinion implemented to improve dam passage/operations for migration.		2,164 average annual adult return to Snake River; includes 1,055 natural-origin fish (1997-2001).
2000-2002	Oxbow Hatchery program begins (2000); Nez Perce Tribal Hatchery program begins (2002); total of four hatchery programs release up to 5.5 million fish.		Abundance increases.
2000-2007	Actions in 2000 FCRPS biological opinion implemented to further improve dam passage/ operations for migration (include increased summer spill from 2005 Court Order).		Abundance increases.
2003-2008	Snake River fall Chinook salmon ESA listing affirmed (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.
2008-2016	Actions in 2008 FCRPS biological opinion implemented to further improve dam passage/ operations for migration, include more summer spill and surface passage at the 8 dams. NMFS determines that "threatened" status for the ESU is still warranted (2016).		50,000+ average annual adult return to Snake River; includes 6,418 natural-origin annual return (2005-2014).

Scientific Foundation ─ ESU Biological Structure

It is critically important to base recovery plans on a solid scientific foundation. To provide this scientific foundation, NMFS appointed teams of scientists with geographic, species, and/or topical expertise. 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. This team defined the historical population structure of the Snake River fall Chinook salmon ESU and identified biological viability criteria for the ESU.

Snake River fall Chinook salmon, as well as other salmonid species, are defined by a unique biological population structure that is critical to their resilience and long-term survival. The biological structure of a species is hierarchical: spawners in the same area of the same stream share more characteristics than they do with those in the next stream over. Recovery planning efforts focus on this biologically based hierarchy, which extends from the species level to a level below the population, and reflects the degree of connectivity between the fish at each level.

The Snake River fall Chinook salmon ESU represents a distinct group of Pacific salmon that is uniquely adapted to its environment. It 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 ICTRT defined a single major population group (MPG) within the ESU. The MPG contains one extant natural-origin population (Lower Snake River population) and one extirpated population (Middle Snake River population).[3] The ICTRT identified five major spawning areas (MaSAs) within the Lower Snake River population: Upper Hells Canyon MaSA (Hells Canyon Dam on Snake River downstream to confluence with Salmon River); Lower Hells Canyon MaSA (Snake River from Salmon River confluence downstream to Lower Granite Dam pool); Clearwater River MaSA; Grande Ronde River MaSA; and Tucannon River MaSA (Figure ES-3). A major spawning area is defined as a system of one or more branches containing sufficient habitat to support at least 500 spawners.

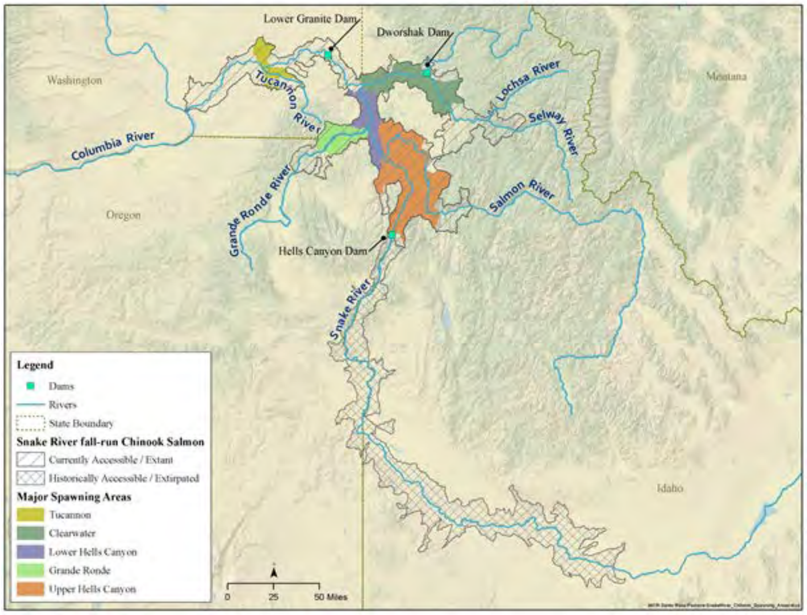

Figure ES-3. Current Snake River fall Chinook salmon Major Spawning Areas and historically accessible area.

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[3] The ICTRT (2005) identified two historical populations above the current Hells Canyon dam site based on historical accounts of spawner distribution and spatial geomorphic considerations (ICTRT 2007). As part of the 2016 ESA 5-year status review, NMFS determined that the two relatively continuous spawning aggregations above the site were more likely part of a single population (NWFSC 2015; NMFS 2016a).

Life History

Most Snake River fall Chinook salmon exhibit a subyearling life-history pattern, where young fish emerge from redds from late winter to early spring, rear in natal habitat for only a short time, and migrate seaward before mid-summer (Figure ES-4). Egg incubation, emergence timing, and early rearing of Snake River fall Chinook salmon are significantly influenced by water temperature regimes. This variation also existed historically, and the water temperature variation between different reaches creates variations in early life-history timing of juveniles from different areas (Connor et al. 2016).

The habitat variation associated with the Lower Snake River fall Chinook salmon population also supports a significant number of yearling migrants. Most of the yearlings are juveniles from the Clearwater River basin but a small percentage (<1 to 2 percent) originate from other Snake River areas. These juveniles overwinter in the reservoirs and other cool-water refuge areas and migrate downstream to the ocean as yearlings.

Snake River fall Chinook salmon generally spend two to five 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.

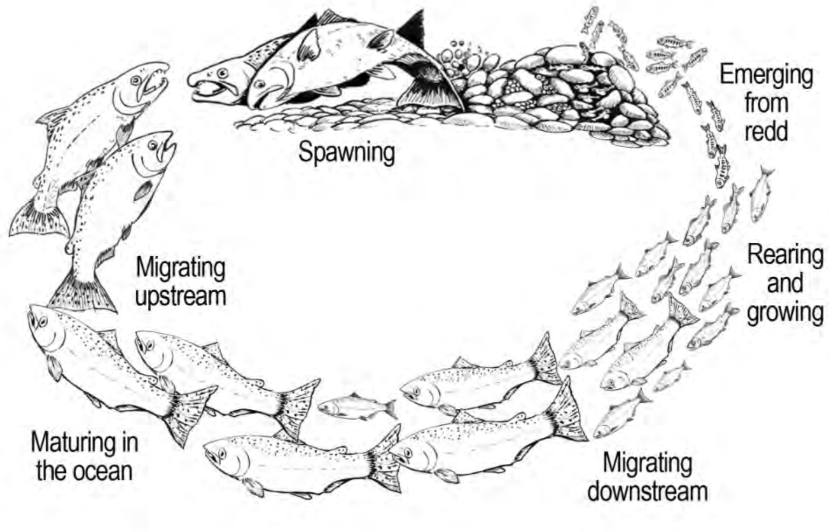

Figure ES-4. Snake River fall Chinook salmon life cycle.

Redd (spawning nest) surveys since the ESU was listed under the ESA provide a general depiction of the spawning distribution. Since 1992, the highest percentage of fall Chinook salmon redds have been counted in the Upper Hells Canyon MaSA (32 percent), followed closely by the Clearwater River MaSA (27 percent) and Lower Hells Canyon MaSA (21 percent). The Tucannon and Grande Ronde MaSAs contributed an average of 6 percent and 5 percent, respectively.

Recovery Goals, Objectives and Criteria

The recovery plan provides NMFS' recovery goals, objectives, and criteria for the Snake River fall Chinook salmon ESU. The primary goal for the species is ESA recovery to a self-sustaining condition that would support delisting. NMFS' approach to recovery aims to achieve this ESA recovery goal while recognizing federal legal obligations, mitigation goals, and other social, cultural, and economic values regarding the listed species. Chapter 3 describes the ESA recovery goal in more detail, as well as objectives, delisting criteria, 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 major population groups 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 artificial propagation measures to achieve its viable characteristics. Artificial propagation may contribute to recovery, but is not a substitute for addressing the underlying factors (threats) causing or contributing to a species' decline.

ESA Recovery Objectives: The ESA recovery objectives define general characteristics relative to abundance and productivity, spatial structure, diversity, and threats to the species that are consistent with the ESA recovery goal.

Abundance and Productivity: Abundance and productivity affect population-level persistence in the face of year-to-year variations in environmental influences. The objective is that:

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

Spatial Structure: Refers to population- and ESU-level geographic distribution and the processes that generate that distribution. The objective is that:

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

Diversity: Refers to the distribution of traits within and among populations and is important for long-term evolutionary potential. The objective is that:

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

Threats: Threats are the human activities or natural processes that cause or contribute to the factors that limit species viability. The objective is that:

- The threats to the species have been ameliorated so as not to limit attainment of its desired status and regulatory mechanisms are in place to 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 recovery of the species, the Plan also identifies broad sense goals. These broad sense goals go beyond the requirements for delisting under the ESA to address other legislative mandates, tribal treaty and trust responsibilities, and social, cultural, ecological, or economic benefits of having healthy, diverse salmon populations. The Plan incorporates broad sense goals related to: (1) visions for desired future conditions established in subbasin plans developed under the Northwest Power and Conservation Council's subbasin planning process; (2) treaty and trust obligations to Columbia Basin tribes and obligations under Secretarial Order #3206, "American Indian Tribal Rights, Federal-Tribal Trust Responsibilities, and the Endangered Species Act;" (3) federally authorized objectives for mitigating Snake River fall Chinook salmon production lost due to Snake River hydropower development and to help maintain fisheries and contribute to conservation of existing wild stocks; and (4) reintroduction of fall Chinook salmon above the Hells Canyon Complex. While broad sense goals are not relevant to or considered in an ESA delisting decision, we include them here to inform management decisions and to provide a comprehensive overview of the management goals of the many stakeholders concerned with fostering a thriving Snake River fall Chinook salmon ESU.

NMFS is supportive of the broad sense recovery goals and believes that achieving viability of natural populations and delisting is consistent with broader goals to reach a stable, long-term condition in which fall Chinook salmon are thriving and harvestable. Upon delisting, NMFS will work with co-managers and local stakeholders, using our non-ESA authorities, to pursue broad sense recovery goals while continuing to maintain robust natural populations. In addition, NMFS has considered broad sense goals in designing a recovery scenario in this Plan, which is compatible with tribal treaty and trust obligations regarding harvest, and with maintaining hatchery production at levels consistent with mitigation goals (see Section 3.1.2).

ESA Delisting Criteria: Under the ESA, NMFS is responsible for the listing and delisting of Pacific salmon and steelhead. 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: *biological viability criteria*, which deal with population or demographic parameters, and *threats criteria*, which address the five listing factors in ESA section 4(a)(1). The biological viability criteria provide a measure for determining whether the threats have been adequately addressed to support delisting, and the threats criteria ensure that adequate conservation mechanisms are in place to protect a species after delisting.

Table ES -2 shows the biological viability criteria associated with achieving the ESA recovery goal and objectives under potential recovery scenarios. The threats criteria are identified in Section 3.2.2. 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. The criteria in the Plan are based on the best available scientific information and incorporate the most current understanding of the ESU and the threats it faces. NMFS expects that as this recovery plan is implemented, new information will likely become available that improves our understanding of the status of the ESU as well as of threats, their impacts, and the extent to which they have been ameliorated. If appropriate, NMFS will review and revise delisting criteria in the future based on this new information.

Potential ESA Recovery Scenarios

As with most ESUs, there is more than one path to achieve ESA recovery 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. Abundance of this population has grown substantially since ESA listing.

The ESU’s unique characteristics may allow recovery with just the one extant Lower Snake River population. However, continued exploration and work toward establishing passage and a second population above the Hells Canyon Complex 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 three potential ESA recovery scenarios that would meet the ESU recovery objectives: Scenario A would achieve ESU viability with the two populations (the extant Lower

Snake River population and the extirpated Middle Snake River population). Scenarios B and C describe alternative approaches for achieving viability with the single extant Lower Snake River population. Table ES-2 and Chapter 3 (Section 3.2.1) describe the scenarios in more detail.

The scenarios represent a range of potential strategies that can be pursued simultaneously in the near future, and that address the entire life cycle of the species. They are based on the best available information, but it is also possible that other scenarios could achieve ESU viability and delisting. Thus, the recovery scenarios may be refined 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 — Two Populations: Achieve highly viable status for the extant Lower Snake River population and viable status for the currently extirpated Middle Snake River population.
Biological Viability Criteria: 1. a) Lower Snake River population: Combination of natural-origin abundance and productivity exhibits a 50 percent probability of exceeding the viability curve for highly viable status (i.e., has a 50% probability of a 1% or less risk of extinction over 100 years). b) Middle Snake River population: Combination of natural-origin abundance and productivity exhibits a 50 percent probability of exceeding the viability curve for viable status (i.e., has a 50% probability of a 5% or less risk of extinction over 100 years). 2. a) Both populations exhibit robust spatial distribution of spawning aggregations. b) All major habitat types within a population are occupied. c) Current range of genetic and life-history diversity includes historically dominant patterns. d) Any difference(s) from historical diversity patterns represent positive natural adaptations to prevailing environmental conditions. e) Evolutionary trajectory of populations is dominated by natural-selective processes.
Scenario B — Single Population: Achieve highly viable status for Lower Snake River population (measured in the aggregate).
Biological Viability Criteria: 1. Combination of natural-origin abundance and productivity for the Lower Snake River population exhibits an 80 percent or higher probability of exceeding the viability curve for highly viable status (i.e., has an 80% probability of being at or below a 1% risk of extinction over 100 years). 2. a) Population exhibits robust spatial distribution of spawning aggregations. b) All major habitat types within the population are occupied. c) Current range of genetic and life-history diversity includes historically dominant patterns. d) Any difference(s) from historical diversity patterns represent positive natural adaptations to prevailing environmental conditions. e) Evolutionary trajectory of population is dominated by natural-selective processes.
Scenario C — Single Population: Achieve highly viable status for Lower Snake River population (with Natural Production Emphasis Areas).
Biological Viability Criteria: 1. Combination of natural-origin abundance and productivity for the Lower Snake River population exhibits an 80 percent or higher probability of exceeding the viability curve for highly viable status (i.e., has an 80 percent probability of being at or below a 1% risk of extinction over 100 years). 2. a) Population exhibits robust spatial distribution of spawning aggregations. b) All major habitat types within the population are occupied. c) Current range of genetic and life-history diversity includes historically dominant patterns. d) Any difference(s) from historical diversity patterns represent positive natural adaptations to prevailing environmental conditions. e) Evolutionary trajectory of the NPEA component of the population is dominated by natural-selective processes.

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 of 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 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, measured in the aggregate) described above and in Chapter 3. Chapter 4 summarizes the current biological status assessment, which is described in more detail in Appendix A.

Current Risk Rating

The Lower Snake River fall Chinook salmon population is currently rated as **viable,** at low (1-5 percent) risk of extinction within 100 years, based on current population low risk rating for abundance/ productivity and a moderate risk rating for spatial structure/ diversity. 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 20-year productivity is 1.53 (1991-2010 brood years), which indicates remaining uncertainty that current increases in natural-origin abundance can be sustained over the long run. The population's current rating of moderate risk for structure/diversity 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 3.2.2, the one extant population must achieve a viability rating of highly viable, at very low (< 1 percent) 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 in 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 Lower 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. Reasons for listing 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.

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. Actions have boosted adult and juvenile survival of the extant population downstream of Hells Canyon Dam and 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. Still, threats to the species persist: historical spawning and rearing habitats upstream of the Hells Canyon Complex remain inaccessible and too degraded to support significant anadromous fish production, 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. Chapter 5 provides a detailed discussion of these limiting factors and threats. The modules also present more detailed discussions.

What are limiting factors and threats?

Limiting factors are the biological, physical, and chemical conditions and associated ecological processes and interactions that result in reduction in species' viability (e.g., high water temperature).

Threats are the human activities or natural events 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.

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 tributary reaches and in the Columbia River estuary, plume, and ocean, and from climate change.

Middle Snake River Upstream of Hells Canyon Complex — The Hells Canyon Complex of dams (and five additional upstream Snake River dams) blocks access to 367 miles of once highly productive spawning habitat in the Middle Snake River mainstem. Currently, however, the mainstem habitat in the blocked area is too degraded to support significant fall Chinook salmon production. Water quality factors include high water temperatures, excessive nutrients and algal growth, and anoxic or hypoxic conditions in spawning gravels. Other factors affecting habitat quality include altered flows, inundated habitat, increased sediment, and low dissolved oxygen.

Upper Hells Canyon Reach of Lower Snake River Mainstem (below Hells Canyon Dam to the mouth of the Salmon River) — This mainstem Snake River reach (RM 247 to 188) is part of the Upper Hells Canyon MaSA and serves as a primary production area for the Lower Snake River population. Operation of the Hells Canyon Complex affects Snake River fall Chinook salmon in this reach in several ways: (1) Operations alter water quality. The altered thermal regime has both beneficial and adverse effects. The thermal regime is more conducive to fall Chinook salmon incubation and rearing compared to historical conditions, and has accelerated fry emergence and early rearing. In contrast to these benefits, however, the effects of the altered thermal regime on adult fall Chinook salmon are uncertain but could be negative. Many adults migrate, hold, and spawn in the reach in late summer and early fall and are exposed to warmer temperatures for longer periods than occurred historically. The temperatures could also reduce egg viability and egg-to-fry survival in some cases. 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 and higher predation.

Lower Hells Canyon Reach of Lower Snake River Mainstem (mouth of Salmon River to Lower Granite Dam Reservoir) — This mainstem Snake River reach (RM 188 to 147) serves as the primary production area for fall Chinook salmon in the Lower Hells Canyon MaSA. Hells Canyon Complex operations affect fall Chinook salmon production in this reach by altering flow and thermal regimes. The altered flow regime has reduced high peak flows that occurred historically. Daily and hourly fluctuations can strand fry in shallow areas when the flows recede. Idaho Power Company reduces these effects by providing stable flow from Hells Canyon Dam during the fall Chinook salmon spawning season and to support incubating eggs and emerging fry. The altered thermal regime due to operation of the Hells Canyon Complex has beneficial and negative effects. While it provides more productive habitat for fall Chinook salmon in this reach than existed historically, the high water temperatures can limit adult fall Chinook salmon use in the reach (although 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. At Lower Granite Reservoir, the altered flow regime inundates mainstem and shallow-water spawning and rearing areas, and contributes to an altered thermal regime. The altered conditions in Lower Granite Reservoir can increase habitat for non-native fish that prey on migrating juvenile fall Chinook salmon, especially subyearlings.

Tributary Spawning Areas — Three large lower Snake River tributaries provide fall Chinook habitat:

Lower Clearwater River MaSA: The flow and water temperature downstream from the confluence of the North Fork Clearwater River are dominated by the outflow of Dworshak Dam, creating winter flows that are slightly warmer than historically and summer flows are significantly colder. Land uses have also affected habitat conditions. Limiting factors for fall Chinook salmon spawning and rearing in the lower Clearwater River include reduced habitat complexity and floodplain connectivity, increased water temperatures, increased sediment, 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, glides, and spawning gravels), excess fine sediment, degraded riparian conditions, low summer flows, and poor water quality (high summer water temperatures, low dissolved oxygen, and 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 Lower Snake and Columbia River — The dams and reservoirs in the mainstem lower Snake and Columbia River migration corridor remain a threat to Snake River fall Chinook salmon viability. Four Federal Columbia River Power System (FCRPS) projects on the lower Snake River (Lower Granite, Little Goose, Lower Monumental, and Ice Harbor) and four FCRPS dams on the Columbia River (McNary, John Day, The Dalles, and Bonneville) limit passage for juveniles migrating to the ocean and for adults returning to spawn. In addition to inundating historical fall Chinook salmon production areas, hydropower system development and operations reduce mainstem habitat quality, affecting both juvenile and adult migration.

Specific limiting factors for adult fall Chinook salmon in the migration corridor include: difficulty finding fish ladders, temperature-related delayed/ blocked upstream migration, fallback, reduced spawning area, and impaired homing ability. Limiting factors for juvenile fish include slowed migration, increased mortality, injuries or stress due to dam passage, and increased predation. The migrating fish are also exposed to agricultural and industrial chemicals.

Columbia River Estuary, Plume, and Ocean — The cumulative impacts of past and current land use (including 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 affected by reduced habitat as a result of changes in sediment/nutrient levels and flow, reduced floodplain connectivity, increased water temperature, changes in food sources, altered predator/ prey relationships, and exposure to toxic contaminants.

Plume: Snake River fall Chinook salmon that pause in the plume to feed and acclimate to salt water can be affected by changes in flow and sediment, as well as changes in the food web.

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. Warm ocean years are related to low adult returns of Snake River fall Chinook salmon 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 their freshwater, estuarine, and marine habitats. Stream flows and temperatures ─ the freshwater environmental attributes most affected by climate change ─ already limit fall Chinook salmon productivity in some mainstem and tributary reaches. 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 fall Chinook salmon. Potential limiting factors include passage delays, reduced egg and fry survival, pre-spawn mortality, a shift in fry emergence and outmigration timing, reduced prey availability, and increased predation. The magnitude of these effects will depend on how Snake River fall Chinook salmon respond to the changes, which remains unclear.

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

Bird Predation. Primary bird predators of Snake River fall Chinook salmon are double-crested cormorants and Caspian terns, with gulls and pelicans having relatively insignificant impacts. In general, rates of predation by birds on Snake River fall Chinook salmon are relatively low.

Marine Mammals. Marine mammals prey on migrating adult salmon in the Columbia River estuary and as they attempt to pass over Bonneville Dam. California sea lions that gather at Bonneville Dam have generally left the area by the time of the fall Chinook salmon migration. However, the number of Steller sea lions in the area has increased since 2011, and they are assumed to take adult Snake River fall Chinook salmon, although the level of take is not known.

Fish Predation. Both native and non-native fish prey on fall Chinook salmon. Northern pikeminnow are the primary native fish predator, and non-native predatory species (e.g., smallmouth bass, walleye, etc.) also feed on migrating juveniles. Northern pikeminnow predation has been reduced through a bounty reward program, while recent research indicates that current predation by smallmouth bass is higher than it was in the past.

Competition and Other Ecological Interactions

The productivity of juvenile Snake River fall Chinook salmon depends in part on the food web and prey communities that support growth and survival, and on competition for food and space with other fish. Competition can escalate when habitat capacity is limited and unable to support the number of fish competing for key resources at the same time. For example, 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 (Connor et al. 2016). Competition can occur between hatchery-origin and natural-origin salmonids.

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 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 cases because the Lower Snake River 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, Adaptive Management Framework, and Site-Specific Management Actions

Recovery Strategy

The recovery strategy for Snake River fall Chinook salmon is designed to ensure that the ESU and the ecosystems upon which it depends have been conserved to a point that the ESU is self-sustaining in the wild and no longer needs the protections of the ESA. The overall approach to recovery of the ESU is threefold. First, the recovery strategy aims to maintain recent improvements in the species' status through ongoing implementation of actions that have contributed to those improvements. Second, continued RM&E will be designed and implemented to confirm the driving factors for the recent improvements in abundance and productivity, and to evaluate other critical uncertainties regarding the status of the Lower Snake River population and the combined and relative effects of limiting factors and threats. Third, the recovery strategy calls for an adaptive management framework and using the information gained through RM&E to identify and implement additional actions needed to address the limiting factors and threats to the species and achieve recovery.

The recovery strategy also aims to be consistent with broad sense recovery goals to meet hatchery mitigation goals and tribal treaty and trust responsibilities related to harvest, and to maintain long-term opportunities to achieve goals that go beyond ESA-delisting. These long-term goals include reestablishing natural production of Snake River fall Chinook salmon above the Hells Canyon Complex.

The recovery strategy focuses on recovery for the extant Lower Snake River population, concurrent with scoping efforts for reintroduction above the Hells Canyon Complex. The recovery strategy takes a comprehensive, all-H,[4] and life-cycle approach to achieve the ESA recovery goal and 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. The Plan identifies both ongoing and potential additional actions to achieve ESU viability.

At the same time, the recovery strategy continues to explore opportunities for reintroduction of a second viable population above the Hells Canyon Complex. Many of the actions identified for the Lower Snake River 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 the Hells Canyon Complex. Successfully reestablishing significant natural production in the historically productive Middle Snake River mainstem, however, would require substantial effort to improve habitat conditions in the reach,

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[4] An approach to recovery in which actions are implemented to improve the status of a salmon or steelhead species by reducing adverse effects throughout the species life-cycle and in all threat categories. This is commonly referred to as an "all H" approach because the most common threat categories are hydropower, hatcheries, habitat, and harvest (as well as predation and other ecological interactions).

which are now severely degraded. In addition, providing safe and effective downstream passage for migrating smolts remains a substantial technical challenge. It would likely take many decades to restore a viable fall Chinook salmon population above the Hells Canyon Complex.

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 and conducts research and monitoring to improve the science and inform key uncertainties; and updates actions based on new knowledge (Figure ES-5). A life-cycle context is essential to this adaptive approach. The use of multi-stage, life-cycle models and other tools will improve our understanding of the combined and relative effects of limiting factors and recovery actions across the life cycle, and guide us in effectively molding our efforts to achieve recovery.

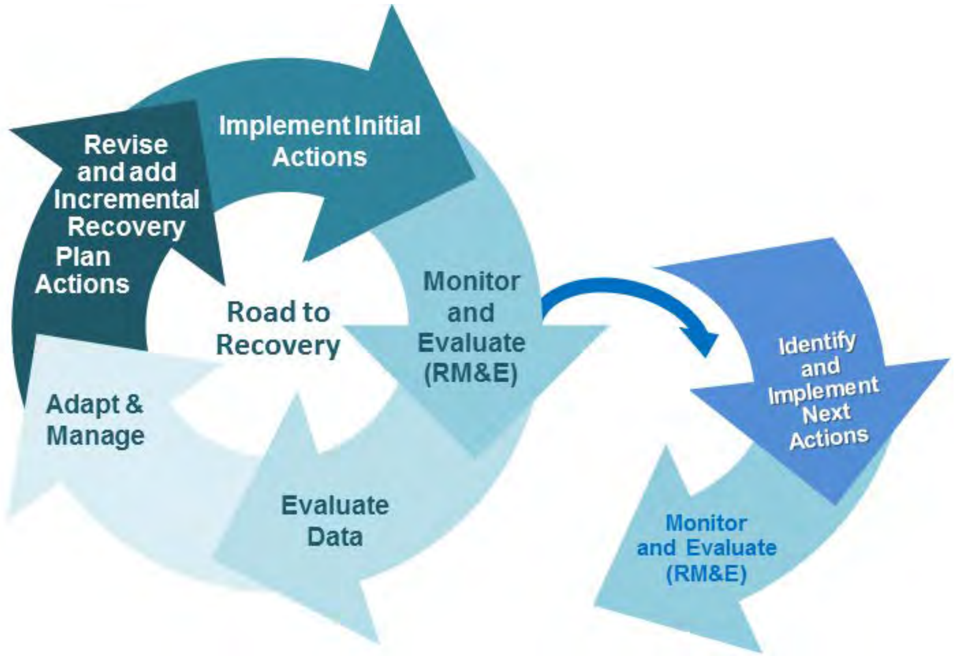

Figure ES-5. Adaptive Management Process Framework.

ESU Adaptive Management Framework

1. Establish recovery goals, objectives, and biological viability and threats criteria for delisting (Chapter 3).
2. Determine the species' current status and the gaps between the current status and biological viability criteria (Chapter 4).
3. Assess limiting factors and threats throughout the life cycle that are contributing to the gaps between current status and recovery objectives (Chapter 5).
4. Identify, prioritize and implement recovery strategies and management actions (Chapter 6) that target limiting factors and threats (Chapter 5).
5. Prioritize and implement RM&E to evaluate the status and trend of the species, the status and trend of limiting factors/threats, and the implementation and effectiveness of actions (Chapter 7).
6. Establish contingency actions to be implemented in event of a significant decline in species status or lack of continued progress toward recovery (Chapter 6).
7. Regularly review implementation progress, species response, and the results of research and monitoring and adjust management actions through an implementation structure that recognizes the interests of different stakeholders and the best opportunities to improve viability (Chapter 8).
8. Continue adaptive management in a continuous loop of action implementation, monitoring and evaluation, assessment of new information, and updated actions.

Site-Specific Management Actions

The site-specific management actions address the limiting factors and threats described in Chapter 5. The actions are organized under ten management strategies that describe broadly what needs to be accomplished to protect and restore Snake River fall Chinook salmon, while the site-specific management actions detail how to implement the strategies. Together, the management strategies and site-specific actions are designed to evaluate and improve viability across the life cycle. They address limiting factors in all threat categories: hydropower; mainstem, tributary, and estuary habitat; harvest; predation, prey base, competition, and other ecological interactions; hatcheries; and toxic pollutants. They also propose actions to mitigate and/or adapt to potential effects of climate change.

The ten management strategies (eight for the extant Lower Snake River population and two for the extirpated Middle Snake River population) are identified below. The site-specific actions to implement the strategies are discussed in Chapter 6. Table 6-1 in Chapter 6 shows the site-specific actions, limiting factors and viable salmonid parameters they address, their associated timing and costs, and potential implementing entities.

Management Strategies for the Lower Snake River Population

1. Develop tools, including life-cycle models, for evaluating and improving our understanding of the combined and relative effects of limiting factors and recovery actions across the life cycle.
2. Maintain and improve spawning, incubation, rearing, and migration conditions by continuing ongoing actions and implementing additional actions as appropriate in the lower mainstem Snake and Columbia Rivers and lower Snake tributaries.
3. Address loss of off-channel habitat in the estuarine floodplain and altered food web by continuing ongoing actions and implementing additional actions identified in the Estuary Module (Appendix F), FCRPS biological opinion (NMFS 2008b, 2010, and 2014c) and this recovery plan, as appropriate.

4. Continue ongoing actions and implement additional actions as appropriate to gain a better understanding of potential impacts from climate change during freshwater, estuarine, and ocean life stages, and to support Snake River fall Chinook salmon adaptation and resilience in response to climate change.
5. Implement harvest management programs in a manner that protects and restores Snake River fall Chinook salmon.
6. Continue ongoing actions and implement additional actions as appropriate to reduce predation and competition and address other ecological interactions that affect Snake River fall Chinook salmon.
7. Continue ongoing actions and implement additional actions that will improve ESU viability by reducing the impacts of hatchery-origin fish on natural-origin Snake River fall Chinook salmon.
8. Continue RM&E to gain a better understanding of potential negative impacts from exposure to toxic pollutants and develop actions to reduce potential effects of toxic contaminants on natural-origin Snake River fall Chinook salmon.

Management Strategies for the Extirpated Middle Snake River Population

1. Evaluate feasibility of providing adult and juvenile fish passage to and from spawning and rearing areas above the Hells Canyon Complex.
2. Restore habitat conditions that can support Snake River fall Chinook salmon spawning and rearing above the Hells Canyon Complex by encouraging local governments and stakeholders to implement actions to reduce nutrients and sediment to improve mainstem habitat.

For most of the management strategies, both ongoing and potential additional actions to achieve ESU viability are identified:

> *Ongoing management actions* have contributed to improvements seen in the extant population's status since listing. It is essential that these actions continue as presently designed unless new information demonstrates that changes are warranted to maintain or continue to improve the species status. As described in Chapter 7 and Appendix B, these actions should be paired with monitoring to help evaluate whether changes are needed.
>
> *Potential additional actions* identify additional actions in each sector across the life cycle that may be needed to achieve and maintain ESA recovery goals and objectives. The adaptive management framework will be used to evaluate these actions and identify the most effective opportunities to close the gap between the species' current status and the recovery objectives.

Prioritizing and Sequencing Actions

An important step in implementation of this recovery plan will be to further prioritize and sequence the site-specific actions and RM&E actions within an adaptive management framework. Prioritizing the actions will help in coordinating funding and implementation of the actions across existing programs.

Many of the ongoing management actions identified in the Plan are being implemented through other existing forums, each with their own distinct mandates. 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 effectiveness monitoring or other information demonstrates that changes are warranted to maintain or continue to improve the species status. We anticipate that these actions will be evaluated based on new RM&E results and that their implementation will continue or that the actions will be updated as appropriate and in consideration of recovery goals.

Potential additional actions are identified that may be needed to achieve ESA recovery. In general, the potential additional actions require additional evaluation to determine which provide the best and most timely opportunities for improving viability of the extant population and to determine appropriate prioritization. (Some have already been evaluated and implementation is proceeding, although the effects of these additional actions have not yet been realized or demonstrated in species status.)

The sequencing and rate at which additional actions are implemented are key variables that will influence how quickly the Snake River fall Chinook salmon ESU moves from its current status to achieving ESA recovery goals and objectives. The Plan suggests 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 (2018-2022), although additional evaluation and prioritization will be needed. 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.

Research, Monitoring, and Evaluation

Chapter 7 summarizes the key features of the research, monitoring, and evaluation (RM&E) plan for Snake River fall Chinook salmon. The RM&E plan plays an important role in the adaptive management framework, where actions are designed, prioritized, and implemented based on best available science. The RM&E plan builds on current monitoring efforts for the species.

Key objectives of the RM&E plan, described in Chapter 7, are to identify the driving factors for the recent improvements in species abundance and productivity, assess the status and trends in population viability, evaluate critical uncertainties, and monitor the effectiveness of management actions in addressing threats and bringing Snake River fall Chinook salmon to recovery. The data obtained through RM&E implementation will be used to assess and, where necessary, correct current strategies and actions. The full RM&E plan in Appendix B provides more detail.

The RM&E plan will continue to be updated during Plan implementation as new information emerges regarding potential new threats and critical uncertainties, and to better evaluate action effectiveness. A priority during Plan implementation will be to prioritize and sequence RM&E activities and strategically fill gaps in monitoring to inform critical uncertainties and gain needed assurance that the ESU meets the recovery objectives and can be self-sustaining in the wild.

Implementation

Ultimately, the recovery of Snake River fall Chinook salmon depends on the commitment and dedicated actions of the many entities and individuals who share responsibility for the species' future. Chapter 8 proposes a framework for achieving coordinated implementation of the Plan by building on and enhancing existing partnerships.

During implementation of this recovery plan, NMFS will rely, to a great extent, on the continued implementation of ongoing programs and management actions. 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.

Chapter 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 plan 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 additional actions to close the gap between current status and viability. It also depends on decisions regarding a viability scenario. Achieving Scenario A would most likely take many decades because it depends on establishing a viable population above the Hells Canyon Complex, in addition to improving the extant population to highly viable status. Scenarios B and C 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 5-year implementation period, specific actions and costs will be estimated for subsequent years. Table 6-1 provides the estimated costs for actions identified in this recovery plan, where information was sufficient to provide these estimates. Chapter 9 discusses cost estimates for the actions. It estimates the total cost of recovery actions during the 5-year period from 2018 to 2022 ($1.845 million), and the total cost of recovery actions for Snake River fall Chinook salmon over the next 25 years ($5.2 million).

1. Introduction

This is an Endangered Species Act (ESA) recovery plan (Plan or recovery plan) for Snake River fall-run Chinook salmon,[5] an evolutionarily significant unit (ESU) of Chinook salmon (*Oncorhynchus tshawytscha*).[6] NOAA's National Marine Fisheries Service (NMFS) listed Snake River fall Chinook salmon as a threatened species under the ESA on April 22, 1992 (57 FR 14653). NMFS revisited the listing in 2005 in light of its subsequent Hatchery Listing Policy, and determined that the species should remain listed as "threatened" (70 FR 37160). In 2010 and 2016, NMFS conducted 5-Year reviews of the status of the species, and based on the best scientific information available at that time, determined that the "threatened" classification remained appropriate (NMFS 2011a, 2016a). This recovery plan provides a road map to improve the status of the ESU to a point where it no longer requires ESA protection.

1.1 Historical Context ─ Declines, Listings, and Recent Improvements

At one time approximately half a million adult fall Chinook salmon traveled 300 miles up the Columbia River and into the Snake River basin each year (Connor et al. 2016). The fish spawned throughout the 600-mile reach of the mainstem Snake River from its confluence with the Columbia River upstream to Shoshone Falls, a 212-foot natural barrier to salmon migration near river mile (RM) 615, as well as in several major tributaries.

This once mighty fall Chinook salmon run began to decline in the late 1800s and continued to decline through the 1900s as a result of overfishing and other human activities ─ including the construction of major dams on the mainstem Snake River and tributaries that barred fish access to primary spawning and rearing habitats. Further dam construction and operations on the lower Snake and Columbia Rivers and tributaries also contributed to the run's decline. By the late 1980s, average runs of natural-origin fall Chinook salmon to the Snake River had dropped to approximately 100 adults annually. Only about 78 natural-origin adult fish returned in 1990 (Lavoy and Mendel 1996).

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 (57 FR 14653), and subsequent affirmations of the species' threatened status, on the results of status reviews conducted by its biological review teams and the Northwest Fisheries Science Center (70 FR 37160; Waples et al. 1991; Busby et al. 1999; Good et al. 2005; Ford et al. 2011; NWFSC 2015; NMFS 2011a, 2016a). These status reviews cite the loss of primary spawning and rearing areas upstream of Hells Canyon Dam (RM 247), which is the lowest of three dams that form the Hells Canyon Complex on the Snake River; the effects of lower Snake and Columbia River hydropower and

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[5] NMFS' official nomenclature for this ESU is Snake River Fall-run Chinook salmon. To be more consistent with the vernacular, hereafter we generally refer to the ESU as Snake River fall Chinook salmon.

[6] An ESU is a group of Pacific salmon that is discrete from other groups of the same species and that represents an important component of the evolutionary legacy of the species. Under the ESA, an ESU is treated as a species (56 FR 58612).

water storage projects associated with the Federal Columbia River Power System (FCRPS); the increase in non-local 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. The 1991 status review (Waples et al. 1991) and the most recent status reviews (ICTRT 2010; Ford et al. 2011; NWFSC 2015; NMFS 2011a, 2016a) have also noted concerns about the effects of hatchery operations and high proportions of hatchery-origin spawners on the productivity and diversity of natural-origin Snake River fall Chinook salmon.

While state, federal, and tribal co-managers had initiated some actions to improve the status of Snake River fall Chinook salmon before the ESA listing, the pace and magnitude of actions intended to reverse the species decline accelerated after the listing. The combined effect of management actions implemented by various entities have contributed to increasing Snake River fall Chinook salmon abundance and productivity. While historical spawning and rearing habitat upstream of the current site of Hells Canyon Dam remains inaccessible, the implemented actions have boosted adult and juvenile survival in the Snake River downstream of Hells Canyon Dam and through the hydropower system, reduced losses to harvest, lowered predation rates, improved habitats, reduced straying of out-of-ESU hatchery fish, and increased natural abundance of the remaining fall Chinook salmon population 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 biological status of the fish and the effectiveness of different actions.

Still, while these actions have brought us a long way toward recovering the ESU, more effort is needed to ensure that the ESU can be naturally self-sustaining. Uncertainty remains regarding the status of the species' productivity and diversity, whether recent high abundances can be maintained, and whether the ESU can be self-sustaining in the wild over the long term. This Plan identifies actions to inform these uncertainties and to improve the ESU as needed so that we are confident of its ability to be self-sustaining in the wild into the future.

The ESU contains one extant population that includes all natural-origin fall Chinook salmon originating from the lower Snake River below Hells Canyon Dam and from the Tucannon River, Grande Ronde River, Imnaha River, Salmon River, and Clearwater River subbasins (Figure 1-1). The spawning and rearing habitat associated with this population represents approximately 20 percent of the habitat that was historically available to Snake River fall Chinook salmon (Dauble et al. 2003). The area upstream of the three-dam Hells Canyon Complex, which once supported the majority of all Snake River fall Chinook salmon production, remains inaccessible. The 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 (64 FR 50406).

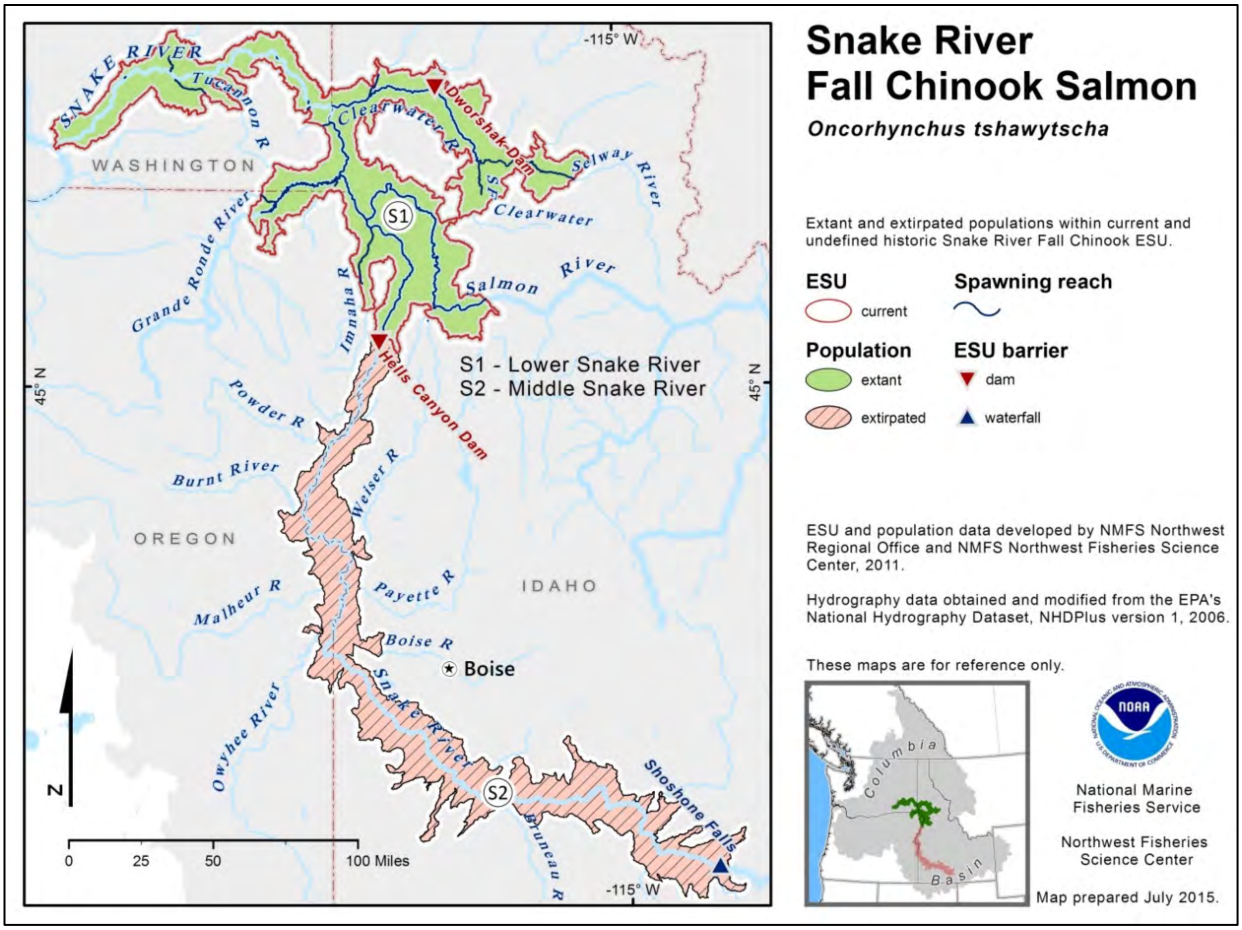

Figure 1-1. Snake River fall Chinook salmon current and historical spawning range.

1.2 Purpose and Contents of Plan

The goal of ESA recovery, and the goal of this Plan, is to improve the status of the Snake River fall Chinook salmon ESU and the ecosystems upon which it depends to the point that the ESU is self-sustaining in the wild and no longer needs ESA protection.[7] The Plan provides a roadmap for ESA recovery of the ESU that builds on past and current efforts to recover the species. It lays out where we need to go and defines a path to get there. It includes strategies and actions that address the factors that are limiting the species' recovery and identifies research, monitoring, and evaluation needed to address key uncertainties and hone strategies and actions to be most effective, within an adaptive management framework.

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[7] A self-sustaining, viable ESU depends on the status of its component populations and major population groups 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 artificial propagation measures to achieve its viable characteristics (see Chapter 3).

The recovery plan is based on the best available science and contains the following elements, consistent with ESA requirements (see Section 1.3 below):

- Description of the context for and process of plan development and how NMFS intends to use the Plan (Chapter 1);
- Background on Snake River fall Chinook salmon life history, historical and current distribution, recent history and programs implemented since listing to recover the ESU; and the relationship of other programs to this recovery plan (Chapter 2);
- Recovery goals, objectives, and delisting criteria for the ESU (Chapter 3);
- Assessment of the current status of the ESU and gaps between current and target status (Chapter 4);
- Summary of limiting factors and threats and how they are affecting the ESU's status (Chapter 5);
- Strategy and site-specific management actions for recovery of the ESU (Chapter 6);
- Research, monitoring, and evaluation needs for the ESU (Chapter 7);
- Framework for implementation of the Plan, including adaptive management (Chapter 8); and
- Time and cost estimates to achieve recovery (Chapter 9).

The Plan also includes several appendices that provide additional background information on specific topics:

- 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 (USFWS 2015).

In addition, the Plan includes four "modules" as Appendices D through G. NMFS developed these modules to support recovery planning. The modules provide detailed information that applies to all Snake River ESA-listed salmon and steelhead species (see Section 1.4.2).

1.3 Endangered Species Act 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 as recovery plans. Recovery plans identify actions needed to restore threatened and endangered species to the point where they are again self-sustaining in the wild and no longer need the protection of the ESA.

ESA section 4(a)(1) lists five factors for determining whether a species is endangered or threatened. These five factors must be addressed in an ESA recovery plan:

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; and
E. Other natural or human-made factors affecting its continued existence.

These listing factors, or threats, need to be ameliorated to the extent that the species may be removed from the list and the removal is not likely to result in re-emergence of the threats and a need to re-list the species. Recovery plans identify actions to address threats to a species caused by these factors.

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

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) of the ESA requires monitoring of the species for a period of not less than five years to ensure that it retains its recovered status.

1.4 Plan Development

This recovery plan is the product of a process initiated by NMFS and strengthened through regional and local participation. The goal was to produce a recovery plan that would meet ESA requirements for recovery plans as well as broader needs. Throughout the recovery planning process, NMFS received input from the states of Washington, Oregon, and Idaho, as well as from other federal agencies, tribal governments (in particular, the Nez Perce Tribe), representatives of industry and environmental groups, other stakeholders, and the public.

NMFS developed this recovery plan by synthesizing information on Snake River fall Chinook salmon status, limiting factors and threats, and ongoing and prospective actions intended to improve the status of the ESU. The Plan incorporates information from the Interior Columbia Technical Recovery Team (discussed in Section 1.4.1) and related recovery plan modules (discussed in Section 1.4.2), as well as additional analyses by technical experts. For example, the recovery plan draws upon the resources of NOAA's Northwest Fisheries Science Center (NWFSC) and on research conducted by the U.S. Fish and Wildlife Service, Idaho Power Company, and other federal, state, and tribal agencies.

NMFS believes that ESA recovery plans for salmon should be based on federal, state, tribal, local, and private conservation efforts already underway throughout the region, and that successful implementation of recovery plans depends on support by those whose activities directly affect the species and whose actions will be most affected by recovery efforts. Accordingly, this Plan incorporates information, direction, and recent findings from other related planning processes, including the FCRPS biological opinion, Hatchery and Genetics Management Plans, and the relicensing process for the Hells Canyon Complex. The draft Plan went through multiple reviews and revisions in response to comments from both technical reviewers and the public.

1.4.1 Recovery Domains and Technical Recovery Teams

The Snake River fall Chinook salmon ESU is one of 28 evolutionarily significant units (ESUs) and distinct population segments (DPSs) of Pacific salmon and steelhead listed under the ESA as threatened or endangered throughout the NMFS West Coast Region (the states of California, Oregon, Washington, and Idaho). For the purpose of recovery planning for these species, NMFS West Coast Region identified geographically based "recovery domains." Figure 1-2 shows these domains in Oregon, Washington, and Idaho: Puget Sound, Willamette/Lower Columbia, Oregon Coast, Southern Oregon/Northern California, and the Interior Columbia. The Interior Columbia domain was divided into three sub-domains: the Upper Columbia River, Middle Columbia River, and Snake River The spawning and rearing range of the Snake River fall Chinook salmon ESU is in the Snake River sub-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.[8]

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[8] These species are addressed in separate recovery plans. Snake River sockeye salmon are addressed in the *ESA Recovery Plan for Snake River Sockeye Salmon (Oncorhynchus nerka)* (NMFS 2015) and spring/summer Chinook and steelhead are addressed in the *ESA Recovery Plan for Snake River Spring/Summer Chinook Salmon (Oncorhynchus tshawytscha) & Snake River Steelhead (Oncorhynchus mykiss)* (NMFS 2017b).

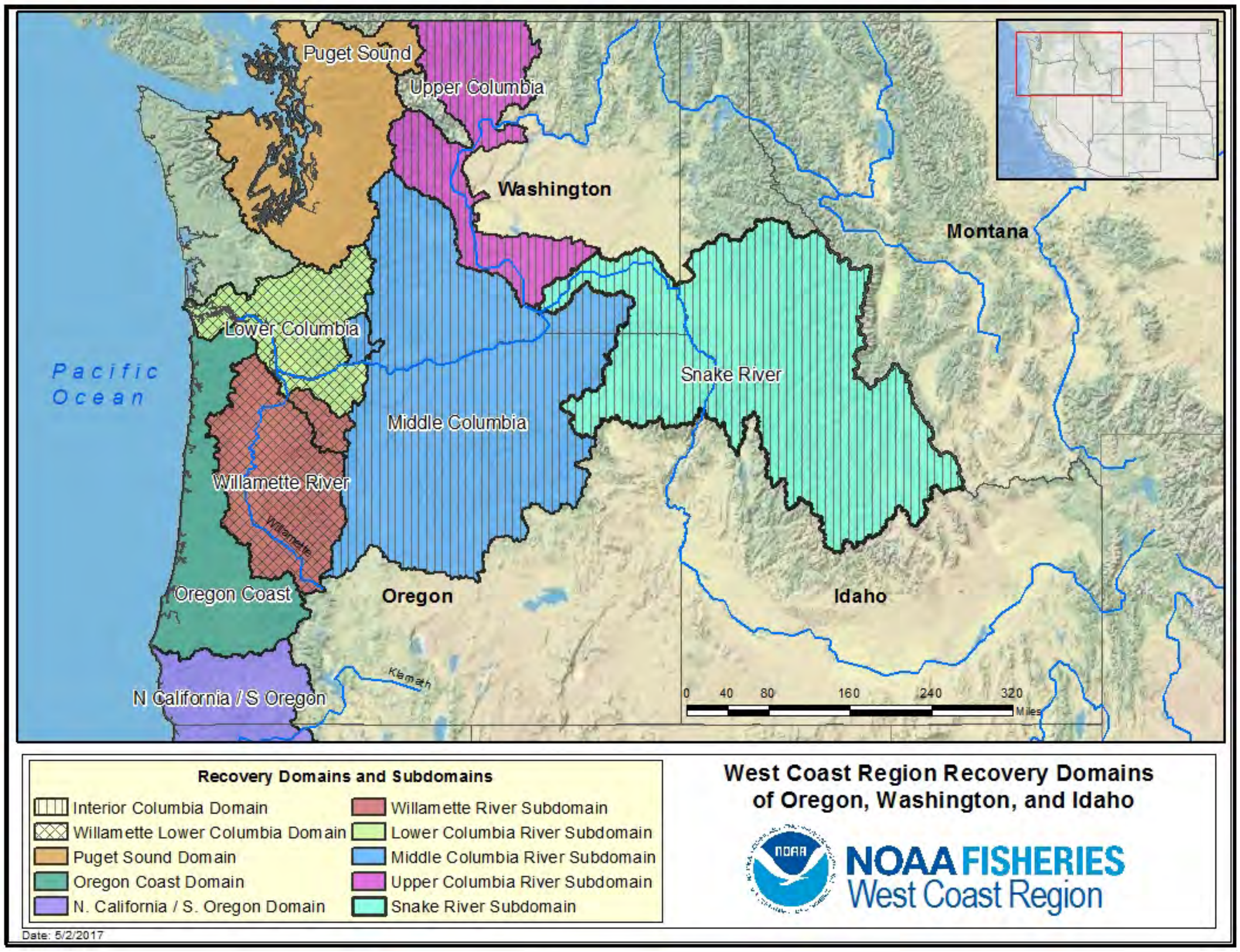

Figure 1-2. NMFS West Coast Region recovery domains of Oregon, Washignton, and Idaho.

Interior Columbia Technical Recovery Team

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, state and tribal entities, and academic institutions.[9] NMFS directed each technical recovery team to define the historical population structure of each ESU or DPS, 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 (in addition to species in the Middle Columbia and Upper Columbia River recovery domains).

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[9] 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).

The ICTRT and NMFS' other technical recovery teams used a common set of biological principles in developing their recommendations for species and population viability criteria. The biological principles are described in the NMFS technical memorandum "*Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units*" (McElhany et al. 2000). McElhany et al. describe viable salmonid populations (VSP) in terms of four parameters: abundance, population productivity or growth rate, population spatial structure, and life-history and genetic diversity. Each 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.

NMFS used the ICTRT's recommendations as the basis for the ESA recovery objectives and biological delisting criteria in this recovery plan. As the agency with ESA jurisdiction for salmon and steelhead, NMFS makes final determinations of ESA delisting criteria.

1.4.2 Recovery Planning Modules

NMFS developed several additional documents to address regional issues and assist in recovery planning for ESA-listed salmon and steelhead in the Columbia River basin. Because these documents provide consistent information applicable to multiple species and are incorporated into specific recovery plans as appropriate, NMFS refers to them as "modules." This Plan incorporates four modules as appendices: (1) *Module for the Ocean Environment* (*hereafter* Ocean Module) (Appendix D [Fresh et al. 2014]); (2) *2017 Supplemental Recovery Plan Module for Snake River Salmon and Steelhead Mainstem Columbia River Hydropower Projects* (*hereafter* Hydro Module) (Appendix E [NMFS 2017a]); (3) *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (*hereafter* Estuary Module) (Appendix F [NMFS 2011b]); and (4) *Snake River Harvest Module* (*hereafter* Harvest Module) (Appendix G [NMFS 2014b]). These modules provide information that applies to Snake River fall Chinook salmon, as well as to other Snake and Columbia River basin ESA-listed salmon and steelhead. The modules will be updated periodically to reflect new data.

Ocean Module

The Ocean Module (*Module for the Ocean Environment*, Fresh et al. 2014) 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 included in this Plan as Appendix D and is also 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.

Hydro Module

The 2017 Hydro Module (*2017 Supplemental Recovery Plan Module for Snake River Salmon and Steelhead: Mainstem Columbia River Hydropower Projects*, NMFS 2017a) supplements the 2008 *Hydro Module for Mainstem Columbia River Hydropower Projects* (NMFS 2008a) and the 2014 *Supplemental Recovery Plan Module for Snake River Salmon and Steelhead: Mainstem Columbia River Hydropower Projects* (NMFS 2014a). The 2008 Hydro Module (NMFS 2008a) overviewed limiting factors, summarized current recovery strategies, and provided survival rates associated with the Federal Columbia River Power System (FCRPS). The FCRPS, which is discussed in Section 2.8.1, consists of Columbia and Snake River hydropower and water storage projects that are operated as a coordinated system for power production, flood control, and other purposes. The 2017 Hydro Module (NMFS 2017a) provides new information relevant to the Snake River species, including the most recent survival estimates and discussion of latent and delayed mortality. The 2017 Hydro Module (NMFS 2017a) is included in this Plan as Appendix E and is also available on the NMFS West Coast Region web site: http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/interior_columbia/snake/2017_hydro_supplemental_recovery_plan_module.pdf.

Estuary Module

The Estuary Module (*Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead*, NMFS 2011b) discusses limiting factors and threats that affect all the salmonid populations in the mainstem Columbia River estuary and plume, and presents actions to address those 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 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 module is included in this Plan as Appendix F and is also available on the NMFS West Coast Region web site: http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/estuary-mod.pdf.

Harvest Module

The Harvest Module (*Snake River Harvest Module*, NMFS 2014b) describes fishery policies, programs, and actions affecting ESA-listed Snake River salmon and steelhead, including Snake River fall Chinook salmon. The Harvest Module (NMFS 2014b) is included in this Plan as Appendix G and is also 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, reflecting thousands of years of use of this resource for subsistence, religious and/cultural ceremonies, and commerce. Many Northwest Indian tribes have legally enforceable treaties reserving their right to fish in usual and accustomed places, including within the geographic areas covered by this recovery plan.

Treaty tribes within the range of Snake River fall Chinook salmon in the Columbia and Snake River basins include the Nez Perce Tribe, the Confederated Tribes of the Umatilla Indian Reservation (the Walla Walla, Cayuse, and Umatilla tribes), the Shoshone-Paiute Tribes, the Shoshone-Bannock Tribes, the Confederated Tribes and Bands of the Yakama Nation, and the Confederated Tribes of the Warm Springs Reservation of Oregon.

The U.S. District Court for the District of Oregon in the case of *United States v. Oregon* (*U.S. v. Oregon*) (Case No. 68-513, U.S. District Court, Oregon) affirmed language in the "Stevens treaties,"[10] i.e., "the right of taking fish at all usual and accustomed grounds and stations, in common with all citizens of the Territory" (Article III, Treaty with the Yakama, 1855; 12 Stat., 951), and later reserved for the tribal parties to this case up to 50 percent of the harvestable surplus of fish passing through their usual and accustomed fishing areas.

Tribal parties to *U.S. v. Oregon* case include the Shoshone Bannock Tribes, the Confederated Tribes of the Warm Springs Reservation of Oregon, the Confederated Tribes of the Umatilla Indian Reservation, the Nez Perce Tribe, and the Confederated Tribes and Bands of the Yakama Nation, often referred to as "the Columbia River Treaty Tribes." Also party to the case are the states of Oregon, Washington, and Idaho, and the United States. All parties have developed the *U.S. v. Oregon* Management Agreement to provide a framework within which they may exercise their sovereignty in a coordinated manner to protect, rebuild, and enhance Columbia River fish runs while providing harvest for both treaty Indian and non-treaty fisheries.

The Stevens Treaties include the Treaty with the Yakama Tribe, the Umatilla Tribe, the Nez Perce Tribe, and the Tribes of Middle Oregon. The Shoshone and Bannock Tribes entered into peace treaties in 1863 and 1868, known today as the Fort Bridger Treaty. The Fort Bridger Treaty defined a reservation for the Shoshone and Bannock Tribes, and confirmed "hunting" rights as follows: "they [Indians] shall have the right to hunt on the unoccupied lands of the United States so long as game may be found thereon" (Article 4, 15 Stat., 673). In 1972, in *State of Idaho v. Tinno,* the Idaho Supreme Court ruled that the Shoshone word for "hunt" also included "to fish."[11]

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[10] Isaac Stevens, governor of Washington Territory from 1853 to 1857, presided at treaty councils with Indians west of the Cascade Mountains between December 25, 1854, and February 26, 1855, and with tribes east of the mountains between May 21 and October 17, 1855.

[11] State of Idaho v Tinno, 94 Idaho (1972).

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.

Other tribes in the Columbia River basin do not have treaties that were ratified by the U.S. government. Although these tribes do not have reserved treaty rights, they do have a trust relationship with the federal government and an interest in salmon and steelhead management, which includes harvest and hatchery production. The trust relationship between federal agencies and the tribes includes a "trust responsibility," which recognizes the federal duty to protect tribal lands, resources, and the native way of life. Each federal agency is bound by this trust responsibility and must respond to its independent obligations while carrying out statutory programs that affect the tribes (Wood 1995). The trust responsibility stands independent of treaties for the benefit of all tribes, treaty and non-treaty alike. For example, in the Upper and Middle Snake River basins, the Burns Paiute Tribe, Shoshone Paiute Tribes of the Duck Valley Reservation, and the Fort McDermitt Paiute-Shoshone Tribe have reservations that were created by Executive Order. These tribes have common vested interests to protect rights reserved through the United States Constitution, federal unratified treaties (e.g., the Fort Boise Treaty of 1864 and the 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 may not be limited solely to hunting, fishing, gathering, and subsistence uses. Federal agencies must take these, and other tribal interests, into consideration when developing salmon recovery strategies.

Restoring and sustaining a sufficient abundance of salmon and steelhead for harvest while achieving viable escapements is important in fulfilling tribal fishing needs. NMFS is committed to meeting federal treaty and trust responsibilities to the tribes. It is our policy that the recovery of salmon and steelhead 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.[12]

Thus, it is appropriate for recovery plans to acknowledge treaty-reserved rights, trust responsibilities, 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 partnership with the Pacific Northwest tribes is critically important to the region's future success in recovery of listed Pacific salmon.

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[12] Garcia, Terry D., 1998. U.S. Department of Commerce, Office of the Assistant Secretary for Oceans and Atmosphere. Letter to Ted Strong, Executive Director, Columbia River Inter-Tribal Fish Commission, July 21.

1.6 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, and with local stakeholders. Recovery plans are guidance, not regulatory, documents and their implementation is voluntary, except when they incorporate actions required as part of a regulatory process, such as under ESA sections 7, 10, and 4(d). Recovery plans provide the following:

- A context for regulatory decisions;
- A guide for decision making by federal, state, tribal, and local jurisdictions;
- A basis and criteria for evaluating species status and delisting decisions;
- A structure to organize, prioritize, and sequence recovery actions;
- A structure to organize, prioritize, and sequence research, monitoring, and evaluation efforts; and
- A framework for adaptive management that uses the results of research, monitoring, and evaluation to update priority actions.

NMFS encourages federal agencies and non-federal entities to use recovery plans as they make decisions and 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 research, monitoring, and evaluation 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 as a source of context for evaluating the effects of actions on listed species, expectations, and goals. Recovery plans and recovery plan actions do not pre-determine the outcomes of any regulatory reviews or actions.

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2. Background

This chapter provides important context for understanding the history of the Snake River fall Chinook salmon ESU and the remaining steps to its recovery. It describes the geographic setting of the ESU and changes in the species' habitats and distribution over the years. It also discusses key concepts in salmonid biology, i.e., the basic biological hierarchical population structure of the species and the parameters that influence its viability, and describes the species' life-history characteristics. In addition, the chapter discusses biological criteria that the ICTRT recommended for use in assessing species and population viability, and the critical habitat that has been designated for the species. It also identifies the programs, processes, and actions that have been initiated since listing to improve the status of the ESU.

2.1 Geographic Setting

The Snake River is the 13th longest river in the United States and the largest and longest tributary of the Columbia River. From its headwaters in Yellowstone National Park in western Wyoming, the river extends over 1,000 miles and drops nearly 7,000 feet in elevation before joining the Columbia River near Pasco, Washington, approximately 319 miles from the Pacific Ocean. The river system drains approximately 87 percent of the state of Idaho, over 18 percent of the state of Washington, and about 17 percent of the state of Oregon.

Historically, Snake River fall Chinook salmon spawned in the mainstem Snake River from its confluence with the Columbia River upstream to Shoshone Falls, a 212-foot natural barrier to salmon migration near RM 615, and in the lower reaches of several major tributaries to the Snake River (Figure 2-1).

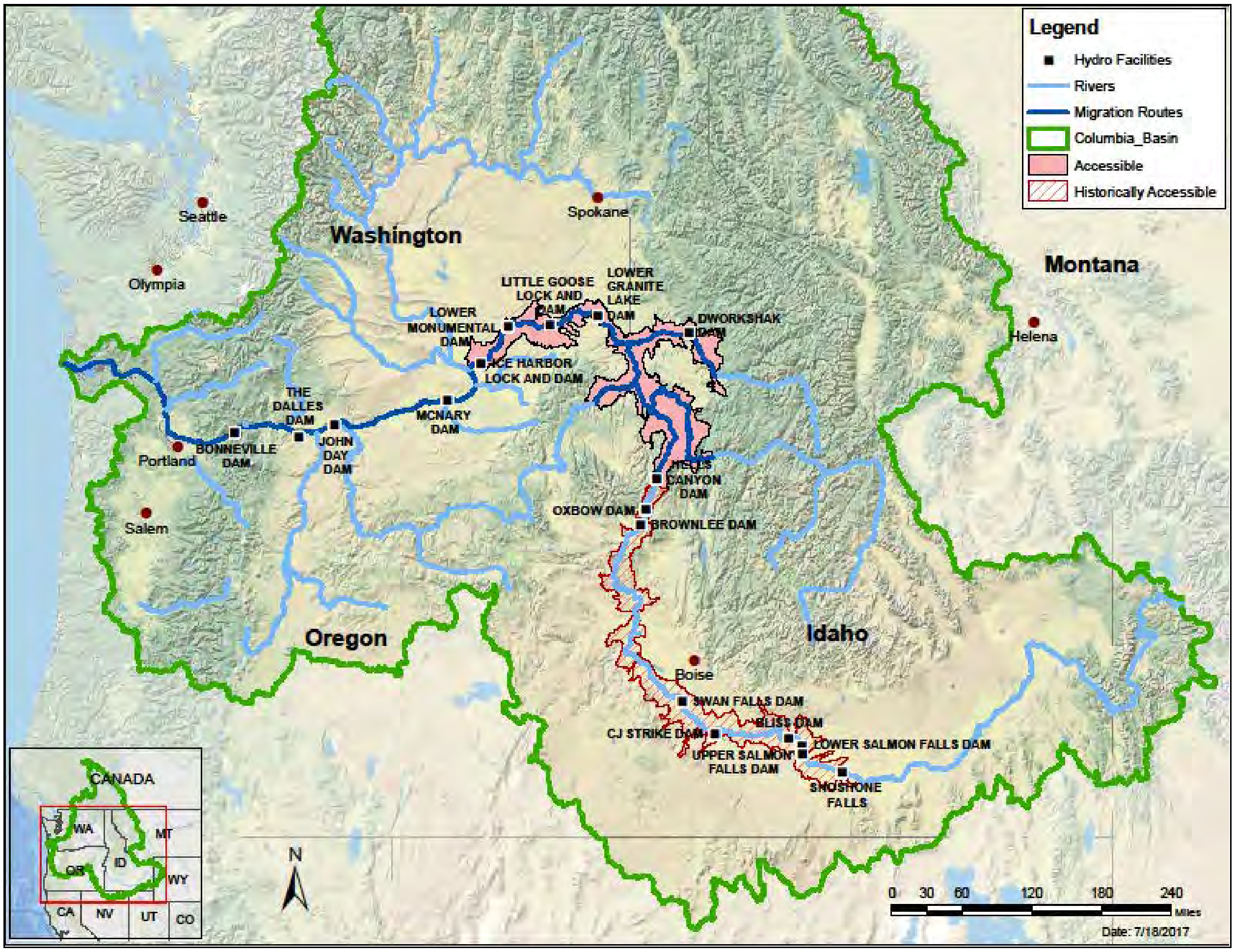

Figure 2-1. Historical distribution of Snake River fall Chinook salmon (and dams on the Snake and Columbia Rivers thgroughout currently and historically accessible habitat).

The Snake River once flowed freely from its headwaters in western Wyoming into southeastern Idaho and across the Snake River plain. There, an extensive complex of springs from the Eastern Snake River Plain Aquifer supplemented flows in the mainstem Snake River. These springs once contributed about 4,000 cubic feet per second of flow at an average temperature of approximately 60 °F (15.5 °C) to the mainstem Snake River. The springs contributed to the Snake River over a distance of approximately 86 miles, but their influence was most pronounced from downstream of Shoshone Falls (RM 615) to Bancroft Springs (RM 553) (Connor et al. 2016).[13] Within this area, a particularly large spring complex, known as Thousand Springs (RM 584), was a major contributor of spring water to the mainstem Snake River (Figure 2-2). Flow inputs from the aquifer reduced temperatures during spawning and ameliorated winter and early spring low temperatures in the upper sections of the Middle Snake River, providing prime spawning, incubation, and rearing conditions for fall Chinook salmon. While the spring-fed influences were the most beneficial in the upper sections of the Middle Snake River mainstem,

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[13] This inflow would have constituted an estimated 31 percent of the flow volume in the Middle Snake River mainstem downstream to Bancroft Springs after late October (Connor et al. 2016). The aquifer currently contributes about 2,500 cubic feet per second of flow to the river (IDWR 2013; Connor et al. 2016).

positive impacts extended downstream through the reach near the present-day town of Marsing (RM 425 [west of Boise]) and benefitted fall Chinook salmon production in that reach until it was blocked by completion of the three-dam Hells Canyon Complex in the late 1960s (Connor et al. 2016).

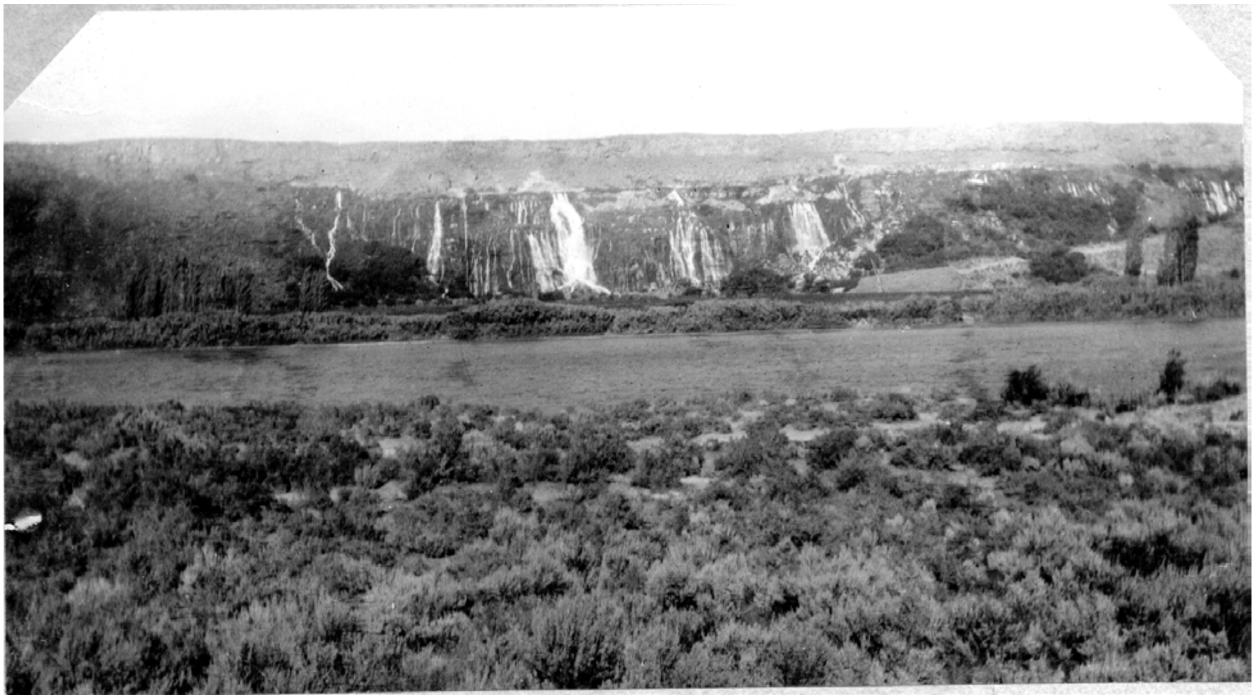

Figure 2-2. The area known as Thousand Springs (RM 584) contributes spring water from the Eastern Snake River Plain Aquifer to the Middle Snake River (I.C. Russell, United States Geological Survey, 1902).

Nine major tributaries that were historically accessible to anadromous fish feed into this reach of the 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 (RM 247.7), the Snake River turns north and soon flows into Hells Canyon, a deep gorge extending about 79 miles in length. 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 Hells Canyon, the Snake River is steep and swift, dropping 9.5 feet/mile, with numerous large rapids, shallow riffles, and deep pools, surrounded at the upstream end by nearly vertical cliff faces. Today this reach of Hells Canyon contains the three-dam Hells Canyon Complex, which provides electricity for the state of Idaho but blocks all salmonid migration to historical upstream habitats. Downstream of Hells Canyon Dam (the lowermost dam in the Hells Canyon Complex) 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. The canyon separates the states of Idaho, Oregon, and Washington. 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 Salmon River, one of the Snake River’s largest tributaries, joins the river in this Hells Canyon reach.

After leaving Hells Canyon, the river channel becomes less incised and broader near the mouth of the Grande Ronde River (RM 169). The Snake River then flows through the rolling Palouse Hills of eastern Washington before joining the Columbia River. In addition to the Salmon and Grande Ronde Rivers, several other tributaries flow into the lower Snake River, including the Imnaha, Clearwater, and Tucannon Rivers. Today, the lower end of the Snake River is transformed into a series of reservoirs for four lower Snake River dams.

Air temperatures and precipitation vary widely across the Snake River basin, usually depending on elevation. The mountainous areas generally experience cooler and wetter climates, while the lower elevations are warmer and drier. At lower elevations, including Hells Canyon, the climate is hot and dry in the summer, with relatively mild winters. Seasonal temperatures range from about 23 °F (-5 °C) in January to about 95 °F (35 °C) in July. At elevations above 3,280 feet, mean temperatures range from 32 °F (0 °C) in January to between 82 °F (27.8 °C) and 91 °F (32.8°F) 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 mainstem Snake River and tributaries course through a mosaic of state, local, tribal, and federal jurisdictions. The states of Idaho, Oregon, and Washington manage natural resources in river areas that fall within their state borders. The Bureau of Land Management (BLM) and U.S. Forest Service (USFS) manage most of the public land in Hells Canyon and in other parts of the drainage, including parts of the Wallowa-Whitman National Forest in Oregon and the Payette and Nez Perce National Forests in Idaho. Other state and federal natural resource agencies with management authorities in the area include the Idaho Department of Lands, NMFS, Bureau of Indian Affairs, Idaho Department of Fish and Game (IDFG), Oregon Department of Fish and Wildlife (ODFW), Washington Department of Fish and Wildlife (WDFW), and U.S. Fish and Wildlife Service. Several special management areas also exist in the Hells Canyon area and are directly administered by the U.S. Forest Service. 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 and Current Fall Chinook Salmon Distribution and Production

2.2.1 Historical Fall Chinook Salmon Distribution and Production

This section describes historical fall Chinook salmon production in the Middle Snake River and the Lower Snake River, two contiguous areas that historically provided different types of habitat conditions. The Middle Snake River stretches from Auger Falls (RM 607, 8 miles below Shoshone Falls) downstream to near the Burnt River mouth at the present site of Huntington, Oregon (approximately RM 327). The Lower Snake River extends from the Powder River (RM 248) to the Snake River's confluence with the Columbia River.[14]

Middle Snake River

Historically, most Snake River fall Chinook salmon spawned and reared in areas of the Middle Snake River upstream of Hells Canyon (NMFS 2006), where relatively warm, spring-fed water released from the Eastern Snake River Plain Aquifer created prime habitat conditions. According to Evermann (1896), an ichthyologist with the U.S. Fish Commission, "the spawning grounds of chinook salmon in Snake River between Huntington and Auger Falls have been, and perhaps still are, the most important in Idaho." Historical reports also describe the reach near the town of Marsing, Idaho (RM 425) as highly productive in terms of redd capacity and juvenile rearing capacity (Zimmer 1950; Dauble et al. 2003). The furthest downstream point of aquifer discharge was Bancroft Springs (RM 552.8), and the influence of the aquifer ─ and level of fall Chinook salmon use ─ diminished between the mouths of the Boise and Burnt Rivers (Connor et al. 2016).

The reports by Evermann (1896) suggest that differences in gradient and channel morphology in the Middle Snake River downstream of Auger Falls influenced the level of spawning activity. The area between Auger Falls and Lower Salmon Falls was largely characterized as low gradient and relatively shallow, with abundant potential spawning and rearing habitat. Evermann (1896) described Millet Island, which sits within this reach, as "the largest and most important salmon spawning ground of which we know in the Snake River" (Figure 2-3). Below Lower Salmon Falls, the river flowed through a canyon with a steep gradient. The channel morphology then changed in the vicinity of King Hill, Idaho, near Glenns Ferry. There the river gradient decreased and the channel became braided, with many islands surrounded by gravel beds, continuing downstream to the mouth of the Burnt River. These conditions likely provided good spawning and rearing habitat for fall Chinook salmon (Connor et al. 2016). This is consistent with findings by Dauble et al. (2003) that "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

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[14] The Upper Salmon River area lies above Shoshone Falls, a natural barrier to all anadromous fish upstream passage.

spawning occurred downstream of the Burnt River mouth, where warm water contributions from the aquifer dissipated (Connor et al. 2016).

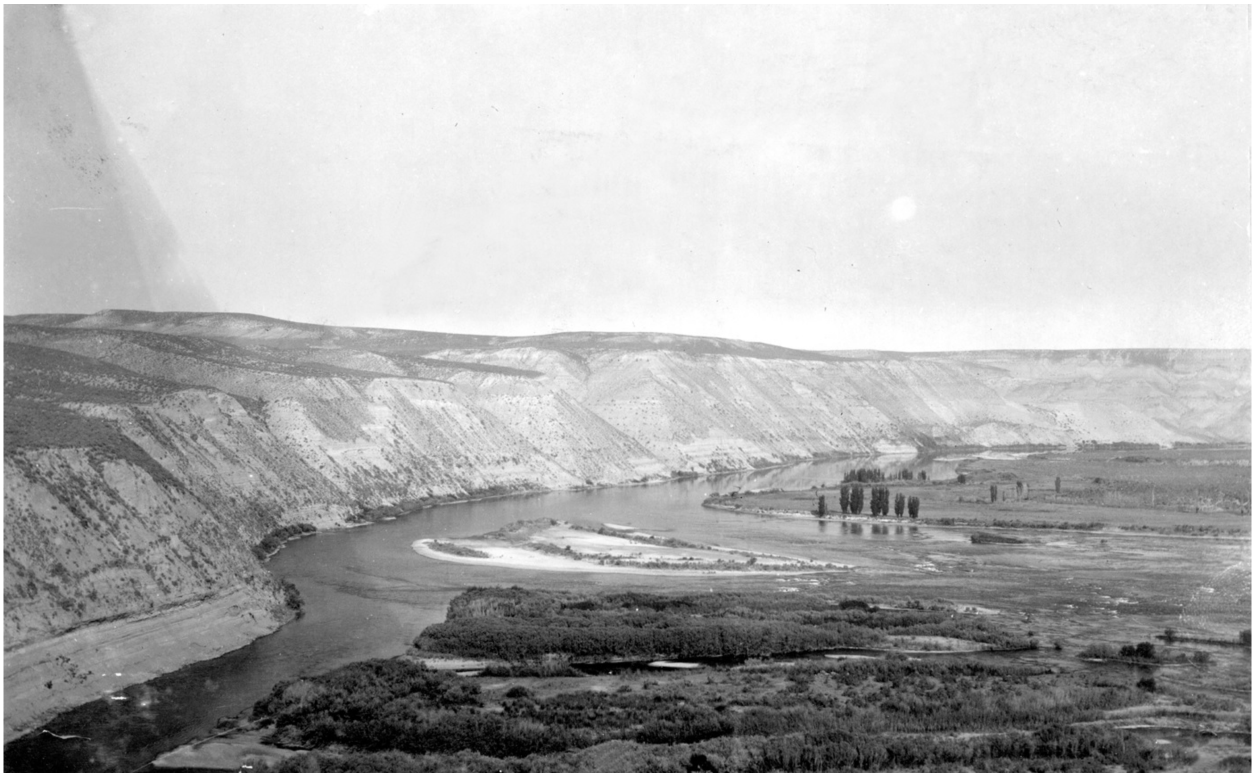

Figure 2-3. Millet Island along the Middle Snake River. (Photo Credit: I.C. Russel, United States Geological Survey, 1902, from Connor et al. 2016.)

Fall Chinook salmon spawners in the Middle Snake River targeted two expanses of river, identified as the Salmon Falls and Glenns Ferry spawning areas. The Salmon Falls area, which supported the primary production, extended downstream from Auger Falls to Lower Salmon Falls, with production centered on Millet Island (Figure 2-4). The Glenns Ferry spawning area extended downstream from Kings Hill, above Glenns Ferry, to the mouth of the Burnt River. The upper reaches of the Glenns Ferry spawning area were highly productive, but the lower reach was less productive because the influence of the aquifer diminished (Connor et al. 2016).

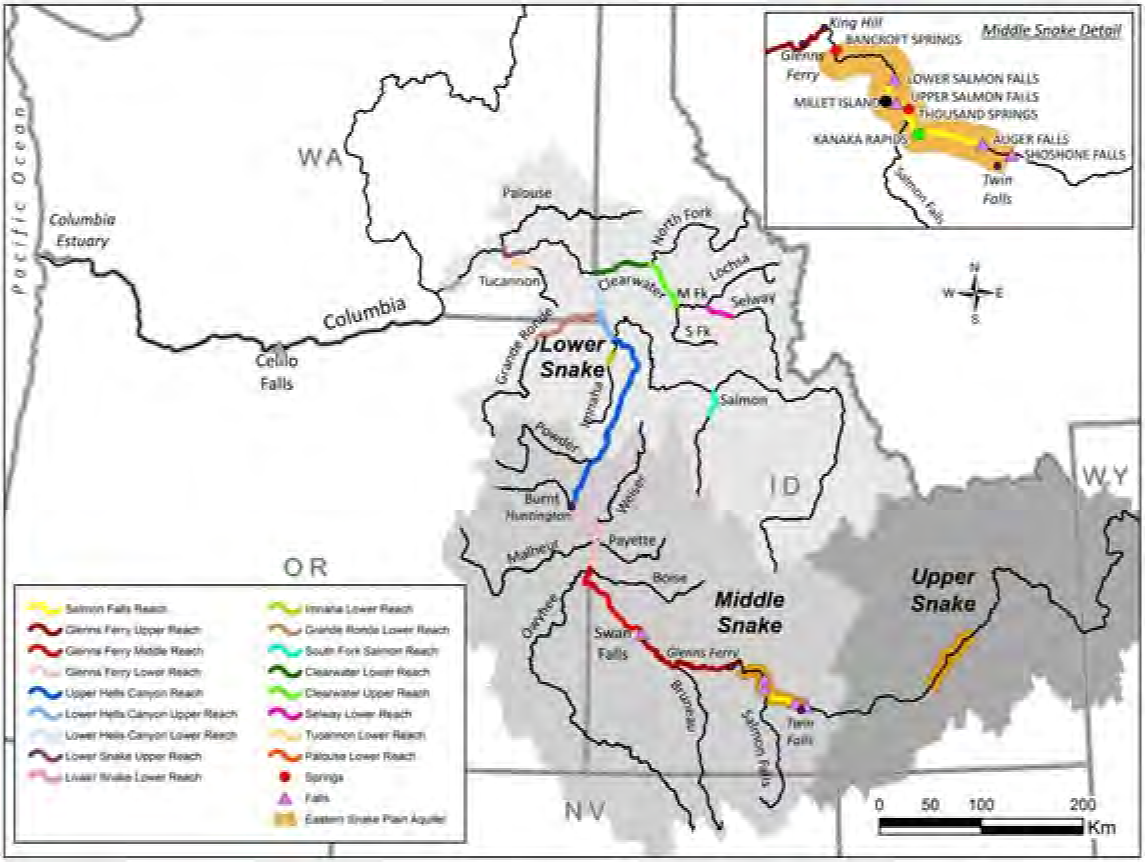

Figure 2-4. Historically important spawning areas for Snake River fall Chinook salmon (Connor et al. 2016). (The Marsing reach, not shown on this map, was within the Glenns Ferry middle reach. It was the primary spawning reach after construction of Swan Falls Dam and before construction of the Hells Canyon Complex.)

The nine major tributaries to the Middle Snake River ─ Salmon Falls Creek and the Owyhee, Bruneau, Boise, Payette, Weiser, Malheur, Burnt, and Powder Rivers ─ were also accessible to fall Chinook salmon and other anadromous fish and it is likely that their lower mainstem reaches supported some production. Most fall Chinook salmon, however, spawned in the mainstem Snake River.

Lower Snake River

The Middle Snake River transitioned into the Lower Snake River downstream of the Powder River (RM 247.7). This reach of the mainstem Snake River contains the rugged Hells Canyon area, which probably supported minimal fall Chinook salmon spawning activity historically because of its inhospitable features. Dauble and Geist (2000) found that the confined river channel, steep hydraulic gradient, and limited alluvial features within Hells Canyon reduced the quantity of spawning habitat. In addition, lacking the influence of the aquifer found in the Middle Snake River, the Hells Canyon reach froze heavily during the fall Chinook salmon egg incubation period in some years (Dauble and Geist 2000; Connor et al. 2016). Channel elevation in the Lower Snake River ranges from 1,130 feet above sea level to 5,760 feet above sea level in Hells Canyon (Dauble and Geist 2000).

Downstream of the Grande Ronde River mouth, the Snake River channel broadened and the geomorphologic setting became more conducive to fall Chinook salmon production (Figure 2-5) (Connor et al. 2016). However, the Lower Snake River basin's arid high desert environment and climate still hindered fall Chinook salmon production. 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. 2016).

Figure 2-5. Landscape of Lower Snake River near the Grande Ronde River mouth. (Photo Credit: Idaho Historical Society digital image P1997.23.213 from Connor et al. 2016.)

Historical accounts describe fall Chinook salmon in the lower 169 miles 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). Although spawning habitat in this stretch of the river was described as extensive (Parkhurst 1950; Fulton 1968), confirmed accounts of spawning are lacking (Connor et al. 2016). Accounts of fall Chinook salmon use of Lower Snake River tributaries are also limited. Schoning (1947) reported that no fall Chinook salmon were ever found in the Salmon River or its tributaries. That account was later challenged by Burns (1992), who compiled anecdotal evidence for fall Chinook salmon spawning in the lower-most portion of the South Fork Salmon River during 1899, the 1930s, and as recently as 1982 (Connor et al. 2016).

Some anecdotal information suggests that the Clearwater River historically may have supported substantial numbers of Chinook salmon. 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, a migration timing similar to the current adult fall Chinook salmon migration.

Overall, however, the Lower Snake River supported far less fall Chinook salmon activity historically than the warmer, ice-free, spring-fed reaches of the Middle Snake River. The Lower Snake River was subject to large variations in seasonal water temperature and some ice formation during the winter (Connor et al. 2016). In addition, the geomorphology of the Lower Snake River was less suitable for fall Chinook salmon production compared to reaches of the Middle Snake River (Dauble et al. 2003).

European-American Settlement and Influences on Fall Chinook Salmon

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. 2016). The number of fall Chinook salmon returning to the Snake River began to decline toward the end of the 19th century. At that time European-American commercial harvest of Columbia River salmon increasingly focused on fall Chinook salmon, as catches of spring and summer Chinook salmon declined. Annual catches of fall Chinook salmon at the time ranged from 3,000 to nearly 10,000 tons (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, increasing 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 the quality of spawning and rearing habitats 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 (leading to increased stream temperatures), and altered stream banks and channels. As summarized by Murray (1964), “from 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 on the Middle Snake River (RM 458) to generate electricity for mines in the Owyhee Mountains further reduced fall Chinook salmon production by blocking access to prime historical habitat. Swan Falls Dam eliminated passage to the largest and most productive aquifer-fed habitats in the Middle Snake River. After construction of Swan Falls Dam, thousands of spawners were displaced from their natal upriver spawning areas to the remaining downstream aquifer-influenced reaches of the Middle Snake River (Haas 1965; Irving and Bjornn 1981). The reach from Swan Falls Dam downstream to the town of Marsing, Idaho, became the population's primary spawning area until this area was also lost to production following construction of projects associated with the Hells Canyon Complex. Redd surveys conducted between 1947 and 1952, after Swan Falls Dam construction but before the Hells Canyon Complex construction, showed that about 95 percent of the fall Chinook salmon 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).

Returns of Snake River fall Chinook salmon continued to diminish in the early 20th century. European 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 Oregon Department of Fisheries in 1907. In 1908, the state of Oregon 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 and was eventually outlawed completely by the states of Oregon and Washington in 1928 and 1935, respectively (Oregon Historical Society 2003). The two states also agreed to implement a restricted fall fishing season and to construct hatcheries below 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.

Following the construction of Swan Falls Dam, additional dams were constructed upstream of that dam, beginning with Lower Salmon Falls (1910), Upper Salmon Falls, Bliss (1950), and CJ Strike (1952) Dams, all of which are now operated by the Idaho Power Company. Then, in 1955 the Idaho Power Company began construction of Brownlee Dam at RM 284.6, the first of three dams on the Snake River downstream of Swan Falls Dam that became known as the Hells Canyon Complex. The Idaho Power Company completed Brownlee Dam in 1958, and the resulting impoundment was approximately 279 feet deep and 1,381 feet wide at the dam and extended a distance of 57.8 miles upstream at full pool (Haas 1965). Construction of Oxbow Dam, 12 miles downstream of Brownlee Dam, in 1961 impounded the 12.4-mile stretch between Oxbow and Brownlee Dams, and was followed by the construction of Hells Canyon Dam, 26 miles downstream from Oxbow Dam, in 1967 (Table 2-1).

At first, adult fish were successfully passed around Brownlee Dam, and then Oxbow 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 impounded river reduced the ability of the young fish to migrate through the reservoir in a timely manner before summer arrived and high water temperatures and low dissolved oxygen levels began to reduce fish survival (Graban 1964; Haas 1965). They were also exposed to predators in the impounded reservoir reaches. 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. Table 2-1 lists the eight dams on the mainstem Snake River from below Shoshone Falls through Hells Canyon.

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

River Mile (RM)	Year Completed	Idaho Power Company Project	Type of Project
580.8	1950	Upper Salmon Falls Dam	Run-of-the-river
575.3	1910	Lower Salmon Falls Dam	Run-of-the-river
560.3	1950	Bliss Dam	Run-of-the-river
494	1952	C.J. Strike Dam	Storage, hydro
457.7	1901	Swan Falls Dam	Run-of-the-river
284.6	1958	Brownlee Dam	Storage, flood control, hydro
272.5	1961	Oxbow Dam	Run-of-the river
247.6	1967	Hells Canyon Dam	Run-of-the river

While construction of the Hells Canyon Complex significantly further reduced the habitat range for Snake River fall Chinook salmon, it also had effects that helped preserve the quality of remaining spawning habitat in the Lower Snake River (Bennett and Peery 2003; Hanrahan 2007; Connor et al. 2016). First, sediment and nutrient loads from upstream agricultural runoff, which had significant adverse effects on spawning habitat in the Middle Snake River, settled in Brownlee Reservoir and were not passed downstream. Second, the storage and release of water at the Hells Canyon Complex shifted the thermal regime in the Lower Snake River to be warmer in the fall and early-winter months and somewhat cooler in the spring months, which likely accelerated incubation and fry emergence compared to before construction of the dam complex (Connor et al. 2016).

Fall Chinook salmon also lost historical habitat in the Clearwater River basin in 1927, when Lewiston Dam was constructed on the mainstem Clearwater, six miles up from the river's mouth. The dam resulted in the extirpation of upstream Chinook salmon populations because its fish ladder became dry after the spring runoff, when all water was routed through the powerhouse. While this problem was remedied in 1939 (Chapman 1940), the fall Chinook salmon population associated with the Clearwater River had already been extirpated. Lewiston Dam was removed in 1973, allowing for reestablishment of Chinook salmon in the Clearwater River basin, except in the North Fork Clearwater, where anadromous fish were extirpated following construction of Dworshak Dam on this river, 1.9 miles from its confluence with the mainstem Clearwater River, in 1973.

Construction of four federal dams (Ice Harbor, Lower Monumental, Little Goose, and Lower Granite) on the lower Snake River in the 1960s and early 1970s further restricted fall Chinook salmon production. These four lower Snake River dams inundated 135 miles 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 and triggered implementation of actions to improve passage at the dams (along with other actions to reverse the species' decline).

2.2.2 Current Fall Chinook Salmon Distribution

Today, Snake River fall Chinook salmon spawn primarily in the 100-mile reach of the Lower Snake River downstream of Hells Canyon Dam. The upper end of the Lower Granite Reservoir is effectively the downstream limit of spawning and early rearing habitat for the ESU, although limited spawning occurs in the tailraces of Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Dams on the lower Snake River (Dauble et al. 1999).[15] Substantial numbers of fall Chinook salmon also spawn in the lower mainstem of the Clearwater River. Some fish also spawn in the lower reaches of other major tributaries to the Lower Snake River, including the Tucannon, Grande Ronde, Salmon, and Imnaha Rivers. This area provides the only habitat remaining after the inundation of other Snake River fall Chinook salmon spawning areas by federal and private hydropower development. Figure 2-1 shows the location of dams on the Snake and Columbia Rivers throughout all currently and historically accessible habitat.

2.3 ESU Biological Structure

This section describes the general aspects of salmonid biological structure and the population structure of the Snake River fall Chinook salmon ESU. It also describes the relationship between the Snake River fall Chinook salmon ESU and other Interior Columbia fall Chinook salmon ESUs

2.3.1 General Salmonid Biological Structure

Snake River fall Chinook salmon, as well as other salmonid species, are defined by a unique biological population structure that is critical to their resilience and long-term survival. NMFS' scientific foundation for recovery planning recognizes this population structure. Historically, most salmon and steelhead species contained multiple independent populations connected by some small degree of genetic exchange that reflected the geography of the river basins in which they spawned, and with some spawners straying in from other areas. Thus, the overall biological structure of the species is hierarchical; spawners in the same area of the same stream share more characteristics than they do with those in the next stream over. Fish whose natal streams are separated by hundreds of miles generally have less genetic similarity due to long-term adaptation to their different environments. The species is thus essentially a metapopulation defined by the

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[15] The tailrace is the area downstream of a dam where the water exits and is often turbulent.

common characteristics of major spawning groups or historical populations within a geographic range. Recovery planning efforts focus on this biologically based hierarchy, which extends from the species level to a level below a population, and reflects the degree of connectivity between the fish at each geographic and conceptual level.

McElhany et al. (2000) formally identified two levels in this biological hierarchy for listing, delisting, and recovery planning purposes: the evolutionarily significant unit (ESU) or distinct population segment (DPS) and the independent population. Most of NMFS' technical recovery teams identified an additional level in the hierarchy between the population and ESU levels but gave it different names. The Interior Columbia Technical Recovery Team defined this level as a major population group (MPG) (McClure et al. 2003). The three levels in the hierarchy are defined below. Figure 2-6 shows the relationship between the three levels.

- **Evolutionarily Significant Unit:** NMFS defines a salmon ESU as a distinctive group of Pacific salmon that is uniquely adapted to a particular area or environment. Two criteria define an ESU of salmon listed under the ESA: (1) it must be substantially reproductively isolated from other conspecific units, and (2) it must represent an important component of the evolutionary legacy of the species (Waples et al. 1991). ESUs may contain multiple populations that are connected by some degree of migration, and hence may have a broad geographic range across watersheds, river basins, and political jurisdictions. An ESU is treated as a species under the ESA.
- **Major Population Groups:** Within an ESU, independent populations can be grouped into larger aggregates that share similar genetic, geographic, and/or habitat characteristics (McClure et al. 2003). These "major population groups" are groupings of populations that are relatively isolated from one another over a longer time scale than that defining the individual populations, but retain some degree of connectivity greater than that between different ESUs.
- **Independent Populations:** McElhany et al. (2000) defined an independent population as: "…a group of fish of the same species that spawns in a particular lake or stream (or portion thereof) at a particular season and which, to a substantial degree, does not interbreed with fish from any other group spawning in a different place or in the same place at a different season." For our purposes, not interbreeding to a "substantial degree" means that two groups are considered to be independent populations if they are isolated to such an extent that exchanges of individuals among the populations do not substantially affect the population dynamics or extinction risk of the independent populations over a 100-year time frame.

  McElhany et al. (2000) identified four population attributes that influence the biological viability and long-term resilience of independent populations: abundance, productivity, spatial structure, and diversity.

In recovery planning, independent populations are the units that are combined to form alternative recovery scenarios for MPG and ESU viability ─ and, ultimately, are the focus of recovery efforts.

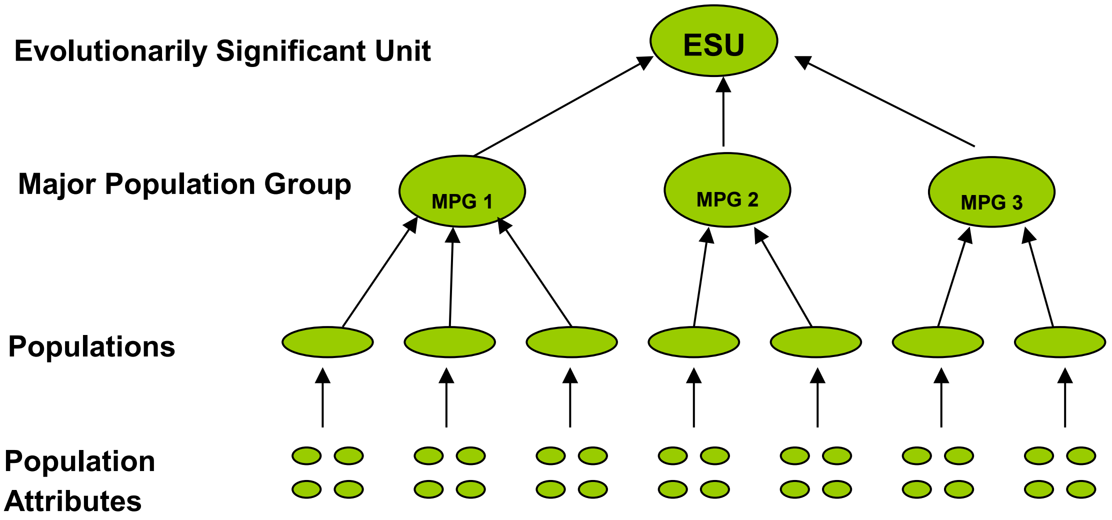

Figure 2-6. Hierarchical levels of salmonid species structure as defined by the ICTRT for ESU recovery planning.

2.3.2 Snake River Fall Chinook Salmon ESU Population Structure

The Snake River fall Chinook salmon ESU reflects the general metapopulation hierarchical structure described above and as defined by McElhany et al. (2000) and the ICTRT (McClure et al. 2003). The ICTRT defined a single MPG within the Snake River fall Chinook salmon ESU. Within that MPG, the ICTRT originally defined three historical populations: the extant Lower Snake River population and two extirpated populations that spawned and reared historically above the current location of Hells Canyon Dam (ICTRT 2005). However, updated information indicates that there was a single historical population above the Hells Canyon Complex, the Middle Snake River population, consisting of two primary spawning areas (NWFSC 2015).[16] Thus NMFS now considers the historical population structure of the Snake River fall Chinook salmon MPG to consist of the extant Lower Snake River population and the extirpated Middle Snake River population.

Extant Lower Snake River Population

Within independent populations, the ICTRT (2005a) also identified major spawning areas (MaSAs), defined as a stream system of one or more branches that contains sufficient spawning and rearing habitat to support at least 500 spawners. The ICTRT (2005a) identified five MaSAs within the extant Lower Snake River population, the locations of which are shown in Figure 2-7.

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[16] The ICTRT (2005) identified two historical populations above the current Hells Canyon dam site based on historical accounts of spawner distribution and spatial geomorphic considerations (ICTRT 2007). As part of the 2016 ESA 5-year status review, NMFS determined that the two relatively continuous spawning aggregations above the current Hells Canyon Dam site were more likely part of a single population (NWFSC 2015; NMFS 2016a). We made this determination based on information submitted to us by the U.S. Fish and Wildlife Service and summarized in Connor et al. 2016. A key factor in that decision was a 56-km gap in suitable spawning habitat reported in Parkhurst (1950). Based on a detailed review of the geomorphic potential in that region, the gap was overestimated and was more likely less than 25 km (Connor et al. 2016).

The population’s major spawning areas include tributary habitats that support diversity and potential resilience for recovery under today’s ecological conditions. The five MaSAs are:

1. Upper Hells Canyon MaSA ─ The primary (largest and most productive) MaSA in the Lower Snake River population extends 59.6 miles from Hells Canyon Dam on the Snake River downstream to the confluence with the Salmon River. Fall Chinook salmon production in the adjoining lower Imnaha and Salmon Rivers is considered part of this MaSA. The ICTRT considered spawning in the lower mainstem sections of the Imnaha and Salmon Rivers to be contiguous with and therefore part of the Upper Hells Canyon MaSA.
2. Lower Hells Canyon MaSA ─ This second mainstem Snake River MaSA extends 42.9 miles downstream from the Salmon River confluence to the upper end of the contemporary Lower Granite Dam pool. It includes production from two adjoining tributaries, Alpowa and Asotin Creeks.
3. Clearwater River MaSA ─ The MaSA includes the lower mainstem Clearwater River. Some historical evidence suggests that the Selway River and other tributaries also supported fall Chinook salmon.
4. Grande Ronde River MaSA ─ The MaSA covers the lower Grande Ronde River. Isolated reaches in tributaries to the Grande Ronde River may have also supported fall Chinook salmon production at one time.
5. Tucannon River MaSA ─ The MaSA includes the lower Tucannon River and the adjacent inundated mainstem Snake River section associated with Little Goose and Lower Monumental Dams.

Fall Chinook salmon spawners may have historically used the lowest potential spawning reaches in the Snake River, currently inundated by Ice Harbor Dam (Dauble et al. 2003). Spawners using these reaches 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 (NWFSC 2015).

Extirpated Middle Snake River Population

The extirpated Middle Snake River population likely consisted of two major spawning areas, referred to as the Salmon Falls and Glenns Ferry spawning areas (Connor et al. 2016). The Salmon Falls spawning area, the primary (largest and most productive) of the two major spawning areas, extended downstream from Auger Falls to Lower Salmon Falls, with production centered on Millet Island. Temperature conditions during spawning and incubation in this area were overwhelmingly influenced by the warm-water releases from the Eastern Snake River Plain Aquifer, which allowed for earlier emergence and rapid growth (Connor et al. 2016; NWFSC 2015). The Glenns Ferry spawning area extended downstream from Kings Hill, near Glenns Ferry, to the mouth of the Burnt River. In contrast to the Salmon Falls spawning area, the influence of the aquifer diminished greatly with distance moving downstream within the Glenns Ferry spawning area. The upper reaches of the Glenns Ferry spawning area were primary production areas for Snake River fall Chinook, capable of supporting at least 500 spawners, while the lower reach, which exhibited weak or no aquifer influence, was a secondary production area, capable of supporting 200 or more spawners (Connor et al. 2016). Figures 2-4 and 2-7 show these areas in the Middle Snake River.

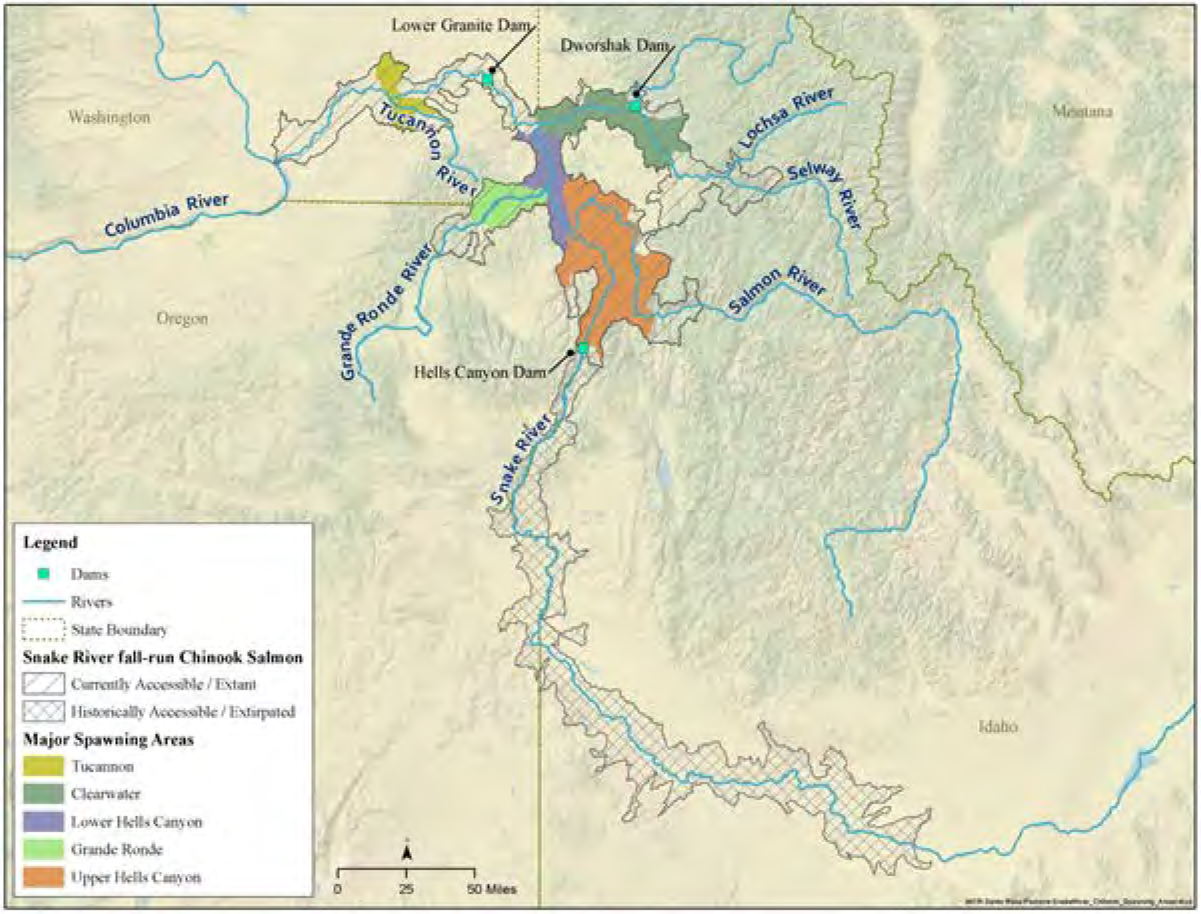

Figure 2-7. Historical Snake River Fall Chinook Salmon populations. The historical Middle Snake River population is shown as historically accessble/extirpated. The extant Lower Snake River Fall Chinook Salmon population includes five Major Spawning Areas (MaSAs), shown on the map. The ICTRT based its designation of MaSAs for this population 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 (ICTRT 2010).

2.3.3 Relationship between Snake River ESU and Other Interior Columbia Fall Chinook ESUs

The Snake River fall Chinook salmon ESU is one of three fall Chinook salmon ESUs that spawn and rear in the Interior Columbia River basin (Figure 2-8) (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. Only the Snake River fall Chinook salmon ESU is ESA-listed.

The Upper Columbia summer/fall Chinook salmon ESU includes production from spawning in the Hanford Reach of the Columbia River and in the lower reaches of major tributaries to the Middle Columbia River. NMFS has determined that this ESU is not warranted for listing under the ESA. It is considered to have the closest genetic 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; 64 FR 50406). NMFS status reviews have also determined that the Deschutes River summer/fall Chinook salmon ESU, which contains a single population, is not warranted for listing under the ESA. Genetic and life-history data for the Deschutes River population indicate a closer affinity to fall Chinook salmon in the Snake River than to those in the Columbia River (Myers et al. 1998).

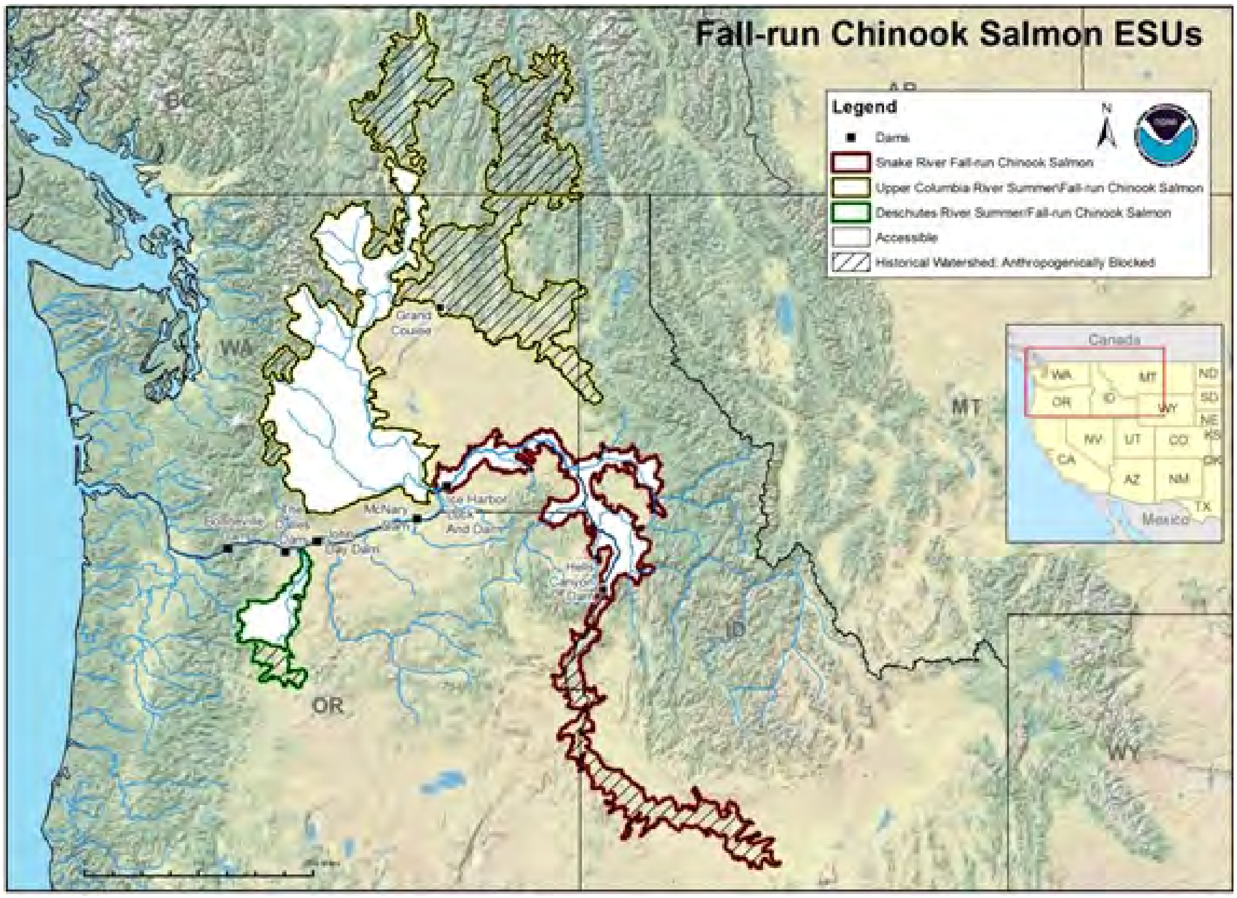

Figure 2-8. Interior Columbia River basin fall Chinook salmon ESUs.

2.4 Viable Salmonid Populations

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

2.4.1 Abundance and Productivity

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

Abundance is 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 often used a recent 10-year geometric mean of natural-origin spawners as a measure of current abundance.

Productivity of a population (the average number of surviving offspring per parent) is a measure of the population's ability to sustain itself. Productivity can be measured as spawner-to-spawner ratios (returns per spawner or recruits per spawner, or adult progeny to parent),[17] 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.

McElhany et al. (2000) offers abundance (size) and productivity guidelines for viable salmonid populations. These guidelines are shown in the box below.

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[17] For returns-per-spawner based estimates, the ICTRT defined productivity as a measure of resilience ─ the estimated or expected average return per spawner from parent spawning levels below minimum abundance targets.

Viable Salmonid Populations Abundance and Productivity Guidelines

(McElhany et al. 2000)

Abundance

1. Be large enough to have a high probability of surviving environmental variation of the patterns and magnitudes observed in the past and expected in the future.
2. Be sufficiently large to provide resilience to environmental and anthropogenic disturbances.
3. Be sufficiently large to maintain genetic diversity over the long term.
4. Be sufficiently abundant to provide important ecological functions throughout its life-cycle.
5. Population status evaluations should take uncertainty regarding abundance into account.

Productivity

1. Demonstrate sufficient natural productivity to maintain abundance above viable levels (support a net replacement rate of 1:1 or higher at abundance levels established as long-term targets).
2. Demonstrate sufficient productivity from naturally produced spawners to maintain abundance at or above viability thresholds in absence of hatchery subsidy (Natural return ratio around 1.0, indicating negligible hatchery influence on the population).
3. Exhibit sufficient productivity during freshwater life history stages to maintain abundance at or above viable thresholds—even during poor ocean conditions.
4. Should not exhibit sustained declines in abundance that span multiple generations and affect multiple brood year-cycles.
5. Should not exhibit trends or shifts in traits that portend declines in population growth rate.
6. Population status evaluations should take into account uncertainty in estimates of population growth rate and productivity-related parameters.

2.4.2 Spatial Structure and Diversity

A population’s spatial structure is made up of both the geographic distribution of individuals in the population and the processes that generate that distribution (McElhany et al. 2000). Spatial structure refers to the amount of habitat available, the organization and connectivity of habitat patches, and the relatedness and exchange rates of adjacent populations. Diversity refers to the distribution of life history, behavioral, and physiological traits within and among populations. Some of these traits are completely genetically based, while others, including nearly all morphological, behavioral, and life-history traits, vary as a result of a combination of genetic and environmental factors (McElhany et al. 2000). Spatial structure and diversity considerations are combined in the evaluation of a salmonid population’s status because they are so interrelated.

Spatial structure influences salmonid viability because populations with restricted distribution and few spawning areas are at a higher risk of extinction as a result of catastrophic environmental events, such as a landslide, than are populations with more widespread and complex spatial structures. A population with a complex spatial structure, including multiple spawning areas, experiences more natural exchange of gene flow and life-history characteristics.

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.

McElhany et al. (2000) offers spatial structure and diversity guidelines for viable salmonid populations. These guidelines are shown in the box below.

Viable Salmonid Populations Spatial Structure and Diversity Guidelines

(McElhany et al. 2000)

Spatial Structure

1. Habitat patches should not be destroyed faster than they are naturally created.
2. Natural rates of straying among subpopulations should not be substantially increased or decreased by human actions.
3. Some habitat patches should be maintained that appear to be suitable or marginally suitable, but currently contain no fish.
4. Source subpopulations should be maintained.
5. Analyses of population spatial processes should take uncertainty into account.

Diversity

1. Human-caused factors such as habitat changes, harvest pressures, artificial propagation, and exotic species introduction should not substantially alter variation in traits such as run timing, age structure, size, fecundity, morphology, behavior, and molecular genetic characteristics.
2. Natural processes of dispersal should be maintained. Human-caused factors should not substantially alter the rate of gene flow among populations.
3. Natural processes that cause ecological variation should be maintained.
4. Population status evaluations should take uncertainty about requisite levels of diversity into account.

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

2.5 ICTRT Biological Viability Criteria

The viability criteria developed by the ICTRT represent a consistent framework that follows guidelines recommended by McElhany et al. (2000). They identify characteristics and conditions that, when met, will describe viable populations ─ expressed in terms of abundance, productivity, spatial structure, and diversity ─ and viable species. The viability criteria also identify metrics and thresholds that may be used to determine the status of a population and the viability risk. Thus, the ICTRT biological viability criteria provided an important foundation for use in defining NMFS' recovery goals, objectives, and delisting criteria for Snake River fall Chinook salmon, described in Chapter 3.

The ICTRT's biological viability criteria are hierarchical. They are designed to assess risk for abundance/productivity and spatial structure/diversity at the population level. These assessments are then "rolled up" to arrive at composites for the MPG and ESU levels. The criteria reflect the best available science and consist of a combination of general statements and metrics that characterize viability.

The ICTRT adapted its approach to accommodate the biological characteristics and available data for the Snake River fall Chinook salmon ESU. These viability criteria are summarized below and outlined in more detail in the ICTRT's draft technical report, *Viability Criteria for Application to Interior Columbia Basin Salmonid ESUs* (ICTRT 2007). The report is available at: http://www.nwfsc.noaa.gov/trt/col/trt_viability.cfm.

2.5.1 Viability Criteria for ESUs with a Single MPG

The ESU-level viability criterion focuses on ensuring the preservation of basic historical metapopulation processes needed to maintain a viable ESU in the face of long-term ecological and evolutionary processes. ESUs that contain only one MPG are inherently at greater extinction risk than salmon species with several MPGs (ICTRT 2007). Such species will, by definition, have a more limited spatial structure, less diversity, and potentially less abundance and productivity than those with multiple MPGs. In addition, such ESUs typically have fewer component populations, which increases their risk level (ICTRT 2007; Boyce 1992; Tear et al. 2005). The ICTRT developed more stringent applications of their biological criteria for ESUs with a single MPG to mitigate this inherently higher risk.

The ICTRT (2007) recommended that ESUs that contained only one MPG historically, or that include only one MPG critical for proper function, should meet the following criteria:

- A single MPG should meet all the ICTRT (2007) criteria for an MPG to be regarded as low risk.[18] In addition:
    1. Two-thirds or more of the historical populations within the MPG should meet viability standards; and
    2. At least two populations should meet the criteria to be highly viable.

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[18] According to the ICTRT (2007), an MPG meeting the following criteria would be at low risk: (1) at least one-half of the populations historically within the MPG (with a minimum of two populations) should meet viability standards; (2) at least one population should be classified as "highly viable"; (3) viable populations within an MPG should include some populations classified (based on historical intrinsic potential) as "very large," "large," or "intermediate," generally reflecting the proportions historically present within the MPG. In particular, very large and large populations should be at or above their composite historical fraction within each MPG; (4) all major life history strategies (e.g., spring and summer run-timing) that were present historically within the MPG should be represented in populations meeting viability requirements; (5) populations not meeting viability standards should be maintained with (a) sufficient productivity so the overall MPG productivity does not fall below replacement (i.e., these areas should not serve as significant population sinks) and (b) sufficient spatial structure and diversity demonstrated by achieved "maintained" standards.

2.5.2 Population-Level Viability Criteria

The ICTRT population-level criteria define the viability status of the individual populations that make up an MPG and an ESU/DPS. The ICTRT's criteria describe a viable population based on the four VSP parameters (abundance, productivity, spatial structure, and diversity). As discussed in Section 2.4, these parameters are important indicators of population extinction risk ─ or, conversely, a population's probability of persistence. The ICTRT grouped the population-level criteria into two categories: measures addressing abundance and productivity, and measures addressing spatial structure/diversity considerations.

Abundance and Productivity

Abundance refers to the average number of spawners in a population over a generation or more. Productivity, or population growth rate, refers to the performance of the population over time in terms of recruits produced per spawner. Together, these two parameters drive extinction risk.

The ICTRT identified the following objective[19] for population abundance and productivity based on guidance from McElhany et al. 2000:

> *Intrinsic productivity and natural-origin abundance should be high enough that (1) declines to critically low levels would be unlikely assuming recent historical patterns of environmental variability; (2) compensatory processes provide resilience to the effects of short-term perturbations; and (3) subpopulation structure is maintained (e.g., multiple spawning tributaries, spawning patches, life-history patterns).*

The ICTRT developed a quantitative tool, called a "viability curve," for evaluating the abundance and productivity of a population (ICTRT 2007). 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 different viability curves corresponding to a range of extinction risks over a 100-year period: less than 1 percent (very low) risk, 1 to 5 percent (low) risk, 6 to 25 percent (moderate) risk, and greater than 25 percent (high) risk. The ICTRT targeted population-level recovery strategies to achieve less than a 5 percent (low) risk of extinction in a 100-year period. This is consistent with the VSP guidelines and conservation literature (McElhany et al. 2000; NRC 1996; ICTRT 2007). The ICTRT considers a population with less than 5 percent risk of extinction in 100 years to be viable, and a population with a less than 1 percent risk of extinction during the period to be highly viable.

The ICTRT recommended a minimum abundance threshold of 3,000 natural-origin spawners for the extant Snake River fall Chinook salmon population.[20] No fewer than 2,500 of those natural-

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[19] This objective is the ICTRT's objective for population abundance and productivity (ICTRT 2007). The ESA recovery objective for abundance and productivity in Chapter 3 is consistent with this ICTRT objective.

[20] The ICTRT (2007) incorporated minimum abundance thresholds into population viability curves to "promote achieving the full range of abundance objectives including utilization of multiple spawning areas, avoiding problems associated with low population densities (e.g. Allee effects) and maintaining populations at levels where compensatory processes are functional." The ICTRT recommended using 10-year geometric

origin spawners should be distributed in mainstem Snake River habitat. Figure 2-9 shows the abundance/ productivity viability curve for Snake River fall Chinook salmon (ICTRT 2007). In the viability curve, abundance is expressed in terms of equilibrium spawning level and productivity is expressed as the expected geometric mean return per spawner at low-to-moderate abundance.

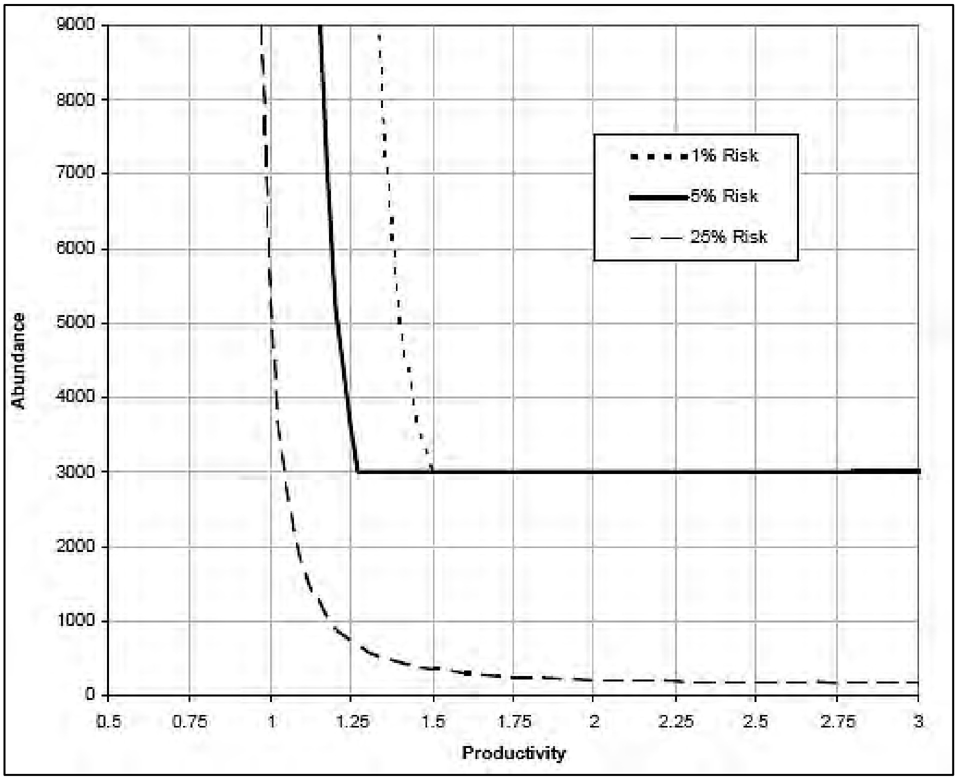

Figure 2-9. Abundance/Productivity Viability Curve for Snake River fall Chinook salmon (ICTRT 2007).

The ICTRT envisioned its viability curve concept as adaptable. The curves can be generated specific to the form of stock-recruit relationship and type of time series data available for a particular population of set of populations. The ICTRT (2007) provided guidance for updating a viability curve and for assessing current status relative to the curve. The ICTRT (2007) also recognized that there could be situations where alternative means of assessing productivity may be needed and provided guidance to adapt the approach to accommodate the biological characteristics and available data for Snake River fall Chinook salmon.

Spatial Structure and Diversity

The spatial structure and diversity criteria are specific to each population, and based on historical spatial distribution and diversity, to the extent these can be known or inferred. The ICTRT

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means of recent natural-origin spawners as a measure of current abundance. It also recommended that current intrinsic productivity should be estimated using spawner-to-spawner return pairs from low-to-moderate escapements over a recent 20-year period. The ICTRT adopted a recommendation from Beven et al. (1994) as the minimum abundance threshold for the extant Lower Snake River Fall Chinook Salmon population.

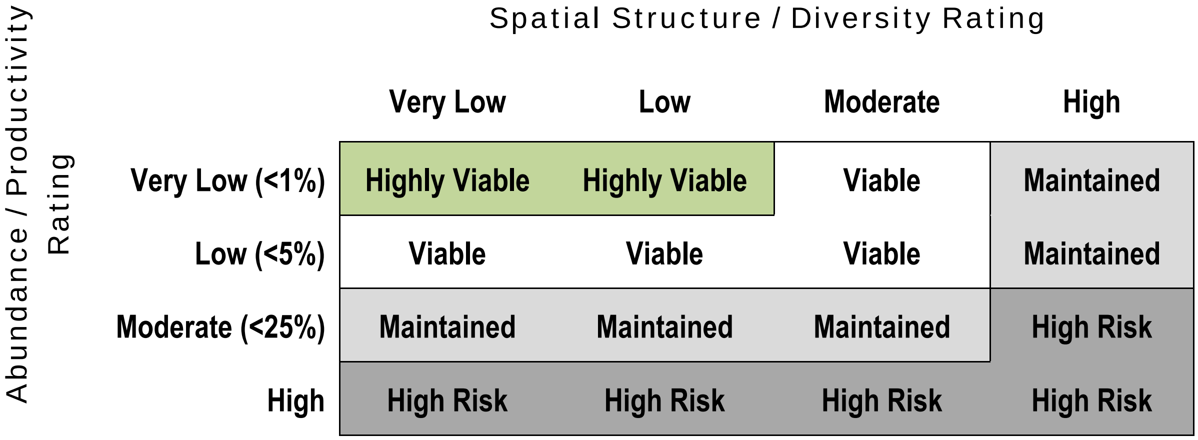
cautions that there is a good deal of uncertainty in assessing the status of spatial structure and diversity in a population (ICTRT 2007; McElhany et al. 2000).

The ICTRT identified two primary goals that spatial structure and diversity criteria should achieve:

- Maintaining natural rates and levels of spatially mediated processes. This goal serves (1) to minimize the likelihood that populations will be lost due to local catastrophe, (2) to maintain natural rates of recolonization within the population and between populations, and (3) to maintain other population functions that depend on the spatial arrangement of the population.
- Maintaining natural patterns of variation. This goal serves to ensure that populations can withstand environmental variation in the short and long terms (ICTRT 2007).

Integrating the Four VSP Parameters

The ICTRT developed a simple matrix approach for integrating all four VSP parameters (Figure 2-10). The abundance and productivity risk level combines the abundance and productivity VSP criteria using a viability curve (see Figure 2-9). The spatial structure and diversity risk level integrates across multiple measures of spatial structure and diversity, defined in ICTRT 2007, which are related to achieving the two primary goals. The overall viability rating for a population is determined using two guiding principles. First, the VSP concept (McElhany et al. 2000) provides a 5 percent risk criterion to define a viable population. Therefore, any population that scores moderate or high risk in the abundance/productivity criteria would not meet the recommended viable standards, and any population that scores high risk in the spatial structure/diversity criteria would not be considered viable. Second, populations with a very low risk rating for abundance/productivity and at least a low risk rating for spatial structure/diversity would be considered highly viable. Populations with a low risk rating for abundance and productivity and a moderate rating for spatial structure and diversity would be considered viable. This integration approach places greater emphasis on the abundance and productivity criteria. These individual ratings were then integrated to determine the viability of major population groups within an ESU, and the viability of the ESU as a whole (ICTRT 2007).



Abundance / Productivity Rating	Spatial Structure / Diversity Rating			
	Very Low	Low	Moderate	High
Very Low (<1%)	Highly Viable	Highly Viable	Viable	Maintained
Low (<5%)	Viable	Viable	Viable	Maintained
Moderate (<25%)	Maintained	Maintained	Maintained	High Risk
High	High Risk	High Risk	High Risk	High Risk

Figure 2-10. Matrix used to assess population viability across VSP criteria. Percentages for abundance and productivity scores represent the probability of extinction in a 100-year time period (ICTRT 2007).

2.6 Snake River Fall Chinook Salmon Life History

Historically, most Snake River fall Chinook salmon production came from large mainstem reaches supporting a subyearling life history, where young fish emerged from redds from late winter through early spring, reared and grew rapidly, and migrated seaward before mid-summer. This life-history strategy reflected the temperature-dependent growth and survival opportunities in the large mainstem reaches of the Snake River basin’s arid high desert environment, which favored relatively short incubation and emergence timing and accelerated early growth. This strategy allowed the fish to leave before rapidly increasing temperatures on the high desert created very warm water conditions in many reaches during summer months, which generally could reduce growth and survival of young fall Chinook salmon that did not migrate. Today, this subyearling life-history strategy contributes the majority of natural-origin adult returns to the existing population. However, the habitat diversity associated with the extant population also supports a significant number of yearling migrants. Most of the yearlings are juveniles from the Clearwater River basin but a small percentage (<1 to 2 percent) originate from other Snake River areas. The juveniles overwinter in the reservoirs and other cool-water refuge areas and migrate downstream to the ocean as yearlings.

This section describes the life history of Snake River fall Chinook salmon (Figure 2-11), with focus on the life stages of adult migration, spawning, egg incubation and fry emergence, juvenile rearing and migration to Lower Granite Reservoir and past Lower Granite Dam, juvenile migration and passage through the Snake and Columbia Rivers, juvenile migration through the estuary, and ocean dispersal and rearing.

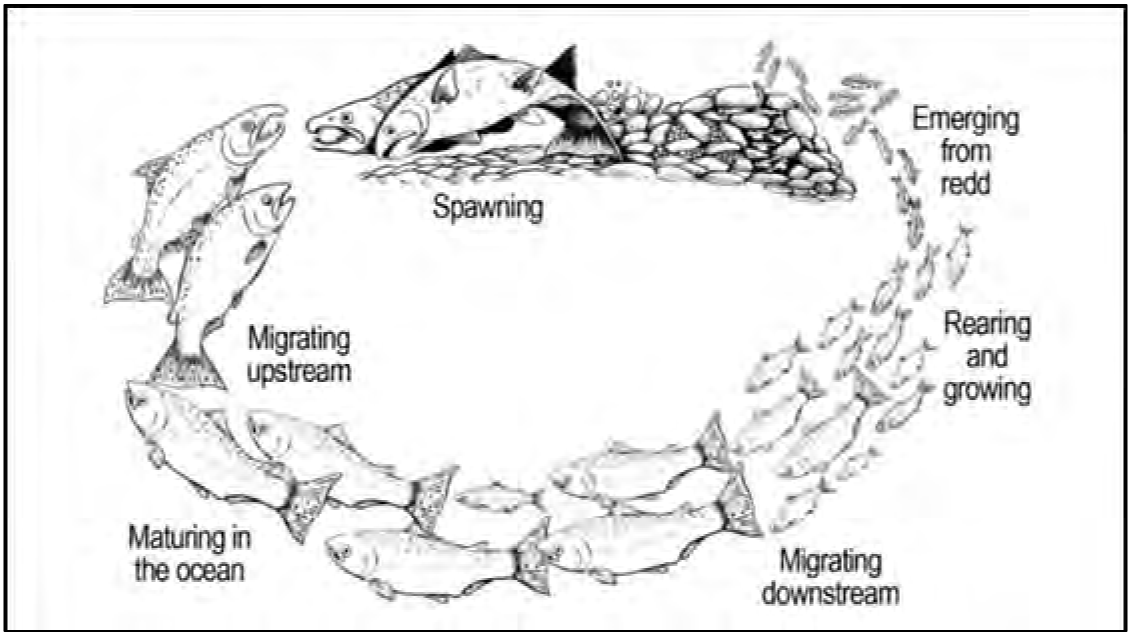


Figure 2-11. Snake River fall Chinook salmon life history.

Adult Migration to the Snake River

Snake River basin fall Chinook salmon generally spend two to five years in the Pacific Ocean, depending on sex and age at the time of ocean entry (Connor et al. 2016).[21] 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 late August and early December, with peak returns in early September to mid-October (DART 2013).

Spawning

Once they reach the Snake River, fall Chinook salmon spawn in the five major spawning areas (MaSAs) described above in Section 2.3.1: Upper Hells Canyon, Lower Hells Canyon, Tucannon River, Grande Ronde River, and Clearwater River.[22] In recent years, adults in the two mainstem Snake River MaSAs (Upper Hells Canyon and Lower Hells Canyon) and in the Grande Ronde and Tucannon River MaSAs have spawned from late October through early December, with peak spawning about the first week in November (Connor et al. 2011). Adults in the Clearwater River MaSA spawn about a week or two earlier than do adults in the other four major spawning areas (Connor et al. 2011).

Redd (spawning nest) survey effort since the Snake River fall Chinook salmon ESU was listed under the ESA provides a general depiction of the spatial distribution of spawning. As shown in Figure 2-12, surveys since 1992 show that the highest percentage of fall Chinook salmon redds have been counted in the Upper Hells Canyon MaSA (32 percent), followed closely by the

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[21] Some maturing males, referred to as “jacks”, spend one year or less in the ocean before returning to the basin.

[22] Natural production is documented for four out of the five MaSAs; there is consistent spawning in the fifth (the Tucannon lower mainstem) but it may be virtually all hatchery returns.

Clearwater River MaSA (27 percent) and Lower Hells Canyon MaSA (21 percent). The Tucannon and Grande Ronde River MaSAs contributed an average of 6 percent and 5 percent respectively. Year to year variability was similar across the MaSAs (standard deviation = approximately 10 percent). The redd count series includes redds constructed by both hatchery and natural spawners. Returns from direct releases at Lyons Ferry Hatchery contributed to escapements in all years in the series. Outplants into each of the MaSAs above Lower Granite Dam increased substantially over the years in this series.

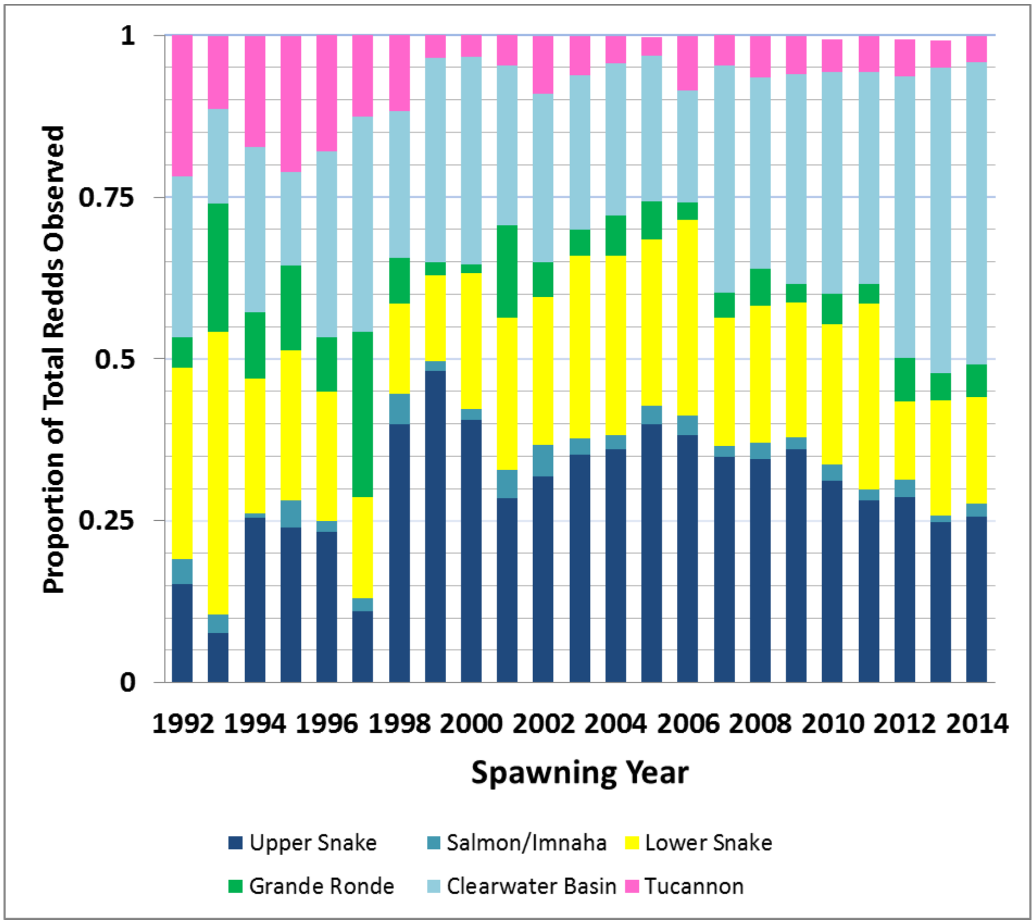

Figure 2-12. Proportion of Snake River basin fall Chinook salmon redds counted in the five major spawning areas and in other adjacent areas surveyed since 1992 (data from the Idaho Power Company, Nez Perce Tribe, U.S. Fish and Wildlife Service, and Washington Department of Fish and Wildlife).

Egg Incubation and Fry Emergence

Emergence timing continues to be an important factor for Snake River fall Chinook salmon production because it synchronizes the timing of juvenile presence with environmental conditions that positively affect growth, migration, and survival to the ocean. Egg incubation, emergence timing, and early rearing of Snake River fall Chinook salmon are significantly influenced by water temperature regimes. Juvenile Snake River fall Chinook salmon exhibit different early life-history timing and growth in different river reaches depending on water temperature and growth opportunity.

Most Snake River fall Chinook salmon emerge from redds in late winter through early spring, rear for a short time, and then migrate seaward before mid-summer (Conner et al. 2016). However, the different water temperature regimes in the Snake River basin create variations in early life-history timing of juvenile fall Chinook salmon from different areas. This variation also existed historically, and the water temperature variation between different reaches of historical habitat fostered phenotypic diversity in spawn timing and fry emergence (Connor et al. 2016).

Historically, the spawning areas of the Middle Snake River mainstem that were directly influenced by discharges from the Eastern Snake River Plain Aquifer supported the earliest fall Chinook salmon emergence. The 60 °F (15.5 °C) spring inflow from the aquifer would have comprised an estimated 31 percent of the flow volume in the Middle Snake River mainstem downstream to Bancroft Springs after late October (Connor et al. 2016). As a result, the spring-fed areas were warmer in winter months and cooler in summer months compared to downstream areas where the aquifer's influence on mainstem Snake River water temperatures declined with distance downstream. This created variation in emergence timing between reaches.

Connor et al. (2016) describe the historical distribution of spawning and fry emergence timing within the Middle Snake River Fall Chinook population. Prior to 1901, natural spawning within the Middle Snake River Fall Chinook population was concentrated in two general areas, the uppermost and likely most productive being the Salmon Falls reach (Lower Salmon Falls to Auger Falls). The second concentration was downstream in the Glenns Ferry reach (Kings Hill down to the Burnt River confluence). The primary spawning sections in the Glenns Ferry reach were above the Boise River and included the Marsing reach. Swan Falls Dam (1901) cut off the entire Salmon Falls reach as well as the uppermost section of the Glenns Ferry reach. Fall Chinook salmon fry in the Salmon Falls reach of the Middle Snake River adjacent to the aquifer and upstream from the present site of C.J. Strike Reservoir emerged earliest, with a median estimated emergence date of February 15 (Figure 2-13). Moving downstream through the Glenns Ferry spawning aggregations, the lessening influence of local inputs of groundwater from the aquifer resulted in later emergence timing. For example, the estimated median date of fry emergence in the Marsing reach section was April 10, a delay of almost two months relative to the upstream Salmon Falls section.

Fall Chinook salmon in the Lower Snake River population spawned in areas outside the aquifer's warming influence (during the winter) and likely produced fry over a wide range of dates. Historically, the Upper Hells Canyon MaSA was likely one of the warmest spawning areas in the Lower Snake River population area, with fry emerging in mid-May. In comparison, the Selway River, a tributary to the Clearwater River, was the coolest spawning area, and fry likely emerged in late June (Connor et al. 2016).

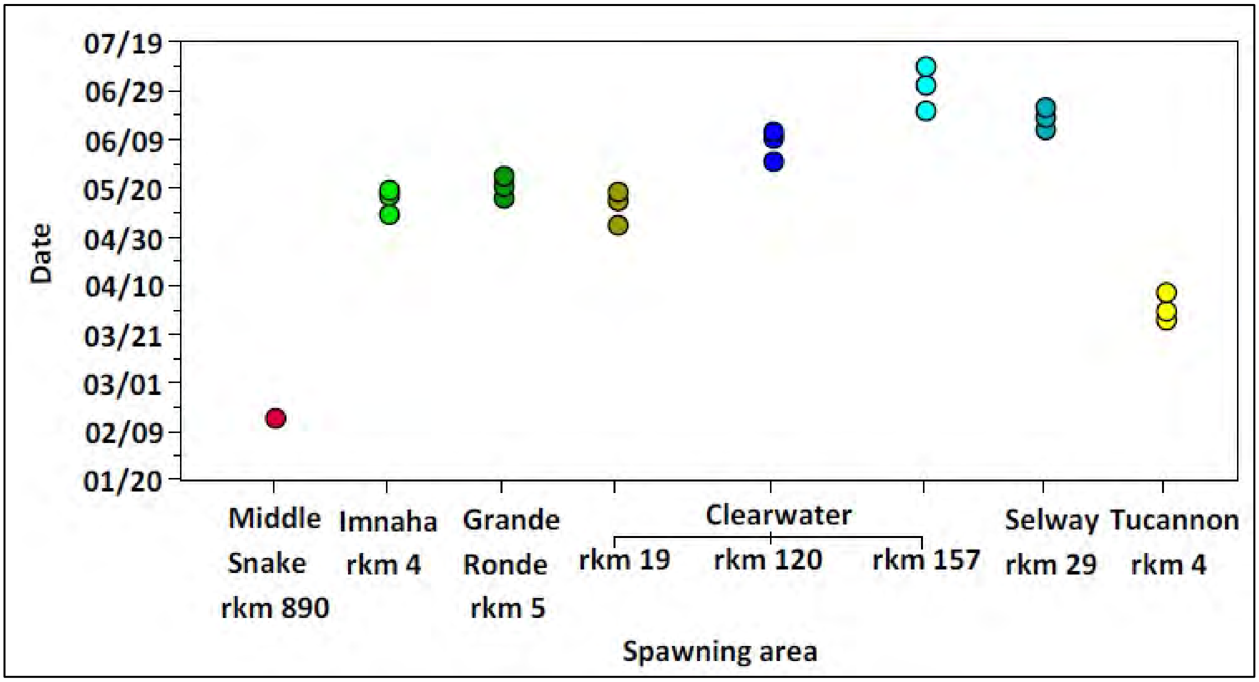

Figure 2-13. Estimated fry emergence dates of juvenile fall Chinook salmon downstream of the Salmon Falls spawning area along the Middle Snake River at RM 580 (rkm 890), and spawning areas in the Lower Snake River basin, including the Imnaha River at RM 2.5 (rkm 4), Grande Ronde River at RM 3.1 (rkm 5), Clearwater River from RM 11.8 to 97.5 (rkm 19 to rkm 157), the Selway River at RM 18 (rkm 29), and the Tucannon River at RM 2.5 (rkm 4). Spawning date was set at 10/23 and a value of 1,066 accumulated cumulative temperature uits (CTUs) was used to estimate emergence date (Connor et al. 2003). Temperature data were collected in the tributaries at times and locations when dam operations were not a factor for temperature variation and spanned three consecutive brood years (Clearwater River RM 11.8 [rkm 19], 1965–1968 U.S. Geological Survey at Spalding, Idaho; all others 1992–1995, Connor et al. 2003).

The warmer winter and early spring water temperatures that fostered early emergence in the Middle Snake River also supported a faster progression to outmigration. The warmer reaches likely produced more food for juvenile Chinook salmon than did the 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 (Connor et al. 2016). In comparison, later-emerging fall Chinook salmon juveniles from colder habitats, such as in the Clearwater River, did not have as much time to rear and grow in their natal habitats before they needed to migrate to avoid rising summer water temperatures in the downstream migratory corridor.

Historically across the ESU, as today, the subyearling life-history strategy was predominant. Young fall Chinook salmon do not thrive when exposed to daytime water temperatures above 68 °F (20 °C) for a month or more each summer. Such conditions often occurred historically in the lower portion of the Middle Snake River, in the Lower Snake River and its tributaries, and in the mainstem Columbia River downstream to the point of ocean influence (Connor et al. 2016). Thus, the viability of fall Chinook salmon in these warm habitats likely depended on localized traits, such as spawning from late September to early October, and rapid outmigration at a smaller size after emergence, to help compensate for the cooler incubation temperatures (Connor et al. 2016). The young fish would continue to feed and grow during their migration, supported by unrestricted access to pristine, abundant, and diverse habitats along the Columbia River mainstem and estuary. They had the opportunity either to enter the Pacific Ocean as subyearlings or to overwinter in fresh or brackish water and enter the ocean as yearlings.

Today, water temperatures continue to influence emergence timing and growth opportunities in ways that create variations in early life history among fish in the five Lower Snake River MaSAs. Recorded water temperatures and emergence timings for brood years 1992 to 1994 indicate that the lower Tucannon River is the warmest of the five MaSAs during egg incubation. The Upper Hells Canyon MaSA is also warm during egg incubation, with water temperatures more conducive to egg incubation than existed historically due to development of the Hells Canyon Complex (Figure 2-14). Water temperatures in this reach are now similar to what was observed historically in the Glenns Ferry reach of the Middle Snake River (upstream of Burnt River confluence and including the Marsing reach), which produced the bulk of Snake River fall Chinook salmon after 1901, when construction of Swan Falls Dam blocked access to the uppermost Middle Snake River spawning reaches, but before construction of the Hells Canyon Complex eliminated all passage to the area (Connor et al. 2002, 2003). The estimated emergence date of fry produced in the Glenns Ferry middle reach during 1961 to 1964 likely ranged from April 4-10 (Conner et al. 2016). The lower Clearwater River remains the coolest of the five MaSAs but is also warmer than in the past due to releases of relatively warm water from the Dworshak Dam reservoir on the North Fork Clearwater River during winter. These releases prevent freezing in the lower Clearwater River and generally foster comparatively accelerated incubation and fry emergence (Figure 2-14) (Connor et al. 2003, 2016).

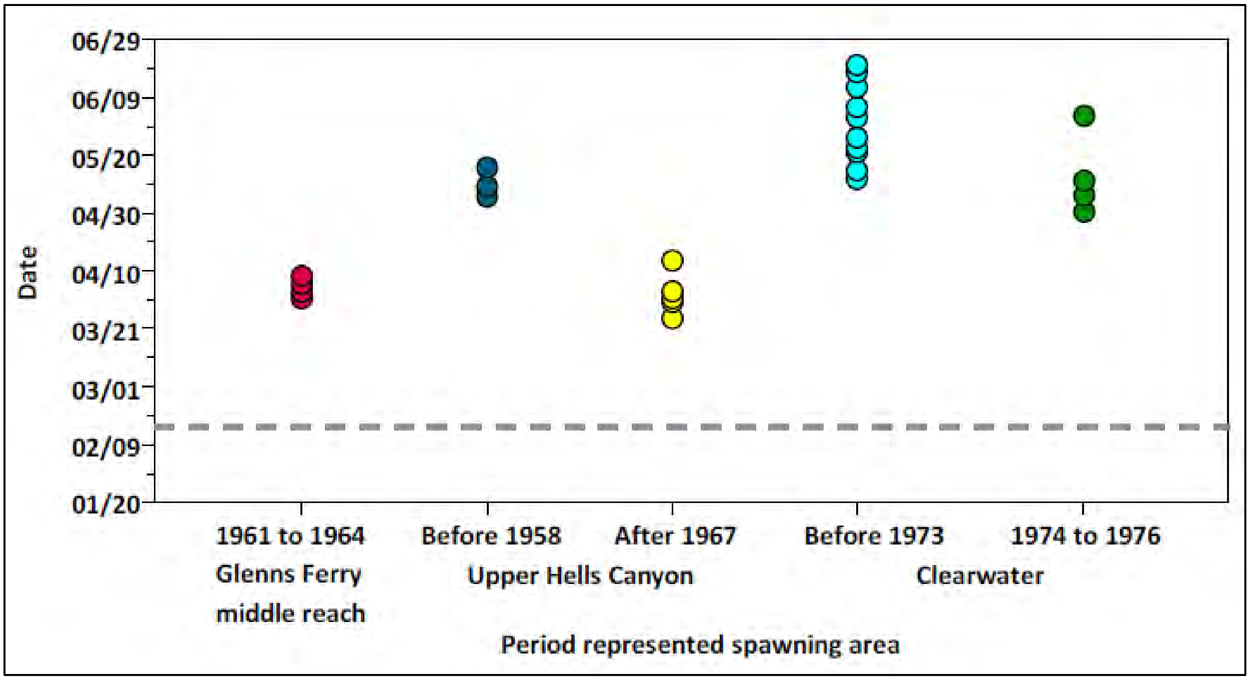

Figure 2-14. Estimated emergence dates for fry within the Glenns Ferry middle reach (Idaho Power Company unpublished 1960–1964 temperature data from the tailrace of Swan Falls Dam, RM 458 [rkm 737.1]); the Upper Hells Canyon spawning area before construction of Brownlee Dam in 1958 (Idaho Power Company unpublished 1954–1957 temperature data from Oxbow Bend, RM 272.7 [rkm 438.9]) and after the completion of the Hells Canyon Complex of dams in 1967 (data collected by the authors 1996-2006 in the tailrace of Hells Canyon Dam, RM 247.7 [rkm 398.7]); and the Clearwater lower reach before (1959–1962; 1963–1971) and after (1973–1976) the completion of Dworshak Dam in 1973 (U.S. Geological Survey temperature data collected at Spalding, Idaho, RM 11.6 [rkm 18.7]). The dashed grey line represents the estimated emergence date of 02/15 for the fry in the Salmon Falls spawning area prior to development and extirpation (see Figure 2-13) (Connor et al. 2016).

Juvenile Rearing in Natal Habitat and Migration to Lower Granite Reservoir[23]

In addition to influencing date of emergence, water temperature also influences the development and migration timing of juveniles. After emerging from the gravel, most young fall Chinook salmon move to shoreline riverine habitat (Connor et al. 2002; Tiffan and Connor 2011). Temperature during shoreline rearing continues to influence food development and growth opportunity and the timing of dispersal from riverine habitat into downstream reservoirs. For example, in the spring of 1995, water temperatures in the Snake River Upper Hells Canyon MaSA averaged 53 °F (11.7 °C) while temperatures in the Lower Hells Canyon MaSA averaged 51.6 °F (10.9 °C), and juveniles in the Upper Hells Canyon MaSA showed more growth than those from the downstream MaSA (an average of 1.2 mm/day and 1.0 mm/day, respectively) (Connor and Burge 2003). Juvenile fall Chinook salmon from the Upper Hells Canyon area also moved downstream into Lower Granite Reservoir earlier than those from the Lower Hells Canyon MaSAs, with peak dates of May 28 and June 4 in 1995, respectively (Connor et al. 2002). In contrast, juvenile fall Chinook salmon in the lower Clearwater River grow more slowly (e.g., in 1995, an average of 0.8 mm/d [Connor et al. 2016]) and linger in riverine habitat longer

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[23] The Lower Snake River transitions from riverine habitat to slack water as it enters Lower Granite Reservoir. Facilities at Lower Granite Dam also provide an opportunity to measure all juvenile production, except that from the Tucannon River.

(e.g., 1995 date of peak dispersal July 2 [Connor et al. 2002]) than do juveniles in the two Hells Canyon MaSAs.

Research suggests that food supply and fish density are also strong factors influencing the behavior of juvenile fall Chinook salmon and the timing of their downstream dispersal from riverine habitat. As discussed in Appendix C, Connor et al. (2013) evaluated factors contributing to timing of dispersal downstream from the Upper and Lower Hells Canyon MaSAs. The data suggested that competition for food and space was a stronger factor for dispersal timing into Lower Granite Reservoir from these two reaches than were flow and temperature. 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 fall Chinook salmon after they initiate downstream dispersal from the relatively cool riverine habitat of the lower Clearwater River is heavily dependent on when they begin to move downstream. Juveniles that begin downstream dispersal in about June likely move downstream rapidly until they reach the lower 6 km of the Clearwater River, where river velocities decline markedly and the river transitions into slack water as it joins Lower Granite Reservoir (Tiffan et al. 2009a). These early dispersing fish have the opportunity to enter Lower Granite Reservoir, grow, and then continue migrating downstream along with their Snake River mainstem counterparts. However, a number of fall Chinook salmon in the lower Clearwater River do not begin downstream dispersal before July when water temperatures begin to rise in Lower Granite Reservoir (Cook et al. 2006). The conditions can potentially delay migration until the water temperatures decline in September (B. Arnsberg, unpublished data). These migrants continue to feed and grow along the cooler near-shore areas and within the reservoir, which is affected by cooler Dworshak Dam flow releases in the Clearwater River. Many of these juveniles do not resume active migration as subyearlings, likely because their slower development exposes them to environmental conditions (e.g., declining photoperiod and temperature) that suppress smoltification (physiological changes where juvenile salmonid fish adapt from living in freshwater to living in seawater) and favor a yearling (over-summering) life-history strategy.

Juvenile Rearing in Lower Granite Reservoir and Passage at Lower Granite Dam

Time of arrival and passage at Lower Granite Dam is closely associated with growth and juvenile development in the Lower Granite Reservoir, which in turn is influenced by water temperatures, fish abundance in the reservoir (including prey density), food availability, and a number of other factors that are not fully understood. Juveniles from the different major spawning areas share a common temperature environment in Lower Granite Reservoir that is regulated by releases of water from upstream storage projects. Maximum daily water temperatures in the surface waters of the reservoir can exceed 68 °F (20 °C) at times during summer months, a threshold known to adversely affect salmonid growth and condition. However, cool-water releases from Dworshak Dam result in substantial thermal stratification within Lower Granite Reservoir, allowing juveniles to avoid the higher surface temperatures by moving to cooler, deeper areas. 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.

Growth and outmigration timing of juvenile fall Chinook salmon in the reservoir is also influenced by fish abundance. Generally, growth of fall Chinook salmon rearing in Lower Granite Reservoir has declined in recent years, as total juvenile abundance (natural- and hatchery-origin) in the reservoir has increased due to actions implemented since listing, including cool-water releases from Dworshak Dam, improvements in flow management, increased hatchery production, reduced harvest rates, and other factors. Total abundance (natural- and hatchery-origin) of juvenile fall Chinook salmon in the reservoir averaged 13,670 in 1992 and 708,730 in 1999, and then increased even more, reaching an average of 1,109,660 in 2007 and 2,727,430 in 2012 (Tiffan and Connor 2015). Growth rates of natural-origin subyearling fall Chinook salmon in Lower Granite Reservoir over this same timeframe dropped, from an average of 0.6 ± 0.4 g/d during 1992-1999 to 0.2 ± 0.3 g/d during 2000-2011 (Connor et al. 2013). Factors contributing to this decline in growth may include increased competition between natural-origin and hatchery-origin and other fish, and changes in food resources.

The overall timing of juvenile outmigration past Lower Granite Dam has shifted and is now earlier than in the past. Juvenile Snake River fall Chinook salmon passed Lower Granite Dam 14 days later during 1992 through 1999 (July 14 ± 10 d) than they did during 2000 and 2011 (June 30 ± 6 d) (Connor et al. 2013). At present, approximately half of the fall Chinook salmon juvenile outmigrants pass Lower Granite Dam by June 30.

A similar response in growth and passage timing has not been documented for juveniles from the lower Clearwater River. Natural-origin juvenile fall Chinook salmon from the Clearwater River do not experience high levels of abundance in Lower Granite Reservoir because hatchery-origin juveniles, which make up the large majority of Snake River fall Chinook subyearlings, pass Lower Granite Dam before natural-origin juveniles from the lower Clearwater River enter the reservoir (Connor et al. 2012). Of all the major spawning areas, juveniles from the Clearwater River pass Lower Granite Dam the latest, and are likely the most benefited by cool-water releases from Dworshak Dam. For example in 2011, the median dates of passage for fish from the Upper Hells Canyon, Lower Hells Canyon, and Lower Clearwater River MaSAs were June 16, July 12, and September 28, respectively (Connor et al. 2012).

Accounts of fall Chinook salmon outmigration before construction of the lower Snake River dams indicate that the fish once exhibited an earlier migration timing than today. Mains and Smith (1964) examined smolt migration timing through the lower Snake River. In 1954 and 1955, they sampled juvenile anadromous salmonids 41 km downstream from the present location of Lower Granite Dam (constructed in 1973) during the outmigration of natural-origin fall Chinook salmon juveniles from the Middle and Lower Snake River. Based on daily catch data, passage of the entire Chinook salmon run was complete by the end of June (Mains and Smith 1964). In comparison, from 1992 through 1999, only 25 percent of the smolts from the Snake

River reaches had passed Lower Granite Dam by the end of June, and from 2000 through 2011, only 50 percent had passed by that time.

Juvenile Migration through Snake and Columbia Rivers, from Lower Granite Dam to Estuary

Consistent with the historically dominant life-history pattern, most juvenile fall Chinook salmon sustain active migration after passing Lower Granite Dam and enter the ocean as subyearlings. However, some juveniles delay seaward migration and enter the ocean as yearlings (Connor et al. 2005; McMichael et al. 2008; Appendix D). Fish that delay seaward migration continue to feed and grow, with little downstream movement, throughout winter in the mainstem Columbia River and estuary before entering saltwater in spring (Connor et al. 2005; Tiffan et al. 2012c).

Although the proportion of natural-origin juveniles that exhibits the yearling life history is not known, its contribution to adult returns has been widely documented. Connor et al. (2005) reported that 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) examined 120 adults presumed to be of natural-origin at Lower Granite Dam during 2006 to 2008 using otolith chemistry analysis. Results were consistent with the general findings in prior studies (Connor et al. 2002, 2005). Fish were successfully assigned to natal origin watersheds based on water chemistry signals in their otoliths. Fish originating from the Clearwater River basin had a significantly higher proportion of yearling ocean entry timing (n=44, 77 percent yearling entry) than the aggregate average. Fish identified as originating from spawning in the Upper Hells Canyon reach had a statistically significant lower proportion of yearling returns (n=16, 13 percent yearling ocean entry).

Hegg et al. (2017a, 2017b) updated results from the ongoing study of otolith patterns. Unmarked returning adults can be separated into six distinct regions of origin: the Clearwater River, the free-flowing Snake River (Upper and Lower Hells Canyon reaches), Lower Granite pool, Lyons Ferry Hatchery, Nez Perce Hatchery, and a group including the Grande Ronde, Imnaha, and Tucannon Rivers (Hegg et al. 2017a). The updated work identified considerable annual variation in regional contributions to aggregate spawning returns. In addition, further refinements in the chemical analyses and the statistical techniques identified more complex early rearing/migration patterns above Lower Granite Dam.

Juvenile Migration through the Estuary

The yearling and subyearling components of the ESU exhibit different strategies during migration through the Columbia River estuary. Yearling Snake River fall Chinook salmon migrate rapidly through the estuary (median travel time = 77.7 km/day), using the navigation channel and other large channels, according to a study using acoustic tags (McMichael et al. 2011). There is little evidence of extended rearing (weeks to months) by Snake River fall Chinook salmon yearlings in the estuary (Appendix D). Instead, they generally move through the estuary in less than a week, similar to yearling Snake River spring/summer Chinook salmon. Some subyearlings enter shallow floodplain habitat below Bonneville Dam (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. 2015; Roegner et al. 2012; Teel et al. 2014).[24]

Ocean Dispersal and Rearing

Yearling and subyearling migration patterns can also differ once they reach the ocean and enter the Northern California Current. Subyearlings migrate more slowly, are found closer to shore, and disperse both north and south of the plume (Trudel et al. 2009; Tucker et al. 2011; Sharma and Quinn 2012; Fisher et al. 2014; Teel et al. 2015; Appendix D). By the beginning of their second year at sea, yearling fall Chinook salmon from the Columbia River basin have moved off the continental 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 two to five years in the Pacific Ocean, depending on sex and age at the time of ocean entry (Connor et al. 2016). 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 (of 1998 to 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 to 2003 returns), while males that enter saltwater as yearlings have a relatively even ocean-age class distribution (of 1998 to 2008 returns, 29 percent returned after two years, 31 percent after three years, and 24 percent after four years). Some maturing males (referred to as jacks) return to the river after one year or less in the ocean (approximately 16 percent of males) and are not considered full-term adults because they are relatively small in body size (Connor et al. 2016). Adult fall-run Chinook salmon, including Snake River fall Chinook salmon, return to the Columbia River in August and September (Connor et al. 2016).

2.7 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, and must be made in an open public process and within specific time

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[24] Data cited in these studies were given a ≥ 80 percent likelihood of Snake River fall Chinook salmon genetic stock assignment. However, there is some potential that these individuals were either Upper Columbia River summer/fall Chinook salmon or Snake River fall Chinook that spawned below Bonneville Dam, based on the presence of fry (< 60 mm) observed during March to June in Roegner et al. (2012). Snake River fall Chinook salmon fry do not emerge from the gravel before late March-early April (Connor et al. 2002) and do not usually emigrate to the lower river before July.

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. Critical habitat is not designated in foreign countries or other areas outside U.S. jurisdiction (50 CFR §424.12 [h]).

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.[25]

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) (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 (58 FR 68543; 70 FR 52630).[26]

By designating these essential features as critical habitat, NMFS recognizes that portions of the designated critical habitat may be in a degraded condition. These physical and biological features have been designated because of their potential to develop or improve and eventually provide the ecological functions needed to support species' recovery. Other portions of critical habitat have been designated because, even in a degraded condition, the value they provide is essential to species survival and recovery.

NMFS designated critical habitat for Snake River fall Chinook salmon on December 28, 1993 (58 FR 68543). The designation consists of all Columbia River estuarine areas,[27] as well as river reaches upstream to the confluence of the Columbia and Snake Rivers, and all Snake River

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[25] Regulations finalized in 2016 addressed this section 7 analysis by defining destruction or adverse modification of critical habitat as "a direct or indirect alteration that appreciably diminishes the value of critical habitat for the conservation of a listed species. Such alterations may include, but are not limited to, those that alter the physical or biological features essential to the conservation of a species or that preclude or significantly delay development of such features" (81 FR 7214).

[26] 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) and in Section 5.2.6.

[27] 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) (58 FR 68543).

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) (58 FR 68543).

2.8 Related Programs and Efforts since Listing

A variety of existing forums ─ each with distinct mandates and appropriate make-up of federal, state, tribal, industry, and local representatives ─ have conducted and are continuing to conduct significant efforts to improve the status of Snake River fall Chinook salmon. While many of these efforts were spurred by the ESA listings, some were underway even before that. The drastic declines in Snake River fall Chinook salmon runs by the early 1970s prompted managers to initiate several actions to improve the runs.[28] These included utilizing the egg-bank program, which had begun in 1976 to provide mitigation for lost habitat, to focus instead on conserving the gene pool and augmenting natural spawning, as well as the use of barges and trucks beginning in the late 1970s to transport some juvenile fall Chinook salmon past the lower Snake River dams. Continued declines in run size also spurred harvest managers to begin developing harvest agreements in the 1980s, including the Pacific Salmon Treaty with Canada in 1985, and then to implement significant harvest reductions in the early 1990s.

Since NMFS listed Snake River fall Chinook salmon under the ESA in 1992, ESA protections have contributed substantially to conserving the species. 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 (58 FR 68543) and the July 10, 2000, 4(d) rule (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 activities authorized by, funded by, or directly 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 or adversely modify its critical

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[28] 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 ESU.

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.

2.8.1 Federal Columbia River Power System

The Federal Columbia River Power System (FCRPS) comprises 31 federally owned multipurpose dams in the Columbia River and its tributaries (i.e., the Willamette River, Upper Snake River, etc.). The system is managed collaboratively by three federal agencies: the Bonneville Power Administration (BPA), the U.S. Army Corps of Engineers (Corps), and the U.S. Bureau of Reclamation (USBR). The FCRPS ESA section 7 consultation focuses on 14 of these projects, which are operated as a coordinated water management system: Bonneville, The Dalles, John Day, McNary, Chief Joseph, Albeni Falls, Libby, Ice Harbor, Lower Monumental, Little Goose, Lower Granite, and Dworshak Dams (operated and maintained by the Corps) and the Hungry Horse Project and Columbia Basin Project, which includes Grand Coulee Dam (operated by the USBR). The FCRPS consultation also includes the mainstem effects of other tributary projects in the Columbia Basin.

Collectively, BPA, the Corps, and the USBR (hereinafter, the FCRPS action agencies) maximize the use of the Columbia River by generating power, protecting fish and wildlife, providing flood risk management, providing irrigation and navigation, and sustaining cultural resources. The FCRPS provides about 60 percent of the region’s hydroelectric generating capacity. It also 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 (federal, non-federal, and Canadian) on the major tributaries and mainstem of the Columbia totals 55.3 million acre-feet.

In 1992, NMFS and the FCRPS action agencies completed their first ESA section 7 consultation on the FCRPS, and NMFS issued a biological opinion. More than two decades of ESA consultations and ongoing litigation involving multiple diverse plaintiffs ─ including environmental organizations, river users, states, and tribes ─ have ensued. NMFS issued the most recent FCRPS biological opinion in 2008 and supplemented it in 2010 and 2014 (NMFS 2008b, 2010, 2014c).[29]

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[29] It is the state of Oregon’s position that additional or alternative actions to the FCRPS biological opinion should be taken in mainstem operations of the FCRPS to advance the persistence and recovery of ESA-listed salmon and steelhead. Some additional or alternative actions recommended by Oregon, while considered, were not included in NMFS’ FCRPS biological opinion. At this time, Oregon is a plaintiff in litigation against the FCRPS action agencies and NMFS, challenging the adequacy of the measures contained in the current (2008 as supplemented in 2010 and 2014) FCRPS biological opinions.

On May 4, 2016, the U.S. District Court for the District of Oregon ruled on litigation concerning the 2008 FCRPS biological opinion and its supplements.[30] The court's order did not vacate the 2008 biological opinion or its supplements, but it did issue a remand requiring NMFS to develop a new biological opinion. It also ordered the Corps and the USBR to comply with the National Environmental Policy Act (NEPA). On July 6, 2016, the court adopted the federal agencies' proposed schedules for these tasks. Under the court-ordered schedule, the FCRPS action agencies are to complete a final environmental impact statement (EIS) no later than March 26, 2021, and issue records of decision no later than September 24, 2021. The EIS will address the operation, maintenance, and configuration of the 14 projects that are operated as a coordinated water management system and that are the focus of the FCRPS biological opinion (see above). NMFS must complete a biological opinion correcting the deficiencies identified in the court's May 4, 2016, ruling on or before December 31, 2018. NMFS will coordinate with the federal agencies as they develop their NEPA analysis. To integrate the decision that will result from the NEPA process with ESA section 7, NMFS expects to complete a subsequent biological opinion following the selection of a preferred alternative in the EIS.

On April 3, 2017, the court issued a related order directing the parties to confer on a process to develop a spill implementation plan for increased spring fish passage spill in 2018 and to begin bypass operations on March 1 of each year. Consistent with prior court orders, the FCRPS action agencies will continue to implement all other actions called for in the 2008 FCRPS biological opinion and its supplements through 2018.

Since ESA listing, the FCRPS action agencies have made significant changes to improve salmon survival. These changes include structural improvements and additions to fish passage facilities, such as the installation of surface passage routes at all eight federal dams with fish passage; operational changes in flow and spill; improvements to the juvenile transportation program; and increased off-site mitigation through tributary and estuarine habitat improvement, predator control, and hatchery reform. Actions implemented under the FCRPS biological opinions have contributed, and will continue to contribute, to improving the status of Snake River fall Chinook salmon, which must navigate six to eight lower Snake and Columbia River projects both as out-migrating juveniles and as returning adults.[31] In future FCRPS biological opinions, we anticipate that the actions benefitting Snake River fall Chinook salmon will be evaluated based on new information and that their implementation will either continue or be updated as appropriate and in consideration of recovery goals.

2.8.1.1 Structural and Operational Improvements

Primarily through the Corps' Columbia River Fish Mitigation Project, structural improvements have been added to improve fish passage at all eight FCRPS dams that Snake River fall Chinook

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[30] *NWF v. NMFS*, 184 F.Supp.3d 861 (D. Or. 2016).

[31] There are four federal dams on the lower Snake River mainstem (Lower Granite, Little Goose, Lower Monumental, and Ice Harbor) and four on the lower Columbia River mainstem (McNary, John Day, The Dalles, and Bonneville). Most Snake River fall Chinook salmon pass all eight projects; fish from the Tucannon River, which joins the Snake River downstream from Little Goose Dam, pass only six of the projects. (A small number of fall Chinook spawn in the tailraces of Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Dams; their progeny pass four to seven of the projects).

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 configuration and operational improvements at the mainstem lower Snake and Columbia River dams, along with improved flow management programs and cool-water releases from Dworshak Dam on the North Fork Clearwater River to reduce summer water temperatures, in concert with other measures described in this section, have substantially increased both juvenile survival rates (Figure 2-15) and the number of returning adults.

Configurations and operations at the dams are designed to achieve the 2008 FCRPS biological opinion hydropower dam passage performance standards of 93 percent survival at each project for subyearling migrating juvenile fish and, for adults, 81.2 percent survival from Bonneville to Lower Granite Dam, after accounting for harvest and estimates of natural straying (NMFS 2008b). Recent estimates of average adult Snake River fall Chinook salmon survival between Bonneville and Lower Granite Dams after accounting for harvest and natural straying are 91.0 percent (95.8 percent from Bonneville to McNary Dam and 94.9 percent from McNary to Lower Granite Dam; Table 2 in Appendix E). Juvenile Snake River fall Chinook salmon passage rates have also improved because of FCRPS changes, including provision of 24-hour summer spill and the addition of surface spillway weirs at the Snake and Columbia mainstem projects. Survival studies show that with few exceptions, the fish passage improvement measures are performing as expected and are achieving, or are very close to achieving, the juvenile dam passage survival objectives (NMFS 2014c; USACE et al. 2017). In addition, hydropower system improvements appear to have substantially decreased travel times and exposure to high temperatures for actively migrating smolts, and substantially and consistently increased their overall survival rates between Lower Granite and McNary Dams (Figure 2-15).

The 2017 Hydro Module (Appendix E) provides further information on changes to the FCRPS since 1994, as well as improvements in passage rates. In addition, the FCRPS action agencies Endangered Species Act Federal Columbia River Power System Annual Progress Reports and Comprehensive Evaluations, detail the implementation and progress of the 2008 biological opinion actions (USACE et al. 2009, 2010, 2011, 2012, 2013, 2015, 2017).

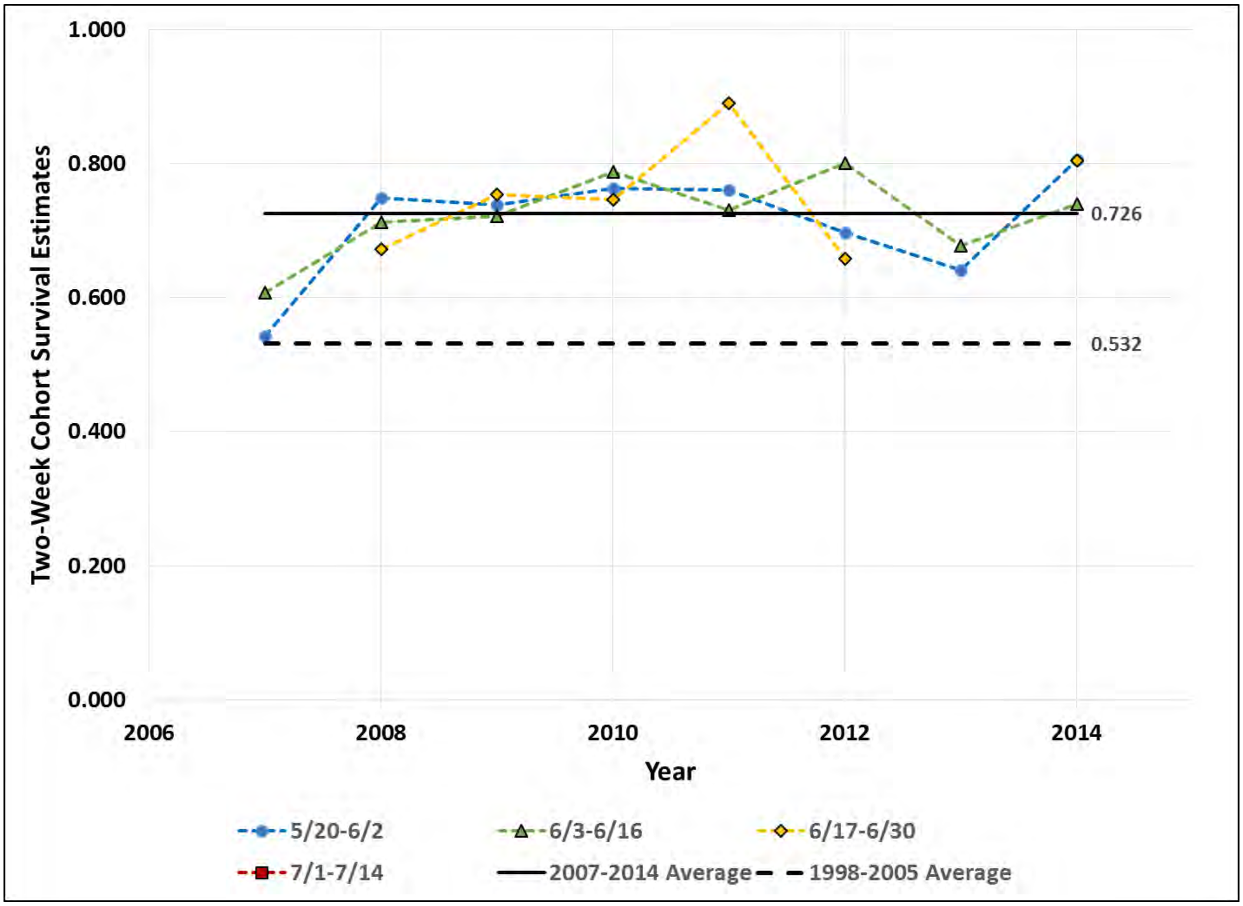

Figure 2-15. Estimated average survival rates for two-week cohorts of hatchery-origin subyearling SR fall Chinook salmon in the reach between Lower Granite and McNary Dams (2007 to 2014). The horizontal solid line is the average annual survival across that eight-year period; the dashed line is the average annual survival during 1998-2005, an earlier period representing limited summer spill and before the installation of surface passage routes.

2.8.1.2 Juvenile Transportation

Since the late 1970s, managers have used barges or trucks to transport some juvenile fall Chinook salmon past the lower Snake River dams. The intent of these transportation programs is to eliminate mortality the juveniles would otherwise experience by passing multiple dams, and thereby to achieve higher rates of juvenile survival. From 2008 to 2011, an average of 52.8 percent of subyearling Snake River fall Chinook salmon were transported (DeHart 2012).

Managers continually evaluate the value of transportation as a strategy to improve juvenile survival. Before 2005, the FCRPS action agencies did not provide any voluntary spill at the Snake River dams during the summer migration season, and transport was considered essential. In 2005, the FCRPS action agencies began providing spill at the lower Snake River projects during the summer months to enhance juvenile migration and survival. In 2007, managers initiated a study to assess the benefit of transporting Snake River fall Chinook salmon juveniles. The study, funded by the Corps of Engineers, was a collaborative effort between NMFS, the Corps, the U.S. Fish and Wildlife Service, the Nez Perce Tribe, and the states of Idaho and Oregon.

The study was designed to compare the adult return rates of juvenile Snake River fall Chinook salmon collected at Lower Granite, Little Goose, or Lower Monumental Dam and transported below Bonneville Dam via barge or truck to the return rates of fish that passed the dams via bypass systems and migrated in-river. All study fish were tagged with passive integrated transponder (PIT) tags and released at various sites upstream of Lower Granite Dam. The results suggest that adult returns would be higher if juveniles migrating early in the season (before July 1) passed the dams via bypass systems and those migrating later in the summer were transported via barge or truck (Smith et al. 2017).

Another study ─ the Comparative Survival Study ─ has also evaluated the relative effects of juvenile transportation versus in-river migration. As part of that study, McCann et al. (2016) assessed the likelihood of adult returns for transported subyearling fall Chinook salmon. These researchers analyzed data only for fish that migrate primarily before July. Their results showed a benefit to in-river migration for 31 of 48 adult return cohorts while 17 cohorts showed a transport benefit.

Managers will use the results of these studies to inform future management decisions.

2.8.1.3 Offsite Mitigation: Habitat Improvement, Predation Control, and Hatchery Reform

Since 2000, FCRPS biological opinions have included offsite mitigation actions in addition to actions related to structural improvements and operational changes at dams as part of a package of actions to meet ESA section 7 requirements. Thus, the FCRPS action agencies have been funding and implementing substantial tributary and estuary habitat improvement programs, predator control for avian predators and northern pikeminnow, and hatchery reform actions. These offsite mitigation actions are described in the reasonable and prudent alternative for the 2008 FCRPS biological opinion well as in the 2010 and 2014 FCRPS supplemental biological opinions. Implementation is summarized in the FCRPS action agencies' Annual Progress Reports and Comprehensive Evaluations (USACE et al. 2009, 2010, 2011, 2012, 2013, 2015, 2017). In general, predator control and estuary habitat actions are likely to benefit juvenile fall Chinook from all five spawning groups while tributary habitat actions should improve conditions for the Grand Ronde and Tucannon spawning groups. The hatchery reform actions in the 2008 FCRPS biological opinion will help to ensure use of best management practices at hatcheries and provide funding for Snake River fall Chinook research.

2.8.2 Columbia Basin Fish Accords

Implementation of many of the 2008 FCRPS biological opinion actions depends on cooperation among federal agencies, states, and tribes. To promote regional collaboration and supplement the 2008 FCRPS biological opinion, the FCRPS action 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.[32] Under these 10-year Accords, BPA provides funding for projects to benefit Columbia basin salmon and steelhead, and receives greater certainty regarding hydropower operations. The Accords are intended to assist the FCRPS action agencies in meeting their obligations under the ESA, and to offer tribes and state fishery managers greater certainty in project funding.

The Accords directly addressed long-standing issues between the tribes and the FCRPS action agencies, including spill regimes, which are particularly important for outmigrating juvenile Snake River fall Chinook salmon. 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 Lyons 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 described below in Section 2.8.8.

2.8.3 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). The Northwest Power 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." It 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 and its licensees. The Council updates its 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 biological opinion, ESA recovery plans, and the 2008 Columbia Basin Fish Accords. The Council sponsors independent scientific review of Columbia Basin Fish and Wildlife Program actions proposed for funding and follows up with science reviews of the actions from the Independent Scientific Review Panel. It also sponsors the Independent Scientific Advisory Board, which serves NMFS, Columbia River tribes, and the Council by providing independent scientific advice and recommendations regarding specific scientific issues.

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[32] Though the Nez Perce Tribe was not a signatory to the agreement, its projects are consistent with those of the other tribes and CRITFC, thereby creating a system-wide approach to salmon restoration.

2.8.4 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 of non-federal hydropower projects, issued a Final Environmental Impact Statement (FEIS) 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, generally from mid-October to early December. It also provides minimum flows through the winter and early spring to protect incubating eggs and emerging fry. Additionally, since 2005, Idaho Power Company has voluntarily implemented a Juvenile Fall Chinook Salmon Entrapment Management Plan to document the extent of use by juvenile fall Chinook salmon rearing in the vicinity of entrapment pool areas between March 15 and June 15. This plan also establishes operational protocols to ensure that high priority entrapment sites are reconnected for at least two hours each day to the main river (Brink and Chandler 2011). These protocols are thought to be far more protective than the ramping rates suggested by FERC in the 2007 FEIS.

NMFS provided comments and preliminary recommended terms and conditions for the Hells Canyon Hydroelectric Project during the relicensing process (NMFS 2006).[33] In its comments, NMFS recommended additional funding to accelerate habitat restoration in the historical Marsing reach downstream of Swan Falls Dam. NMFS did not exercise its authority under section 18 of the Federal Power Act to require fish passage at any of the Hells Canyon Project dams. This is because the water quality impairments in the Snake River upstream of the Hells Canyon Complex would, at present, prevent the successful reintroduction of naturally producing fall Chinook salmon. In addition, insufficient information is available to identify a fish passage method for juveniles that has a reasonable likelihood of success. NMFS recommended that future studies to inform decisions regarding fish passage be required as part of the new license conditions (NMFS 2006).

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. Efforts to resolve the remaining water quality, fish passage, and ESA issues remain underway. Ultimately, after the 401 water quality certification is issued and pertinent ESA section 7 consultations have been completed, FERC will issue a new

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[33] 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).

license governing the future operation of the Hells Canyon Complex for a 30 to 50 year period; however, it is not clear when this process will be completed.

2.8.5 Additional Mainstem and Estuary Programs and Actions

Numerous actions have been implemented or are currently underway to restore habitat conditions in the Columbia River mainstem and estuary. These efforts include reconnecting side channels in floodplain habitats, improving water quality, relocating nesting sites for birds that prey on migrating juvenile salmonids, and implementing other actions that improve migratory and rearing conditions for Snake River fall Chinook salmon and other salmon and steelhead.

Some of these actions, such as those carried out under the FCRPS biological opinion, were prompted by ESA listings. Others have been implemented under other regulatory or voluntary programs. In the estuary (i.e., the lower Columbia River below Bonneville Dam), many actions have been implemented by the Lower Columbia Estuary Partnership, a National Estuary Program working to bring together federal state, tribal, local, and private entities to plan, implement, and monitor habitat protection and restoration efforts in the Columbia River estuary. The number of “on-the-ground” actions has increased in recent years as the Columbia River Estuary Study Taskforce, the Columbia Land Trust, the Oregon Department of Fish and Wildlife, the Washington Department of Fish and Wildlife, and the Cowlitz Indian Tribe also have developed or completed restoration projects.

ESA section 7 consultations have also ensured that activities such as dredging for navigation; development of docks and other overwater structures; port development; issuance of Clean Water Act National Pollutant Discharge Elimination System (NPDES) permits; Clean Water Act 401 water quality certifications; and other urban and agricultural activities with federal funding or permits comply with ESA section 7. Individually, these consultations have resulted in actions that avoided jeopardy to the species and adverse modification of critical habitat within individual action areas. Collectively, these consultations have begun to reconnect off-channel habitat in the historical floodplain, which provides rearing areas for small subyearlings and exports insect prey to the mainstem migration channel where they are consumed by large smolts (Diefenderfer et al. 2016). For more information on actions in the estuary, see the Estuary Module (Appendix F), the Lower Columbia Estuary Partnership’s Year in Review reports (available online at http://www.estuarypartnership.org), and the FCRPS action agencies’ 2016 Comprehensive Evaluation (USACE et al. 2017).

2.8.6 Additional Tributary Habitat Programs and Actions

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. Tributary habitat conditions affect the viability of fall Chinook salmon using those tributary reaches, and provide cold-water refugia that are important for Snake River fall Chinook salmon.

Since the ESA listing, 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 improving ecosystem function in the tributaries.[34]

In addition, many entities throughout the Snake River basin continue to work to protect and restore tributary habitat conditions in Oregon, Washington, and Idaho. These entities include regional recovery boards, watershed councils, tribal governments, state and federal agencies, and non-governmental organizations and private landowners. Collectively the efforts of these entities have improved riparian quality and management, water management, and water quality, all of which have influenced, at least indirectly, Snake River fall Chinook salmon spawning and rearing habitat quality.

2.8.7 Harvest Management

Snake River fall Chinook salmon encounter fisheries in the ocean from Alaska to California, and in the mainstem Columbia River and some tributaries. Fisheries do not directly target ESA-listed natural-origin fall Chinook salmon. Instead they target marked hatchery fish (fall Chinook salmon and other species) and non-listed natural fish (fall Chinook salmon and other species).[35] Natural-origin fall Chinook salmon are caught incidentally in these fisheries, and these fisheries are managed to limit impacts on natural-origin Snake River fall Chinook salmon and other ESA-listed species, while optimizing harvest of healthier stocks to the extent possible within constraining limits for weak stocks. Historically, Snake River fall Chinook salmon were subject to total exploitation rates approaching 80 percent. Since ESA listing, harvest impacts in both ocean and in-river fisheries have been substantially reduced. The total exploitation rate has been relatively stable at 40 to 50 percent since the mid-1990s (Ford et al. 2011).

Multiple entities and processes are involved in managing fisheries that affect Snake River fall Chinook salmon. They are described briefly below:

- Ocean fisheries in Southeast Alaska, British Columbia, and off the coasts of Washington and most of Oregon are managed under the Pacific Salmon Treaty (PST), which was initially ratified by the United States and Canada in 1985. The PST is implemented by the Pacific Salmon Commission, which negotiates, facilitates, and monitors the implementation of fishing regimes developed under the treaty. The fishing regimes are not self-executing, however, so management entities in the United States and Canada must pass regulations that conform with the regimes, which tend to be renegotiated on a decadal schedule. In the United States south of the Canadian border, the Pacific Fishery Management Council is responsible for regulating regimes agreed to by the Pacific

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[34] In addition, as noted above in Section 2.8.1.3, the FCRPS action agencies implement a tributary habitat improvement program as part of the offsite mitigation under the FCRPS biological opinion that has funded hundreds of tributary actions.

[35] Throughout this document we use the term "marked" to denote fish that are identifiable, in most cases either though an external fin clip, an internal coded wire tag (CWT), or both. Thus "marked" fish include both "clipped" and "tagged" fish.

Salmon Commission, while 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 Pacific Salmon Commission reached agreement on the current PST fishing regimes in May 2008; the parties approved them in December 2008, and they went into effect on January 1, 2009, and will continue through December 31, 2018. NMFS completed an ESA biological opinion on these regimes on December 22, 2008 (NMFS 2008b). As mentioned above, renegotiation of PST fishing regimes tends to occur every decade, and negotiations are underway for establishing an updated regime for when the current regime expires.

- The Magnuson-Stevens Fishery Conservation and Management Act (MSA) is the principal law governing fisheries in waters of the United States (i.e., 3 to 200 nautical miles offshore of the U.S. coastline). The Pacific Fisheries Management Council (PFMC), one of eight regional fishery management councils established under the MSA, is responsible for all fisheries (salmon, groundfish, pelagic fish, etc.) off the coasts of California, Oregon, and Washington (including fisheries regimes agreed to by the Pacific Salmon Commission). NMFS consulted on the effect of ocean fisheries on Snake River fall Chinook salmon in a March 8, 1996, biological opinion (NMFS 1996) and subsequently in a November 11, 1999, biological opinion on the 1999 Pacific Salmon Treaty Agreement (NMFS 1999). These opinions set standards regarding the combined effect of all ocean fisheries on Snake River fall Chinook salmon that are applied in annual management decisions. The 1999 biological opinion required 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. This is the current standard that was used in the biological opinion in 2008 (NMFS 2008b), and remains in effect today.
- 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 Northwest Indian Fisheries Commission member tribes; it occurs largely coincident with the PFMC process. In the NOF process, co-managers develop pre-season fishing plans that are coordinated between ocean and in-river fisheries to ensure that conservation and various allocation objectives are met. Allocation objectives include treaty/non-treaty tribal allocations and allocations between various non-treaty user groups, such as commercial and recreational fisheries.
- Fisheries in the Columbia River basin, particularly in the mainstem, are managed pursuant to harvest plans developed by the parties to *U.S. v. Oregon*, the ongoing federal court proceeding that enforces and implements the Columbia River treaty tribes’ reserved fishing rights. Parties to this process include the federal government, the states of Oregon, Washington, and Idaho, the four Columbia River treaty tribes (the Confederated Tribes of the Umatilla Indian Reservation, the Confederated Tribes and Bands of the Yakama

Nation, the Nez Perce Tribe, and the Confederated Tribes of the Warm Springs Reservation of Oregon), and the Shoshone-Bannock Tribes of Idaho. A negotiated *U.S. v. Oregon* Management Agreement for 2008–2017 (U.S. District Court 2008) includes management provisions for fisheries that affect Snake River fall Chinook salmon. NMFS completed an ESA section 7 consultation on this agreement in a biological opinion dated May 5, 2008 (NMFS 2008b).

- Recreational fisheries in the tributaries of the Columbia and Snake Rivers are managed by Idaho, Washington, and Oregon for their respective waters. Each tribe also regulates the tributary fisheries under its respective jurisdiction. 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. Additional harvest impacts to Snake River fall Chinook salmon occur in fisheries in the mainstem Snake River above Lower Granite Dam (outside the scope of the 2008-2017 *U.S. v. Oregon* Management Agreement) and in lower reaches of the associated tributaries, but these are limited primarily to incidental catches that occur in fisheries directed at steelhead.

For more detail on harvest management and harvest impacts to Snake River fall Chinook salmon, see Chapter 5 and the Harvest Module (Appendix G).

2.8.8 Hatchery Programs

The Snake River fall Chinook salmon ESU currently includes four interrelated hatchery programs: the Lyons Ferry Hatchery, the Fall Chinook Acclimation Project, the Nez Perce Tribal Hatchery, and the Idaho Power Company programs. Fish from these programs are all considered part of the Snake River fall Chinook salmon ESU (70 FR 37160).[36] All four programs are funded as mitigation for fish production lost through construction and operation of hydropower dams in the Columbia and Snake River Basins. Releases of hatchery fish from these programs all provide fish for harvest, but some releases are also intended to return hatchery fish to spawn naturally to increase the abundance of the naturally spawning population. This conservation-oriented use of hatchery fish is called supplementation.

Fall Chinook salmon hatcheries have a long history in the Snake River. Connor et al. (2015) provides a comprehensive, extensively documented history of artificial production efforts for this species; unless otherwise noted, all the historical material in the following paragraphs is taken from this report. Gilbert and Evermann (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 at Ontario, Oregon in

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[36] As stated in NMFS Hatchery Listing Policy (70 FR 37160), 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.

1902. In its early years, as many as 25 million eggs were collected from Snake River fall Chinook salmon annually, but in the later years egg-take dropped off to the point where the majority of eggs at the hatchery were transferred from the Big and Little White Salmon hatcheries in the lower Columbia Basin. The hatchery was deemed unsuccessful and abandoned in 1909.

The second major hatchery effort for Snake fall Chinook salmon began as a response to impacts from the Hells Canyon Complex dams, which were constructed beginning in 1955. Initially fish were trapped and passed upstream of the dams, but this proved unsuccessful at maintaining production, so a hatchery operation began in 1962 just downstream from Oxbow Dam. Initially fish for broodstock were captured at Oxbow Dam, but fish collection moved in 1967 to the recently completed Hells Canyon Dam. This program proved incapable of sustaining itself, and was discontinued in 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 River dams. The LSRCP called for the construction and operation of several hatcheries to produce salmon, steelhead, and resident trout as part of the LSRCP mitigation responsibilities. One of these new hatcheries, the Lyons Ferry Fish Hatchery, was designated for the development of a large-scale fall Chinook salmon production program to be managed by the Washington Department of Fish and Wildlife (WDFW).

Because the Snake River fall Chinook salmon run had already dropped to a precariously low level by this time, WDFW also initiated an egg-bank program in 1976 to prevent extinction of the run before the new hatchery could be completed. WDFW collected adult fish for the egg-bank program at Ice Harbor Dam. Juveniles were released either in the lower Columbia River or the Snake River, depending on where they were reared. Some adult fall Chinook salmon from the egg-bank program were also collected as broodstock when they returned to the lower Columbia River. The egg-bank program was terminated in the fall of 1984 when the Lyons Ferry Hatchery became operational.

In the early years of the Lyons Ferry Hatchery program, fall Chinook salmon broodstock were collected by trapping at lower Snake River dams (Bugert and Hopley 1989). This practice incorporated some level of out-of-ESU strays into the Lyons Ferry Hatchery program, which 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. Additionally, since 1990, broodstock have been collected at Lower Granite Dam, the most upstream of the four lower Snake dams, where fewer out-of-ESU strays are likely to occur. 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.

The hatchery effort has grown in size and complexity. The initial focus was to provide fish for harvest as well as to help maintain/rebuild returns of Snake River fall Chinook salmon to mitigate for losses caused by construction and operation of the four lower Snake River dams (assuming the mitigation program premise that approximately 52 percent of the Snake River salmon runs would be naturally produced [NPCC 2008]). Initially, juvenile hatchery fish were released only at the Lyons Ferry Hatchery, which is well below most of the area available for natural spawning. The intent of this phase of the Lyons Ferry Hatchery program was to increase hatchery releases, adult returns, and broodstock availability to levels sufficient to support releases upstream of Lower Granite Dam. However, return rates of hatchery-released fall Chinook salmon declined in the early 1990s (Bugert et al. 1997), and hatchery broodstock collections were compromised (particularly in 1989) by out-of-basin hatchery strays, mostly from the Umatilla program (Hayes and Carmichael 2002), which resulted in a substantial decrease in hatchery releases for several years.

Over time, the hatchery effort has become focused more on supplementation, with an increasing proportion of fish released above Lower Granite Dam; currently 70 percent of the hatchery fish are released above Lower Granite Dam. A major change in this direction of supplementation was the 1995 implementation of the Fall Chinook Acclimation Project,[37] 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 that, through imprinting, the juveniles will return as adults to spawn in the areas where they acclimated, thus reducing straying rates. Initially, the tribe released acclimated juveniles at four locations and WDFW released non-acclimated fish at one site, near Couse Creek on the Snake River. Direct releases of fall Chinook salmon into the Grande Ronde River began in 2005 as an effort to boost production in that area.

Coincident with these increased supplementation releases, added releases of fish intended for harvest have also occurred. The Idaho Power Company program, which releases approximately 1 million fish near Hells Canyon Dam, began in 2000. The program started as a result of the 1980 Settlement Agreement for loss of production of anadromous fish as a result of construction and operation of the Hells Canyon Complex. Eggs were not made available from the Lyons Ferry Hatchery until the fall of 1999 for release 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.

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[37] Often called the Fall Chinook Acclimation Program.

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 75 percent of these fish are acclimated before release. Production goals, release sizes, release locations, release priorities, life stage at release (yearling or subyearling), and marking/tagging rates of released fish for all four Snake River fall Chinook salmon hatchery programs are established through the *U.S. v. Oregon* management process. Figure 2-16 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 (NMFS 2012a). The biological opinion supported NMFS' decision to issue permits to operate the Snake fall Chinook hatchery programs through 2018 as agreed to in the *U.S. v. Oregon* management agreement in terms of release levels, release sites, and marking/tagging. The biological opinion also required additional RM&E (described in Chapters 6 and 7 of this recovery plan) to address key knowledge gaps about the impact of the hatchery programs on the natural population, under the assumption that the data from the enhanced RM&E would be used to guide future hatchery management.

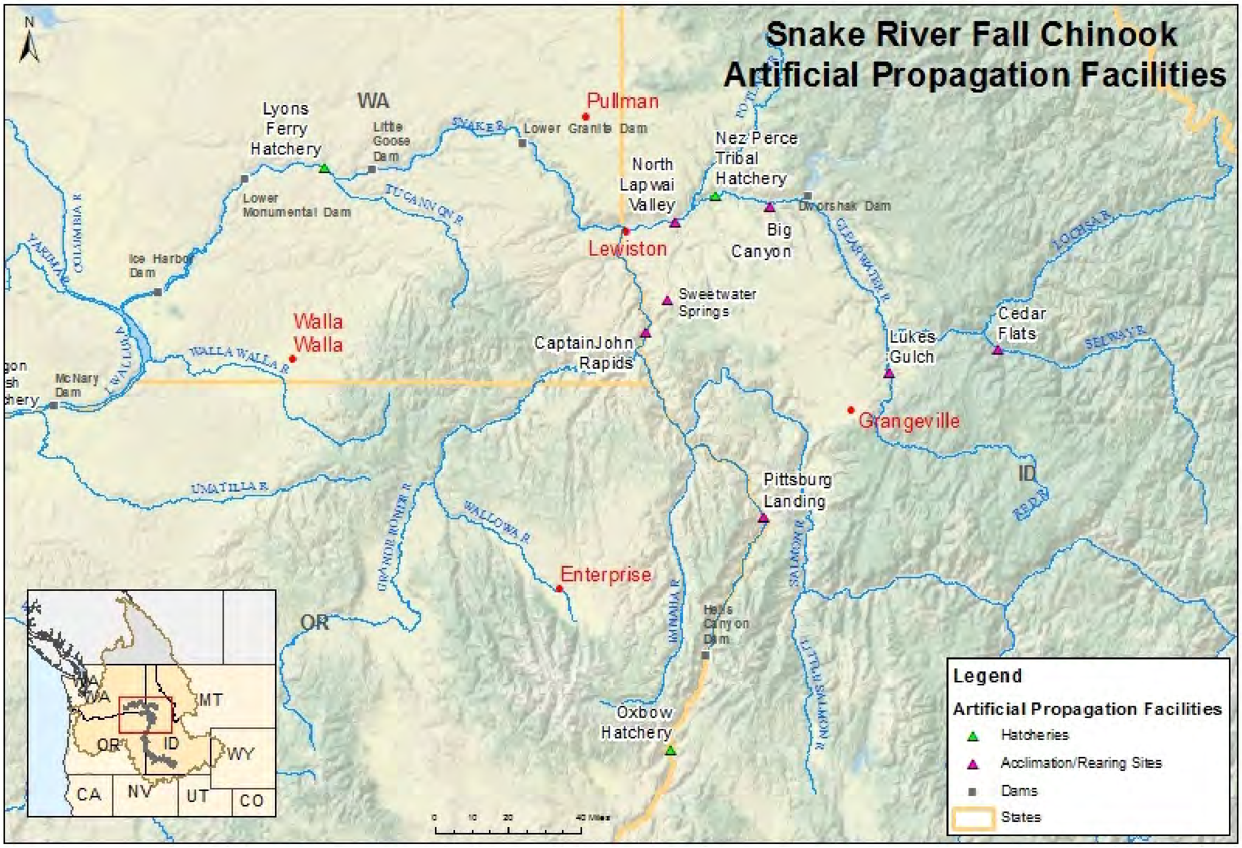

Figure 2-16. Snake River fall Chinook salmon hatcheries and acclimation facilities.

2.9 Relationship of Existing Programs to Recovery Plan

The overall recovery strategy for Snake River fall Chinook salmon incorporates the ongoing implementation of the programs described above, which collectively have contributed significantly to the gains the ESU has made since ESA listing. NMFS intends to continue working with the entities implementing these programs, and to continue working within the framework of existing efforts whenever possible and not create duplicative efforts.

Also, while this recovery plan is not regulatory or binding, it does incorporate the 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 Plan also describes actions needed in addition to existing programs to achieve the Plan’s goals. More details about specific recovery actions are described in Chapter 6 (Recovery Strategy and Site-Specific Actions).

3. Recovery Goals, Objectives, and Delisting Criteria

This chapter describes NMFS' goals, objectives, and criteria for ESA recovery (delisting) of Snake River fall Chinook salmon. The ESA recovery goal provides a general statement of conditions that would support delisting, while the ESA recovery objectives describe general characteristics relative to abundance and productivity, spatial structure, diversity, and threats to the species that further describe a status consistent with the ESA recovery (delisting) goal. The ESA recovery, or delisting, criteria are the "objective, measurable criteria" (ESA section 4(f)) that NMFS will use to evaluate species status and determine whether the species should be removed from the list of threatened and endangered species. NMFS applies two kinds of delisting criteria: biological viability criteria, which describe population or demographic parameters, and threats criteria, which relate to the five listing factors in ESA section 4(a)(1).

The chapter also describes broad sense recovery goals. Broad sense recovery goals generally are developed by stakeholders and go beyond the requirements for delisting under the ESA to address other legislative mandates or social, cultural, ecological, and economic benefits that are derived from having healthy, diverse salmon populations. NMFS includes them in recovery plans to provide additional direction to strategic approaches to ESA recovery and to inform management for the species after delisting occurs; however, broad sense goals do not need to be met as a prerequisite to delisting.

3.1 Snake River Fall Chinook Salmon Recovery Goals and Objectives

3.1.1 ESA Recovery Goal and Objectives

ESA Recovery Goal

ESA recovery 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 component populations and major population groups 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 artificial propagation measures to achieve its viable characteristics. Artificial propagation may contribute to recovery, but is not a substitute for addressing the underlying factors (threats) causing or contributing to a species' decline.

ESA Recovery Objectives

The ESA recovery objectives below define general characteristics relative to abundance and productivity, spatial structure, diversity, and threats to the species that are consistent with the ESA recovery goal. These objectives reflect the guidelines in the NMFS Technical Memorandum *Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units* (McElhany et al. 2000) and in the ICTRT's *Viability Criteria for Application to Interior Columbia Basin Salmonid ESUs* (2007), described in Sections 2.4 and 2.5. They describe the desired characteristics for the ESU and populations that the ICTRT's recommended viability criteria (ICTRT 2007) are designed to achieve. Combined, the objectives are intended to ensure a low risk of extinction as a result of genetic change, demographic stochasticity, and normal levels of environmental variability, to ensure persistence in the face of catastrophic events, and to preserve long-term demographic processes and evolutionary potential (i.e., the ability of the population/ESU to adapt over time). Any ESA recovery scenario for Snake River fall Chinook salmon should be consistent with these objectives.

Abundance and Productivity: Abundance and productivity affect population-level persistence in the face of year-to-year variations in environmental influences. The ESA recovery objective for abundance and productivity is that:

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

Spatial Structure: Spatial structure refers to population- and ESU-level geographic distribution and the processes that generate that distribution. Complex spatial structure provides resilience to the potential impacts of catastrophic events and facilitates natural exchange of gene flow and life-history characteristics. The ESA recovery objective for spatial structure is that:

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

Diversity: Diversity refers to the distribution of traits within and among populations and is determined by genetic factors as well as by response to environmental factors. Adequate diversity is important for long-term persistence potential and resilience to short- and long-term environmental changes. The ESA recovery objectives for diversity is that:

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

Threats: Threats are the human activities or natural processes that cause or contribute to the factors that limit a species viability. The ESA recovery objective for threats is that:

- The threats to the species have been ameliorated so as not to limit attainment of its desired status and regulatory mechanisms are in place to help prevent a recurring need to re-list Snake River fall Chinook salmon as threatened or endangered.

3.1.2 Broad Sense Recovery Goals

Broad sense recovery goals go beyond the requirements for delisting under the ESA to address other legislative mandates or social, cultural, ecological, and economic benefits of having healthy, diverse salmon populations. Broad sense goals typically are long-term goals developed by stakeholders. They incorporate many of the traditional uses of salmon that are important in the Pacific Northwest, and address other tribal and stakeholder values.

While broad sense goals are not relevant to or considered in an ESA delisting decision, we include them here to inform management decisions and to provide a comprehensive overview of the management goals of the many stakeholders concerned with fostering a thriving Snake River fall Chinook salmon ESU. NMFS is supportive of broad sense recovery goals. We believe that achieving viability of natural populations and delisting is consistent with broader goals to reach a stable, long-term condition in which fall Chinook salmon are thriving and harvestable. Upon delisting, NMFS will work with co-managers and local stakeholders, using our non-ESA authorities, to pursue broad sense recovery goals while continuing to maintain robust natural populations. In some situations, it is also appropriate to consider broad sense goals in designing ESA recovery strategies and scenarios. For instance, in this Plan, NMFS has identified a recovery scenario that, if successfully implemented, is compatible with tribal treaty and trust obligations regarding harvest, and with maintaining hatchery production at levels consistent with mitigation goals (see section 3.1.2 below).

Specifically, this Plan includes broad sense goals related to:

- Visions for desired future conditions established in subbasin plans developed under the Northwest Power and Conservation Council's subbasin planning process.
- Treaty and trust obligations to Columbia Basin tribes and obligations under the Secretarial Order 3206, "American Indian Tribal Rights, Federal-Tribal Trust Responsibilities, and the Endangered Species Act."

- Federally authorized objectives for mitigating Snake River fall Chinook salmon production lost due to Snake River hydropower development. These help maintain fisheries and contribute to conservation of existing wild stocks.
- Reintroduction of fall Chinook salmon above the Hells Canyon Complex.

Broad Sense Goal to Support Subbasin Plan Visions

During the Northwest Power and Conservation Council's 2002-2004 subbasin planning process for Columbia River salmon and steelhead, groups of local stakeholders developed vision statements describing desired future conditions for their subbasins. These vision statements reflect local input and were developed through collaborative and public processes that included state, tribal, federal, and community representatives. 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). The vision statements for subbasins that support spawning and rearing of Snake River fall Chinook salmon (the lower Snake River, Snake River Hells Canyon, Tucannon, Grande Ronde, Imnaha, and Clearwater River subbasins) paint similar visions of desired future conditions. These vision statements are summarized together here as a broad sense goal:

- 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 Goal 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 Project, and Idaho Power Company Hatchery and Genetic Management Plan (HGMP) (WDFW et al. 2011) and in the 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 and are based on assessments conducted in the mid-60s of fish and wildlife losses resulting from the four lower Snake River dams. Those assessments concluded that 48 percent of the pre-dam runs had been lost due to the dams. LSRCP goals for smolt production and adults returns were developed to make up for that lost production (including lost harvest opportunity). The LSRCP also assumes that the remaining 52 percent of the pre-dam runs would be maintained or increased through natural production (NPCC 2008). The base period for calculating the lost production, 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 above the Hells Canyon Complex.

While NMFS' goal for this recovery plan is to delist Snake River fall Chinook salmon, it is important to simultaneously acknowledge these mitigation goals and to work 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 reflect long-term objectives of the Nez Perce Tribe and the Washington Department of Fish and Wildlife and support mitigation of Snake River hydropower development and include both natural-origin and hatchery-origin goals.

- 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.
- Protect, maintain, or enhance biological diversity of existing wild stocks, as described in the HGMPs for Lyons Ferry and Nez Perce Tribal Hatcheries (WDFW et al. 2011; NPT 2011).

  Natural-Origin Return Goals

  - Achieve ESA delisting (see ESA recovery goal and objectives in Section 3.1.1, above, and delisting criteria, in Section 3.2 below).
  - Achieve interim[38] goal of 7,500 average annual returns of natural-origin fall Chinook salmon (adults and jacks) above Lower Monumental Dam.
  - Achieve long-term goal of 14,360 average annual returns of natural-origin fall Chinook salmon (adults and jacks) above Lower Monumental Dam.

  Hatchery-Origin Return Goals

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

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[38] 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 Goal for Reintroduction above the Hells Canyon Complex of Dams

This recovery plan incorporates as a long-term broad sense recovery goal the reintroduction of Snake River fall Chinook salmon above the Hells Canyon Complex. The plan also incorporates a scenario involving reestablishing a viable population above the Hells Canyon Complex as one of several potential scenarios to achieve ESA delisting (see Section 3.2.1 – other potential scenarios for ESA delisting would not require reestablishing a population above the Hells Canyon Complex).

As also described in Section 3.2.1, based on our current understanding, a single-population scenario appears to be the most likely pathway to ESA delisting. But because of the significant uncertainties related to each potential scenario, it is important to continue to pursue opportunities for reestablishing natural production of fall Chinook salmon above the Hells Canyon Complex in the event that achieving a single-population scenario consistent with delisting criteria proves infeasible or unsuccessful.

In the event that we are able to achieve ESA delisting with the extant Lower Snake River population, NMFS will continue to support efforts, in cooperation with state and tribal agencies, to eventually reestablish natural production of fall Chinook salmon above the Hells Canyon Complex as an important broad sense recovery goal. Reintroducing this population could provide an extinction-risk buffer and greater resilience for the ESU. Furthermore, reintroduction of Snake River fall Chinook salmon above the Hells Canyon Complex would restore lost fishing opportunities for Upper Snake River tribes and address tribal treaty and trust responsibilities. Finally, as described in Section 2.8.4, discussions related to habitat improvement and fish passage above the Hells Canyon Complex are continuing as part of the relicensing of the Hells Canyon Complex by FERC, pursuant to the Federal Power Act.

Under any circumstances, reestablishing natural production of Snake River fall Chinook salmon above the Hells Canyon Complex would be a long-term process, and several significant uncertainties would need to be resolved as part of the process. For instance, habitat above the Hells Canyon Complex would have to be restored to a point where it can support natural production, juvenile passage studies would need to be completed, effective passage systems would need to be designed and installed, and issues related to the use of hatchery fish for reintroduction would need to be evaluated. Assuming these uncertainties are adequately resolved, the following actions would support both the two-population ESA recovery scenario (see Section 3.2.2) and the broad sense goal of reintroduction above the Hells Canyon Complex:

- Restore effective upstream and downstream fall Chinook salmon passage through the Hells Canyon Complex.
- Restore natural production in one or more major spawning areas in the historical Middle Snake River fall Chinook salmon population using hatchery supplementation,
- Restore the extirpated Middle Snake River fall Chinook salmon population above the Hells Canyon Complex to sustainable and harvestable levels.

- Restore meaningful, sustainable fisheries in areas upstream of the Hells Canyon Complex.

3.2 ESA Delisting Criteria

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

The ESA requires that recovery plans, "to the maximum extent practicable, incorporate objective, measurable criteria 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 delisting criteria: biological viability criteria, which deal with population or demographic parameters, and threats criteria, which relate to the five listing factors in ESA section 4(a)(1) and are intended to ensure that threats have been adequately addressed and adequate conservation mechanisms are in place to protect a species after delisting. Together, the biological 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.

Section 3.2.1 below presents three potential ESA "recovery scenarios", or pathways to ESA recovery, for Snake River fall Chinook salmon. Section 3.2.2 describes the biological viability criteria, with potential criteria and metrics for measuring viability characteristics relative to each of the three potential recovery scenarios. Section 3.2.3 defines the threats criteria, which describe the conditions under which the listing factors, or threats, can be considered to be addressed or mitigated.

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, new information will likely become available that improves our understanding of the status of the ESU as well as of threats, their impacts, and the extent to which they have been ameliorated. If appropriate, NMFS will review and revise delisting criteria in the future based on this new information.

3.2.1 Potential ESA Recovery Scenarios

As with most ESUs, there is more than one pathway to achieving ESA recovery of the Snake River fall Chinook salmon ESU. This section presents several alternative scenarios for achieving ESA recovery for the ESU. Each scenario represents targeted levels of viability status for the individual historical populations that, if achieved, would indicate that the ESU has met the recovery goal and objectives in Section 3.1.1.

As described in Chapter 2, the historical population structure for Snake River fall Chinook salmon likely consisted of one MPG with two independent populations: the Middle Snake River population, which spawned above the current site of Hells Canyon Dam, and the Lower Snake River population, which spawned below the site of Hells Canyon Dam. The Middle Snake River population is now extirpated, leaving only one extant population ─ the Lower Snake River population. The ICTRT recognized that an ESU with a single historical MPG would be inherently at greater extinction risk than one with several MPGs (ICTRT 2007). Further, it also recognized that 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 (see Section 2.5). These are key considerations for potential Snake River fall Chinook salmon recovery scenarios.

Under a basic application of the ICTRT's recommended viability criteria (ICTRT 2007), two populations would need to meet criteria for high viability for the Snake River fall Chinook salmon ESU to be at low risk of extinction. The ICTRT recognized that there were significant difficulties in reestablishing fall Chinook salmon above the Hells Canyon Complex and recommended that initial efforts be focused on recovery of the extant population. In general, the ICTRT recommended that a recovery scenario that differs from the basic approach might be appropriate in cases where "…well documented and justified circumstances exist." 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 criteria in Section 2.5 and the ESA recovery objectives in Section 3.1.1 provide a basic framework for tailoring ESU and population-level criteria that reflect the unique biological and environmental characteristics of this ESU. With input from co-managers, NMFS developed three potential recovery scenarios, each consistent with the basic set of viability objectives used by the ICTRT and described in Section 3.1.1. Scenario A would achieve ESU viability with the two populations, while Scenarios B and C describe alternative approaches for achieving viability with the single extant Lower Snake River fall Chinook salmon population. The scenarios are based on best available information, but it is also possible other scenarios could achieve ESU viability and delisting. Thus, the recovery scenarios may be refined over time.

Scenario A - Two Populations (one highly viable, one viable)

This scenario focuses on achieving highly viable status for the extant Lower Snake River population and viable status for the currently extirpated Middle Snake River population that spawned historically above the Hells Canyon Complex. This scenario is a simple, modified application of the ICTRT's general MPG-level viability criteria (which would require that both populations achieve highly viable status). NMFS has determined that this variation on the ICTRTs recommended recovery scenario is appropriate given the spatial and life-history diversity of the extant Lower Snake River population and recognition of the complexities that would be involved in achieving highly viable status for the extirpated Middle Snake River population. NMFS has determined that the protection against short-term environmental survival variations, risks of localized catastrophic losses, and risks to long-term adaptability associated with Scenario A are consistent with the recovery objectives described above in Section 3.1.1.

Given the challenges and uncertainties involved in restoring the severely degraded habitat conditions in the Middle Snake River to levels that would support fall Chinook salmon production, the use of hatchery fish for reintroduction, and providing juvenile and adult passage above the Hells Canyon Complex, achieving this scenario would likely take many decades.

Scenario B – Single Population (highly viable, measured in the aggregate)

This scenario is based on an alternative application of the ICTRT's criteria and proposes to achieve the ESA recovery goal and objectives (see Section 3.1.1) with the single extant population. The scenario focuses on achieving highly viable status, with a high degree of certainty, for the Lower Snake River population. In this scenario, VSP objectives would be evaluated in the aggregate (i.e., population-wide), across all natural-origin adult spawners. The requirement for a high degree of certainty that the population has attained highly viable status would reduce the inherent increased risks associated with a single population ESU.

Achieving ESU viability with the single extant Lower Snake River population may be possible because the population is well distributed across a large area that provides for complex spatial structure and within-population diversity. Fish in this population spawn and rear across a large area and diverse set of habitats in the five major spawning areas. Two of the major spawning areas are in the mainstem Lower Snake River and the other three are in tributary reaches, making fish in the different areas less likely to be exposed to the same catastrophic risks (such as from a fire). In addition, the mainstem reaches are unlikely to be subject to the same types of localized catastrophic risk factors (e.g., fires followed by high temperatures and increased sedimentation) as the tributary spawning/rearing reaches). The population also supports the different life-history expressions represented in the ESU. It has maintained the historically predominant subyearling life-history strategy and also demonstrates an additional yearling life-history strategy adaptation. These characteristics provide opportunities to achieve the ESA recovery objectives (see Section 3.1.1) because they provide for resilience to environmental perturbations and localized catastrophic events. They also provide for a greater degree of within-population adaptation to environmental variation when compared to populations with simpler habitat structure.

However, achieving this scenario could require significant tradeoffs. Under Scenario B, existing levels of hatchery production would need to be substantially reduced for two reasons. First, given our current understanding of the risk of hatchery-influenced selection, the level of hatchery production is probably too high for long-term maintenance of acceptable productivity. Second, the current levels of hatchery production make it nearly impossible to determine the underlying productivity of the population. Once adequate reductions in hatchery-origin spawners had been achieved, it would be possible to directly determine the long-term sustainability of the natural population through a combination of sampling of the aggregate escapement over Lower Granite

Dam and continuing redd count surveys (to ensure spatial complexity objectives are being met). Achieving the abundance/productivity, spatial structure, and diversity criteria for this scenario would indicate that the population is meeting diversity objectives (i.e., responding to natural selection processes). These evaluations would inform a determination of whether the population is highly viable with high confidence, and of whether ongoing recovery actions are sufficient for achieving the recovery objectives or whether additional actions are needed

Scenario C ─ Single Population (highly viable, with Natural Production Emphasis Areas)

This scenario is a variation on the alternative single-population approach to meeting the basic ESA recovery objectives underlying the ICTRT's viability criteria. As with Scenario B, this scenario focuses on achieving highly viable status for the Lower Snake River population with high confidence.[39] In this scenario, however, rather than evaluating population status in the aggregate, as under Scenario B, the VSP parameters would be evaluated based on having a substantial amount of natural production for the ESU come from one or two of the five MaSAs that would demonstrate low hatchery spawner contributions.

These areas would be designated as Natural Production Emphasis Areas (NPEAs). The NPEAs would be managed to have a low percentage of hatchery-origin spawners and to support significant levels of natural-origin spawners. This would make it possible to directly evaluate the productivity of the natural population and ensure that a substantial proportion of the population is subject to natural selection rather than hatchery processes. While the scenario would require large-scale shifts in current hatchery release locations, it is likely that total hatchery production would remain at levels consistent with mitigation goals. Also, while the NPEAs would have a low percentage of hatchery-origin spawners, the other MaSAs could have higher acceptable levels of hatchery-origin spawners. Achieving ESA recovery objectives under this scenario would require meeting the same spatial structure criteria as for Scenario B. The aggregate population-level natural-origin spawning abundance under Scenario C would be higher than under Scenario B; the specific level would be a function of the hatchery proportions in the NPEAs resulting from dispersal from outside the NPEAs, the relative levels of natural production within and outside of the NPEAs, and the proportion of natural returns in the hatchery broodstock.

Under this scenario, it would be possible to achieve recovery in a much shorter timeframe than under Scenario A ─ and, unlike under Scenario B, current levels of hatchery production could be maintained to meet mitigation goals. A key to feasibility of this scenario is whether dispersal rates of hatchery fish into the NPEAs would be low enough to evaluate natural productivity and selection. Preliminary information indicates that it is reasonable to pursue implementing Scenario C. As with Scenario B, once adequate reductions in hatchery-origin spawners had been achieved within the NPEAs, it would be possible to directly evaluate the productivity and abundance of natural-origin fish, as well as whether the population is meeting diversity objectives (i.e., responding to natural selection processes rather than to hatchery selection).

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[39] Under Scenario C, details of how to determine level of certainty of status would still need to be developed.

These evaluations would inform a determination of whether the population is highly viable with high confidence, and of whether ongoing recovery actions are sufficient for achieving the recovery objectives or whether additional actions are needed.

This scenario was identified as a "placeholder" in the Proposed Recovery Plan for Snake River Fall Chinook Salmon. Multiple commenters on the proposed plan expressed interest in further developing details of how such a scenario would be implemented and evaluated; in addition, recent monitoring information indicates that implementing such a scenario is reasonable. NMFS regional and science center staff and co-managers have begun discussing details of how to implement and evaluate such a scenario, as well as contingency plans for various population responses to reduced levels of hatchery-origin spawners. Therefore in this final Plan, NMFS includes this as Scenario C, rather than as a placeholder.

Most Likely Recovery Scenario

As noted above, the potential ESA recovery scenarios provide a range of population characteristics that, if achieved, would indicate that the ESU has met the ESA recovery objectives in Section 3.1.1. Thus they illustrate potential conditions that, if met in combination with meeting the threats criteria described below in Section 3.2.3, would result in a delisting decision. These scenarios are based on current information, and there may be other scenarios that could also achieve ESU viability and delisting.

Each of these scenarios has attendant uncertainties and tradeoffs. Under Scenario A, there are uncertainties related to the feasibility of and time required to (1) restore habitat in the Middle Snake River, (2) develop effective passage systems, (3) understand uncertainties related to reintroducing hatchery fish, and (4) reestablish a viable population above the Hells Canyon Complex. Moreover, Scenario A would take many decades to achieve. Under Scenario B, hatchery production would have to be significantly reduced, which would affect the ability to meet tribal treaty and trust obligations regarding harvest and current hatchery mitigation goals. Under Scenario C, hatchery production could be maintained and recovery could be achieved in a shorter timeframe than under Scenario A, but there are uncertainties regarding (1) whether dispersal rates of hatchery-origin spawners will be low enough to allow natural selective processes to dominate in the NPEAs; (2) whether we can identify methods and metrics to evaluate natural production in the NPEAs; and (3) what the effect on natural production will be of reducing hatchery-origin spawners (e.g., it is possible that natural production will be sustained or increase, but it is also possible that it will decrease substantially, requiring contingency actions of moving hatchery fish back into the NPEAs). Available information indicates that it is reasonable to pursue Scenario C. Further, it provides the fastest potential route to ESA recovery and it allows meeting hatchery mitigation goals. Thus at this time NMFS considers it the most likely path to ESA recovery; however, it will be necessary to develop an implementation plan that addresses uncertainties and includes contingencies and appropriate monitoring.

Pursuing Scenario C is consistent with the ICTRT's recognition that because there are "significant difficulties in reestablishing fall Chinook salmon populations above the Hells

Canyon Complex…initial effort [should] 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" (ICTRT 2007). Because there are uncertainties regarding the feasibility and outcome of Scenario C, it is important that while working toward achieving this scenario, we continue to explore opportunities to reestablish natural production above the Hells Canyon Complex in the event that a single-population scenario proves infeasible. If we do achieve ESA delisting with the extant Lower Snake River population, NMFS will continue to support efforts to eventually reestablish natural production of fall Chinook salmon above the Hells Canyon Complex as a broad sense recovery goal (see Section 3.1.2).

3.2.2 Biological Viability Criteria

NMFS developed potential criteria and metrics for measuring viability characteristics relative to each of the potential recovery scenarios. These criteria were developed through discussions among co-managers and NMFS regional and science center staff. They are consistent with the ESA recovery objectives in Section 3.1.1 and with the ICTRT's recommendations and guidelines in Section 2.5; they also reflect policy choices that are consistent with the ICTRT's recommendations and guidelines. The potential metrics are based on best available information but illustrate example metrics and not absolute standards. NMFS expects these potential metrics to be evaluated relative to the objectives and methods recommended by the ICTRT (2007). The metrics may evolve over time as RM&E results emerge and our scientific understanding improves.

Scenario A - Two Populations: Achieve highly viable status for the extant Lower Snake River population and viable status for the currently extirpated Middle Snake River population.

<u>Biological Viability Criteria</u>

1. Abundance and Productivity:
    a. Lower Snake River population: Combination of natural-origin abundance and productivity exhibits a 50 percent probability of exceeding the viability curve for highly viable status (i.e., has a 50 percent probability of a 1 percent or less risk of extinction over 100 years).
    b. Middle Snake River population: Combination of natural-origin abundance and productivity exhibits a 50 percent probability of exceeding the viability curve for viable status (i.e., has a 50 percent probability of a 5 percent or less risk of extinction over 100 years).
2. Spatial Structure and Diversity:
    a. Both populations exhibit robust spatial distribution of spawning aggregations.
    b. All major habitat types within a population are occupied.
    c. Current range of genetic and life-history diversity includes historically dominant patterns.

  - d. Any difference(s) from historical diversity patterns represent positive natural adaptations to prevailing environmental conditions.
  - e. Evolutionary trajectory of populations is dominated by natural-selective processes.

Metrics

1. Abundance and Productivity:
   - a. Lower Snake River population most recent 10-year geometric mean > 3,000 natural-origin spawners and 20-year geometric mean intrinsic productivity ≥ 1.5.[40]
   - b. Middle Snake River population most recent 10-year geometric mean > 3,000 natural-origin spawners and 20-year geometric mean intrinsic productivity ≥ 1.27.
2. Spatial Structure and Diversity:
   - a. Four of five MaSAs in the Lower Snake River population and one or more spawning areas in the Middle Snake River population are occupied.[41]
   - b. Hatchery influence on spawning grounds is low (e.g., pHOS < 30 percent) for at least one population and hatchery programs are operated to limit genetic risk (e.g., the proportionate natural influence [PNI] > 67 percent[42]).
   - c. Numbers of fish showing the historically dominant subyearling life-history pattern are stable or increasing.
   - d. Adult and juvenile run timing patterns are stable or adaptive.
   - e. Indicators of genetic substructure are trending toward patterns expected for a natural-origin dominated population.

Scenario B – Single Population: Achieve highly viable status for Lower Snake River population (measured in the aggregate).

Biological Viability Criteria

1. Abundance and Productivity:
   - a. Combination of natural-origin abundance and productivity for the Lower Snake River population exhibits an 80 percent or higher probability of exceeding the viability curve for highly viable status (i.e., has an 80 percent probability of being at or below a 1 percent risk of extinction over 100 years).
2. Spatial Structure and Diversity:
   - a. Population exhibits robust spatial distribution of spawning aggregations.

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[40] The ICTRT defined intrinsic productivity as “the expected production rate (expressed as a ratio of returns to spawn in future years vs. parent spawning numbers) experienced when spawner densities are low and compensation is not reducing productivity” (ICTRT 2007). The ICTRT noted that alternatives to simple average return per spawner metrics might be needed to estimate intrinsic productivity if parent escapement levels consistently exceed minimum abundance targets. The proposed metrics for abundance and productivity are based on current estimates of statistical uncertainty in these parameters. If associated statistical uncertainties change in future status reviews, then these numbers would change.

[41] For the ICTRT’s criteria for “occupancy,” see ICTRT 2007, as well as Section 4.2 (discussion of Factor A.1.c) and Appendix A in this Plan.

[42] 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.

  b. All major habitat types within the population are occupied.
  c. Current range of genetic and life-history diversity includes historically dominant patterns.
  d. Any difference(s) from historical diversity patterns represent positive natural adaptations to prevailing environmental conditions.
  e. Evolutionary trajectory of population is dominated by natural-selective processes.

Metrics

1. Abundance and Productivity:
   a. Most recent 10-year geometric mean abundance > 4,200 natural-origin spawners.
   b. Most recent 20-year geometric mean intrinsic productivity ≥ 1.7.[43]
2. Spatial Structure and Diversity:
   a. Four of five MaSAs in the Lower Snake River population are occupied.[44]
   b. Recent (2 or more brood cycles) hatchery influence on spawning ground is low (e.g., pHOS < 30 percent) for the population as a whole and hatchery program is operated to limit genetic risk (e.g., PNI > 67 percent).
   c. Numbers of fish showing the historically dominant subyearling life-history pattern are stable or increasing.
   d. Adult and juvenile run timing patterns are stable or adaptive.
   e. Indicators of genetic substructure are trending toward patterns expected for a natural-origin dominated population.

Scenario C ─ Single Population: Achieve highly viable status for Lower Snake River population (with Natural Production Emphasis Areas).

The NPEA approach represents a new variation on evaluating population status. As noted above, because of certain characteristics of the Lower Snake River population, it appears feasible to achieve a highly viable population in part by having low hatchery influence in one or more NPEAs. These NPEAs would provide the bulk of natural production, while other areas within the population could have higher levels of hatchery-origin spawners. The NPEAs should include the Upper Hells Canyon MaSA, since it was historically a large and productive area in the Lower Snake River population. In MaSAs that are not part of the NPEAs, acceptable levels of hatchery-origin spawners could be within the range of those presently observed.

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[43] The ICTRT defined intrinsic productivity as “the expected production rate (expressed as a ratio of returns to spawn in future years vs. parent spawning numbers) experienced when spawner densities are low and compensation is not reducing productivity” (ICTRT 2007). The ICTRT noted that alternatives to simple average return per spawner metrics might be needed to estimate intrinsic productivity if parent escapement levels consistently exceed minimum abundance targets. The proposed metrics for abundance and productivity are based on current estimates of statistical uncertainty in these parameters. If associated statistical uncertainties change in future status reviews, then these numbers would change.

[44] For the ICTRT’s criteria for “occupancy,” see ICTRT 2007, as well as Section 4.2 (discussion of Factor A.1.c) and Appendix A in this Plan.

The NPEA approach depends upon high homing fidelity of hatchery-origin adults to hatchery release areas (outside of the NPEAs) and low dispersal into the NPEAs. Conditions independent of NPEA specifics, such as distribution of natural-origin spawners across MaSAs and overall stable or increasing natural productivity, will also need to be met. Meeting the relatively low hatchery contribution requirements in the NPEAs provides an opportunity to gain more direct information on intrinsic productivity without the masking effect common when high levels of hatchery-origin spawners are present.

As also noted above, recent research and monitoring results indicate that the NPEA concept is feasible. NMFS is now working with co-managers to explore the specifics of how to implement and evaluate such an approach. Questions being explored include how large, in relative terms, natural production from the NPEAs must be, and how low the hatchery influence must be.

The biological viability criteria and metrics below represent, to the maximum extent practicable, how NMFS would measure viability characteristics relative to Scenario C. As with any other scenario, Scenario C will need to be consistent with the ESA recovery objectives in Section 3.1.1 and with the ICTRT's recommendations. As also noted above, the potential metrics are based on best available information but illustrate example metrics and not absolute standards. Methods to estimate relative contributions of hatchery vs. natural-origin returns to specific MaSAs will be developed. While direct estimation is difficult, new indices should include: (1) estimates of fidelity and dispersal from hatchery release sites, and (2) assessments of the relative proportions of hatchery contribution at the MaSA level based on sampling of adults or juveniles. NMFS expects these potential metrics to be evaluated relative to the objectives and methods recommended by the ICTRT (2007). The metrics may evolve over time as RM&E results emerge and our scientific understanding improves. Evaluating population status relative to these criteria may require the implementation of additional monitoring being developed for this scenario.

Biological Viability Criteria

1. Abundance and Productivity:
    a. Combination of natural-origin abundance and productivity for the Lower Snake River population exhibits an 80 percent or higher probability of exceeding the viability curve for highly viable status (i.e., has an 80 percent probability of being at or below a 1 percent risk of extinction over 100 years).
2. Spatial Structure and Diversity:
    a. Population exhibits robust spatial distribution of spawning aggregations.
    b. All major habitat types within the population are occupied.
    c. Current range of genetic and life-history diversity includes historically dominant patterns.
    d. Any difference(s) from historical diversity patterns represent positive natural adaptations to prevailing environmental conditions.

   e. Evolutionary trajectory of the NPEA component of the population is dominated by natural-selective processes.

<u>Metrics</u>

1. Abundance and Productivity:
   a. Population-level abundance metrics under Scenario C would need to be higher than under Scenario B to accommodate meeting the NPEA requirements. Metrics will vary depending on the proportion of natural production coming from NPEAs and the level of hatchery influence remaining in the NPEAs.
   b. Population-level productivity metrics for Scenario B would apply: most recent 20-year geometric mean intrinsic productivity ≥ 1.7.[45]
2. Spatial Structure and Diversity:
   a. Four of five MaSAs in the Lower Snake River population are occupied.[46]
   b. NPEA PNI ≥ 0.67 and NPEA production accounting for at least 40 percent of the natural production in the population.
   c. Numbers of fish showing the historically dominant subyearling life-history pattern are stable or increasing.
   d. Adult and juvenile run timing patterns are stable or adaptive.
   e. Indicators of genetic substructure are trending toward patterns expected for a natural-origin dominated population.

3.2.3. Threats Criteria

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

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

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[45] The ICTRT defined intrinsic productivity as "the expected production rate (expressed as a ratio of returns to spawn in future years vs. parent spawning numbers) experienced when spawner densities are low and compensation is not reducing productivity" (ICTRT 2007). The ICTRT noted that alternatives to simple average return per spawner metrics might be needed to estimate intrinsic productivity if parent escapement levels consistently exceed minimum abundance targets. The proposed metrics for abundance and productivity are based on current estimates of statistical uncertainty in these parameters. If associated statistical uncertainties change in future status reviews, then these numbers would change.
[46] For the ICTRT's criteria for "occupancy," see ICTRT 2007, as well as Section 4.2 (discussion of Factor A.1.c) and Appendix A in this Plan.

Each species faces a unique set of threats across its life cycle, and these five factors may not all be equally important in securing the recovery of Snake River fall Chinook salmon. It is also possible that the relative importance of threats will change over time. Some threats that led to listing may have been adequately addressed. Some current threats may become less significant 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, threats that are emerging (like climate change) or that are poorly understood (like toxic pollutants and non-native species) may become more significant.

NMFS will use the listing factor (threats) criteria below, considered in context with the biological viability criteria, to help determine whether the Snake River fall Chinook salmon ESU has recovered to the point that it no longer requires the protections of the ESA. It is not necessary to reduce each threat to some specified level of impact but rather for the impact of threats in the aggregate to have been addressed to the point that the species no longer needs ESA protection and delisting is not likely to result in declines in the species status. Further, adequate regulatory or conservation mechanisms must be in place to protect the species after listing. NMFS expects that if the site-specific management actions described in Chapter 6 are implemented, they will address the threats delisting criteria described below.

A. The present or threatened destruction, modification, or curtailment of a species' habitat or range

To determine that the ESU 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 reservoir management for water storage and releases for 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. Under Scenario A, 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 the re-introduction of fall Chinook salmon above the Hells Canyon Complex 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. Land use practices are implemented in a manner that protects and conserves the ecosystem processes upon which Snake River fall Chinook salmon depend.
8. The effects of toxic contaminants on salmonid fitness and survival are understood and are sufficiently limited so as not to affect viability.
9. Relevant mainstem and tributary habitat processes and functions, including substrate and sediment processes, riparian areas, and floodplains, have been restored or maintained to provide adequate rearing and spawning habitat for Snake River fall Chinook salmon.

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

To determine that the ESU 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 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 does not impede achieving recovery.
3. Predation by northern pikeminnow and non-native fish predators (e.g., smallmouth bass, walleye, and catfish) is managed such that competition or predation does not impede recovery.

4. Predation below Bonneville Dam by marine mammals does not impede achieving recovery.
5. Physiological stress and physical injury associated with environmental conditions or fish passage structures that may increase susceptibility to pathogens during rearing or migration is reduced such that it does not impede recovery.

D. The inadequacy of existing regulatory mechanisms

To determine that the ESU 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[47] 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 human-made threats to its continued existence should be addressed as outlined below:

Hatcheries:

1. Snake River fall Chinook salmon hatchery mitigation programs, as well as hatcheries outside the Snake River basin, 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.

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

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.

3.3. Delisting Decision

The biological viability criteria and listing factor (threats) criteria provided in Sections 3.2.2 and 3.2.3 define conditions that, when met, would result in a determination that the Snake River fall Chinook salmon ESU 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, as appropriate, if new information becomes available.

A delisting decision may include both technical and policy considerations, such as acceptable risk levels at the population, MPG, and ESU scales. The recovery scenarios in Section 3.2.1 and associated biological viability and threats criteria presented in Sections 3.2.2 and 3.2.3 illustrate potential scenarios in which NMFS would propose to delist. The criteria represent a point at which delisting is very likely but not necessarily the only scenario under which NMFS would propose to delist. Nothing in these criteria should be understood as precluding a delisting determination under a different scenario, provided that NMFS has determined that the ESU is no longer in danger of extinction or likely to become endangered within the foreseeable future.

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; and
- Other considerations, including: the number and status of extant spawning groups; the status of the major spawning groups; linkages and connectivity among groups; the diversity of life history and phenotypes expressed; and considerations regarding catastrophic risk.

4. Current Status Assessment

This chapter summarizes the current status of the Snake River fall Chinook salmon ESU based on information presented in Appendix A ("Current ESU Viability Assessment").[48] NMFS conducted the assessment using the ICTRT's recommended framework for evaluating population and ESU status, as described in *Viability Criteria for Application to Interior Columbia Basin Salmonid ESUs* (ICTRT 2007) and summarized in Section 2.5.

The ICTRT's framework looks at overall population risk status by combining assessments for two groupings of population parameters: (1) natural-origin abundance and productivity and (2) spatial structure and diversity. The ICTRT recommended criteria and metrics for evaluating these individual parameters, and determining the status of a population and its relative extinction risk level (very low, low, moderate, and high). The abundance and productivity risk level combines the abundance and productivity VSP criteria using a viability curve. The spatial structure and diversity risk level integrates across multiple measures of spatial structure and diversity defined in ICTRT 2007. The ICTRT's recommended approach then integrates the information for all four parameters using a matrix. The ICTRT also recognized that there could be other metrics for evaluating risks for particular viability criteria and provided some guidance for considering alternatives.

Because there is only one extant population, the Lower Snake River population, this assessment focuses on the current status of that population relative to the criteria and metrics for the single-population ESA recovery scenarios, in particular for Scenario B (single population evaluated in the aggregate) (see Section 3.2.1). It also includes brief summaries under specific VSP components of the findings on status relative to Scenario C (single population with Natural Production Emphasis Areas) or descriptions of the additional information that would be required to evaluate status under that scenario. The basic metrics evaluated in the assessment would also apply to Scenario A (two-populations, including reintroduction of fall Chinook salmon above the Hells Canyon Complex).

4.1 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 returns declined substantially following completion of the three-dam Hells Canyon Complex (1959-1967) which completely blocked access to major historical production areas in the Middle Snake River,[49] and of the lower Snake

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[48] Appendix A is consistent with, but contains additional detail not included in, the final Northwest Fisheries Science Center's 2015 status review (NWFS 2015) and NMFS' 2016 5-year status review (NMFS 2016a).

[49] As noted in section 2.2.1, prior to construction of the Hells Canyon Complex, Swan Falls Dam, built on the Middle Snake River (RM 458) in 1901 reduced fall Chinook salmon production by blocking access to prime historical habitat. Swan Falls Dam eliminated passage to the largest and most productive aquifer-fed habitats in the Middle Snake River and displaced thousands of spawners from upriver spawning areas to the remaining downstream aquifer-influenced reaches of the Middle Snake River. The reach from Swan Falls Dam downstream to the town of

River dams (1962-1975), which inundated additional habitat. Based on extrapolations from sampling at Ice Harbor Dam (1977-1990), the Lyons Ferry Hatchery (1987-present), and Lower Granite Dam (1990-present), hatchery strays made up an increasing proportion of returns at Lower Granite Dam through the 1980s (Bugert et al. 1990; Bugert and Hopley 1989). Strays from out-planting of Priest Rapids hatchery-origin fall Chinook salmon (an 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 returns originating from naturally spawning parents, as well as returning hatchery releases. Hatchery-origin fall Chinook salmon escaping upstream above Lower Granite Dam to spawn naturally are now predominantly returns from hatchery program juvenile releases in reaches above Lower Granite Dam and from releases at Lyons Ferry Hatchery that have dispersed upstream.

The NWFSC conducted two types of evaluations using recent data to generate assessments of current abundance and productivity. One evaluation used a relatively simple set of consistent metrics (e.g., 5-year trends) corresponding to those used in prior Biological Review Team (BRT) reviews that allows comparisons across ESUs, DPSs, and domains. A second evaluation used a set of metrics corresponding to the specific viability criteria recommended by the ICTRT for this ESU, which measures over longer time frames (e.g., 10-year trends) to dampen the effects of annual variations (NWFSC 2015). Results from these evaluations show that the geometric mean of natural-origin adult abundance for the 10 years of annual spawner escapement estimates from 2005-2014 is 6,418, with a standard error of 0.19.[50] Natural-origin spawner abundance has increased relative to the levels reported in the previous NWFSC status review (Ford et al. 2011), driven largely by relatively high escapements in recent years (Figures 4-1 and 4-2; Tables 4-1 and 4-2).[51]

Marsing, Idaho, became the population's primary spawning area until this area was also lost to production following construction of projects associated with the Hells Canyon Complex.

[50] Abundance and productivity data used in the status assessment are available on the Northwest Fisheries Science Center website at https://www.webapps.nwfsc.noaa.gov/apex/f?p=261:1.

[51] The ICTRT assumed that variation in annual abundance would be log-normal in nature. The standard error of 0.19 is expressed in terms of natural log abundance.

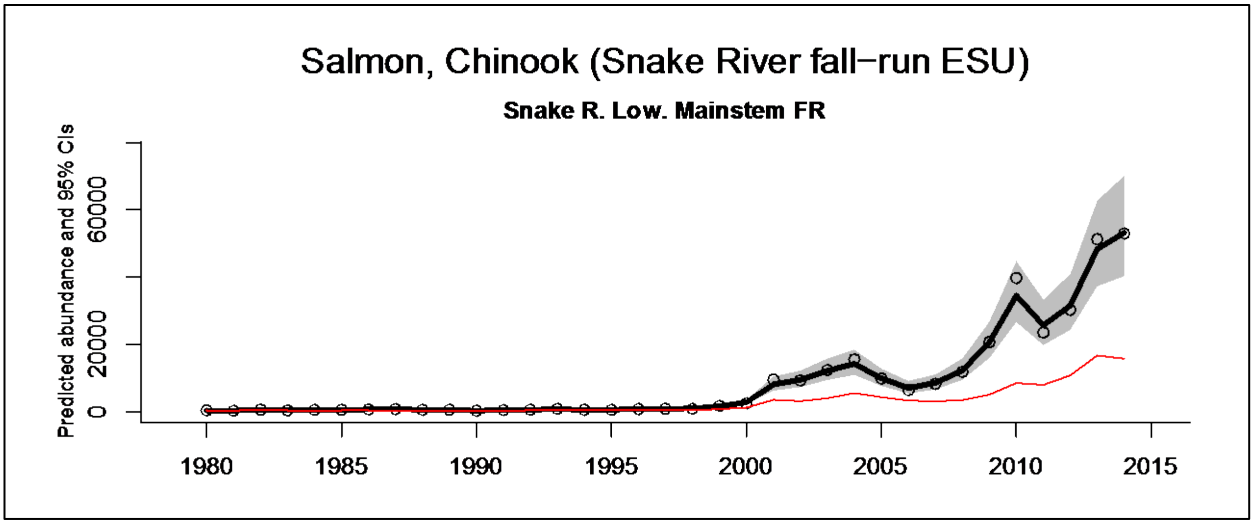


Figure 4-1. Smoothed trend in estimated total (thick black line) and natural (thin red line) population spawning abundance. Points show the annual raw spawning abundance estimates.

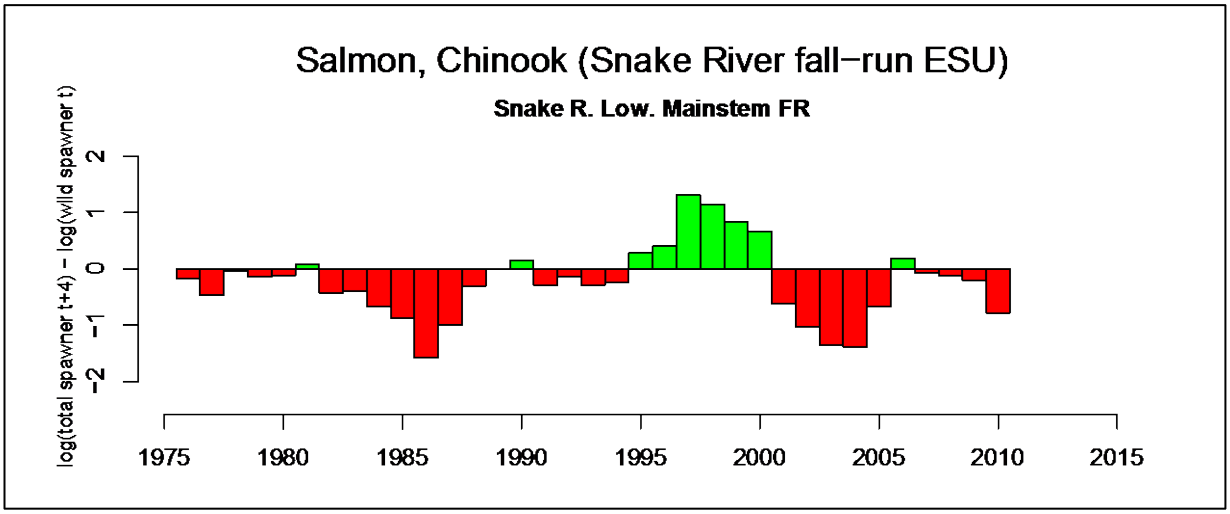


Figure 4-2. Trends in population productivity, estimated as the log of the smoothed natural spawning abundance in year *t* - smoothed natural spawning abundance in year (t – 4). Spawning years on x axis.

Table 4-1. Five-year geometric mean of raw natural spawner counts. This is the raw total spawner count times the fraction natural 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 that no or only one estimate of natural spawners was 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 five-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 natural spawner abundance computed from a linear regression applied to the smoothed natural spawner log abundance estimate. Only populations with at least 4 natural 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 salmon have a very broad ocean distribution and are 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 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.

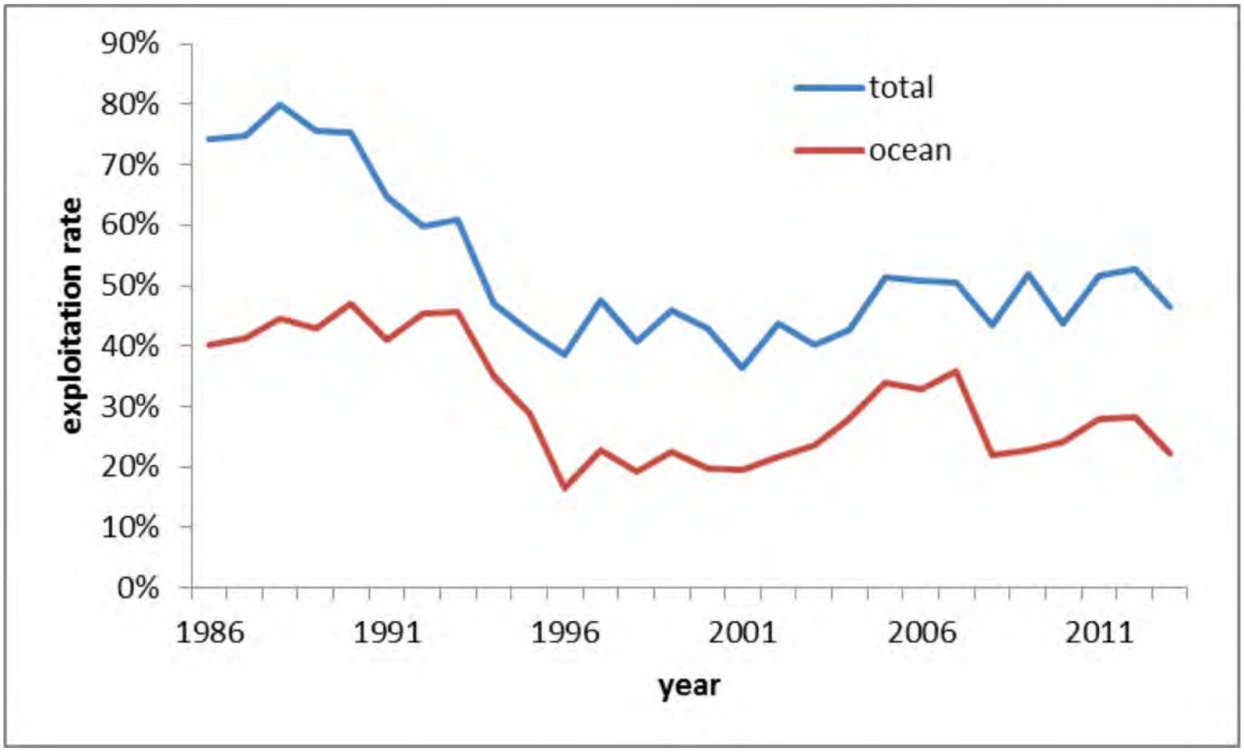


Figure 4-3. Total exploitation rate for Snake River fall Chinook salmon. Data for marine exploitation rates from the Chinook Technical Committee model (Calibration 1503) and for in-river harvest rates from the Columbia River Technical Advisory Committee (TAC 2014).

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 productivity be expressed in viability assessments in terms of returns-to-the-spawning-ground.

Other management applications express productivity in terms of pre-harvest recruits. Pre-harvest recruit estimates are available for Snake River fall Chinook salmon.

The ICTRT report *Viability Criteria for Application to Interior Columbia Basin Salmonid ESUs* (ICTRT 2007) also recognized 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, the ICTRT 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 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 the Lower Snake River fall Chinook salmon 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's simple 20-year R/S method, the current estimate of productivity for this population (1991-2010 brood years) is 1.53 with a standard error of 0.19. 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 2011 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.

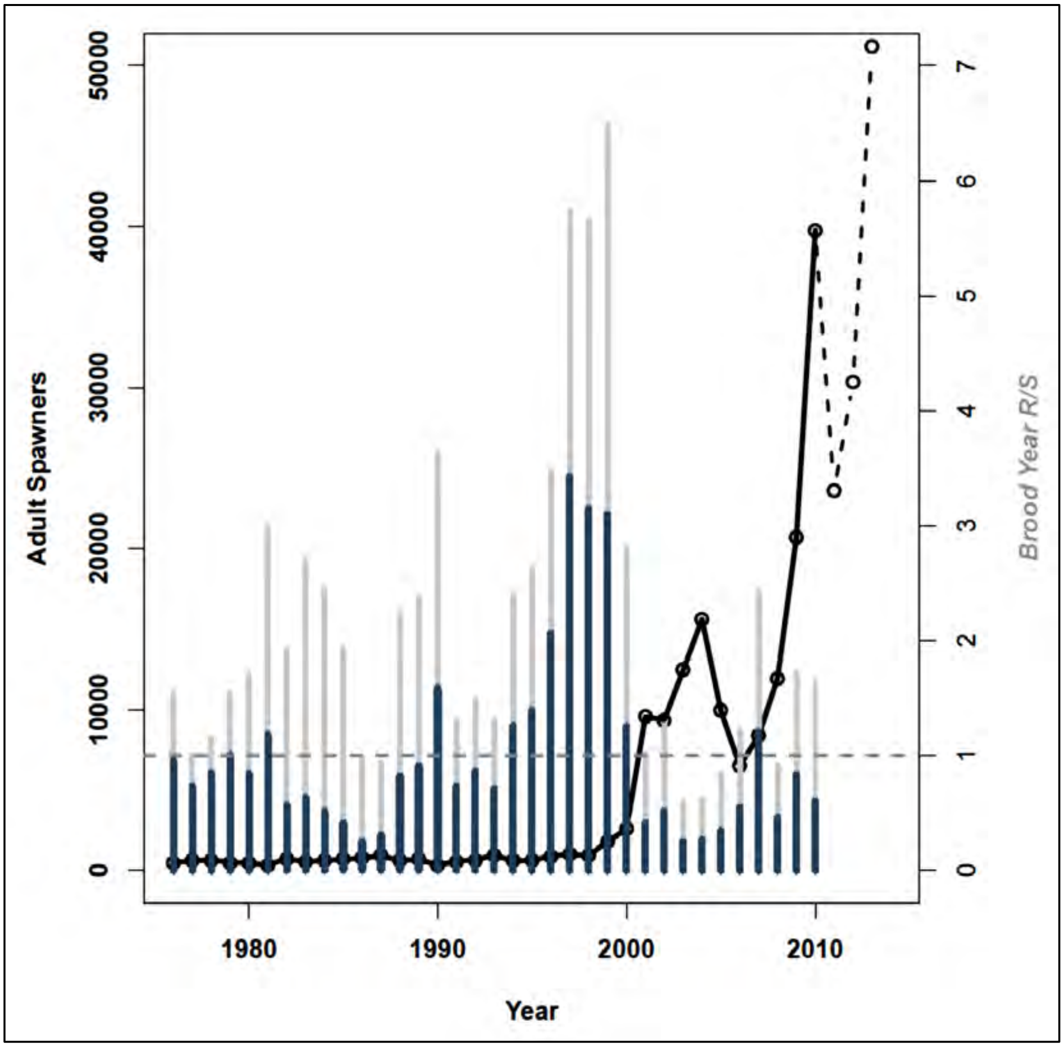


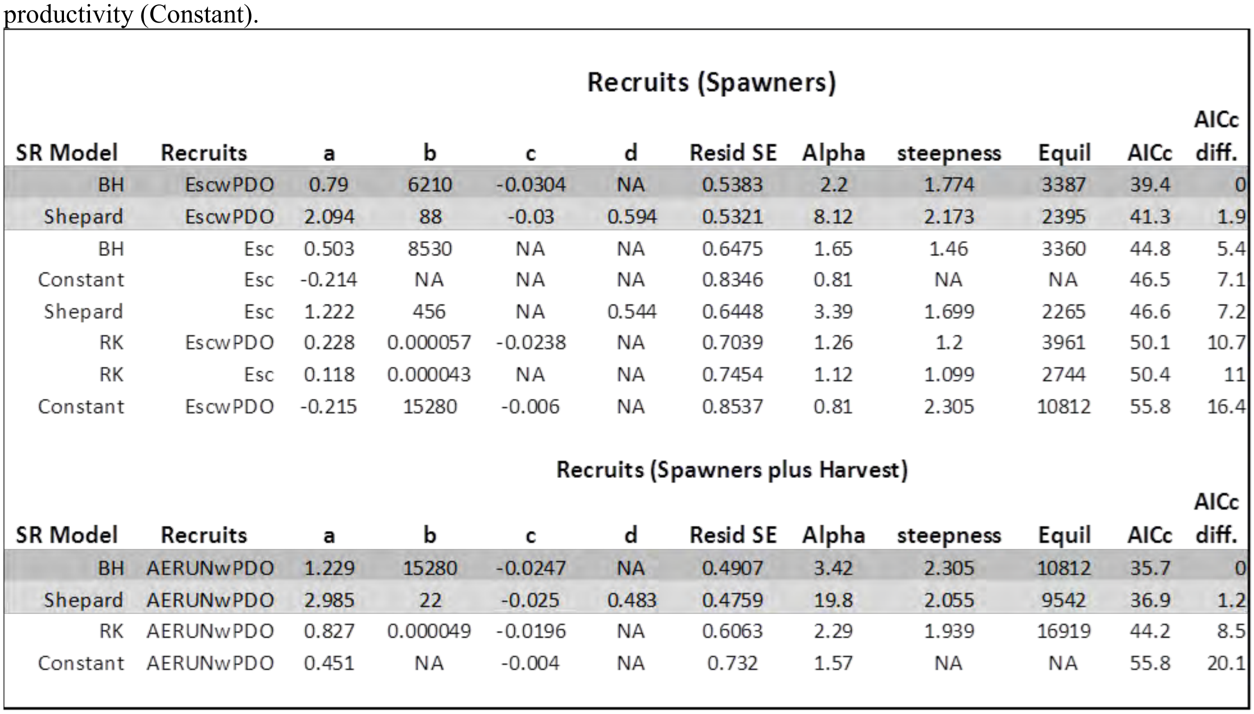
Figure 4-4. Brood year parent spawning levels (left side axis, hatchery plus natural-origin adults) and brood year return per spawner estimates (right side axis, black circles) vs. parent brood year. Light bars: recruits are adult escapement plus ocean (adult equivalent) and in-river harvest. Dark bars: 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 Snake River fall Chinook salmon population. The four models were: (1) a Constant R/S 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 incorporating density-dependent terms (Beverton-Holt, Ricker, and Shepard) (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 versus 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 of that figure 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 requirement in Scenario B for 80 percent of the samples to exceed the curve for very low risk. The spawner/recruit plot includes the 1991-2014 recruit and parent spawner pairs, both unadjusted and adjusted to reflect the fitted PDO relationship included in the analysis.

Table 4-3. Lower Snake River Fall Chinook salmon Population. Spawner=recruit function fits based on results from four stock-recruit models: Beverton-Holt (BH), Shepard, Ricker (RK), and density-independent constant productivity (Constant).



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

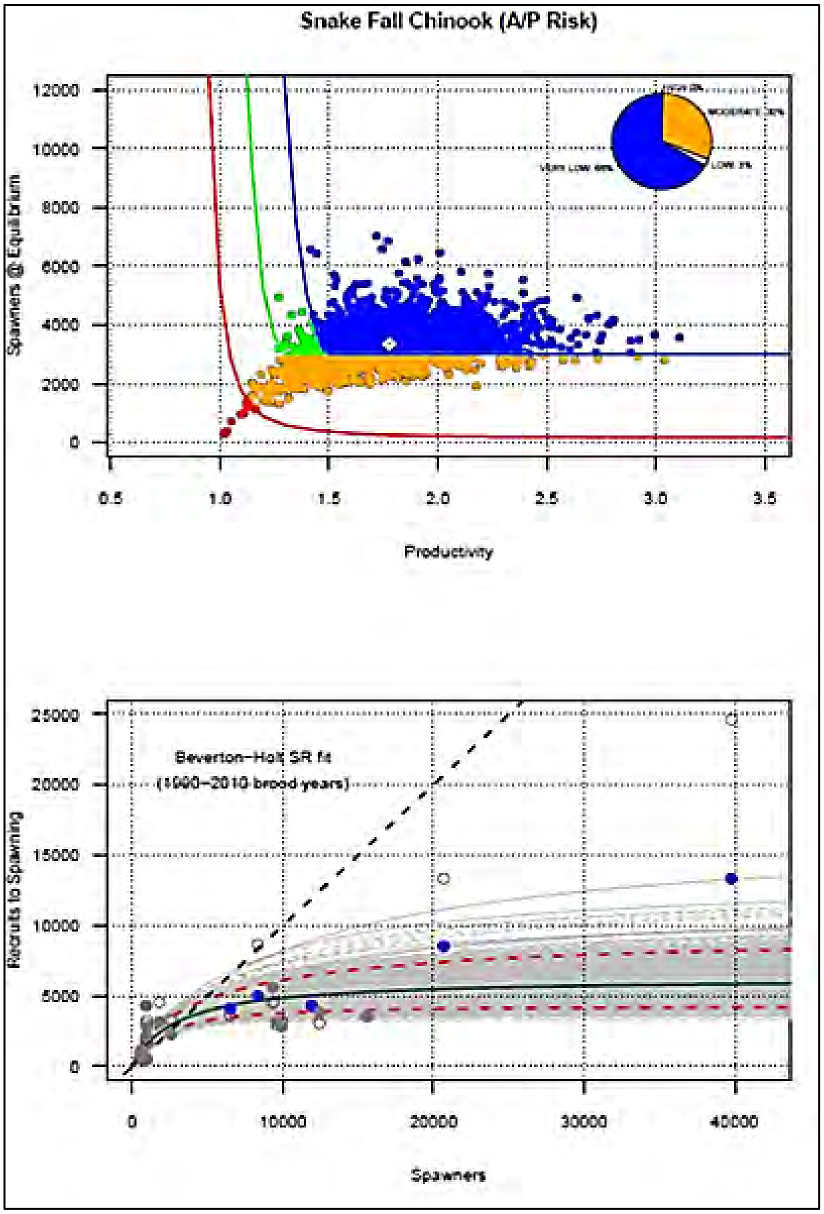


Figure 4-5. Beverton Holt stock recruit relationship fitted to broodyears 1991-2010 Snake River fall Chinook adult escapement estimates. Includes parameter uncertainty generated using the nlsBoot routine for the R statistical package. Top panel: Summary of bootstrap results (2,000 iterations) plotted against Snake fall Chinook viability curves. Pie chart in upper right corner summarizes the proportions of bootstrap runs vs. ICTRT viability curves (High, 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

As shown in Figure 4-6, the point estimate of abundance and productivity corresponding to the geometric mean natural-origin abundance and productivity exceeds the 1 percent viability curve, but by a relatively small margin, insufficient to exhibit the high certainty of exceeding the viability curve for a 1 percent risk of extinction as required under the biological viability criteria for Scenario B (see Section 3.2). Accounting for the need to exhibit sufficient probability of exceeding the viability curve, and given the current level of variability, the point estimate of current productivity would need to exceed 1.7 for the population to be rated at very low risk. The corresponding productivity and equilibrium abundance estimates from the fitted Beverton-Holt and Ricker production functions also fail to meet the criteria relative to the 1 percent viability curve (Figure 4-5). The bootstrapped confidence ranges for both of the fitted stock-recruit models overlap considerably with the 1 percent viability curve.

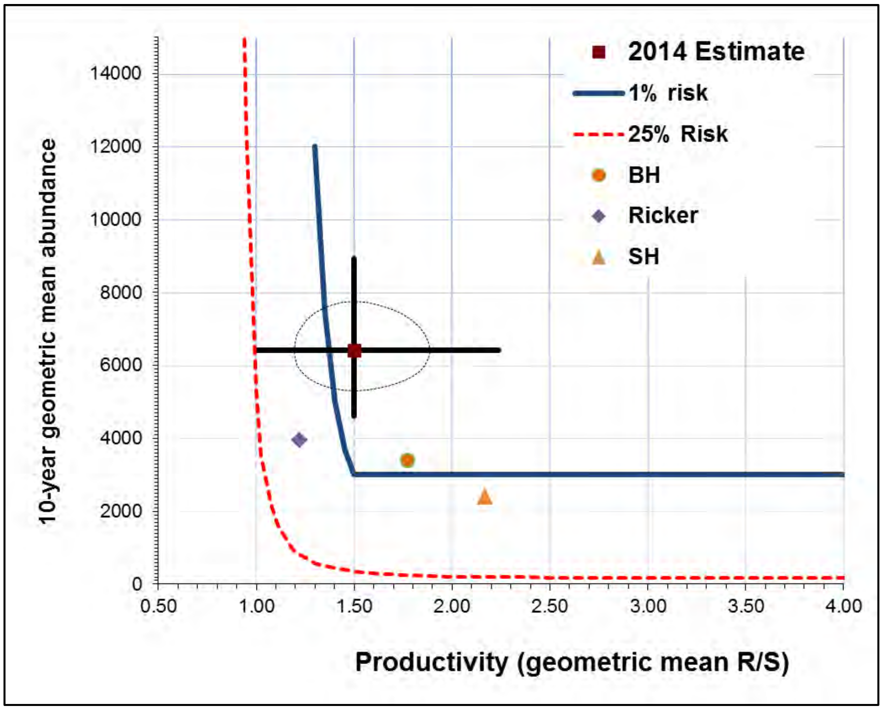


Figure 4-6. Estimated equilibrium abundance vs. productivity for Lower Snake River fall Chinook salmon population based on 1991 through 2013 data series (1991 to 2010 brood years). Oval represents 1 standard error assuming bivariate normal distribution. Lines represent 90 percent confidence limits. Point estimate for standard (empirical) ICTRT method.

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 with high confidence (i.e., an 80 percent or higher probability of exceeding the 1 percent viability curve) as required under Scenario B. The current paired estimates from either the simple empirical method or the fitted stock production functions both indicate that the certainty requirements are not met. The probability that the true underlying abundance and productivity being estimated from the samples falls above the 5 percent viability curve (with minimum abundance threshold) is, however, greater than 80 percent. As a result, the Lower Snake River fall Chinook salmon population is rated at low risk for abundance and productivity.

As described in Chapter 3, Scenario C is a single population recovery scenario in which, given the unique spatial complexity of the Lower Snake River fall Chinook salmon population, Natural Production Emphasis Areas (NPEAs) supporting the bulk of natural returns would be developed to function consistent with long-term diversity objectives. Under Scenario C, 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 designated as NPEAs with relatively low hatchery contributions to spawning. Currently, based on escapements through 2014, and 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.

4.2 Spatial Structure and Diversity

The ICTRT framework for evaluating population-level status in terms of spatial structure and diversity is hierarchical, and 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 mechanisms, factors, and metrics associated with each goal. Mechanisms are the biological or ecological processes that contribute to achieving the goals. Factors are characteristics of a population or its environment that influence mechanisms. Each of the factors has an associated set of metrics for assessing progress towards achieving the goals, or for evaluating a factor’s contribution to risk. The framework also incorporates a scoring system that weights more direct measures of current population performance over indirect indicators. The metrics used to evaluate spatial structure and diversity risk under the goals are summarized below.

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

Metrics:

a. Number and distribution of major spawning areas;
b. Spatial extent and range of spawning areas relative to historical template; and
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; and
f. Selective mortality factors: hydropower system, hatcheries, harvest, habitat.

The extant Lower Snake River fall Chinook salmon population occupies the mainstem Snake River from the upper end of the Lower Granite Dam reservoir (near Lewiston, Idaho) to Hells Canyon Dam, and the lower reaches of several major tributaries. Existing maps of geomorphic spawning habitat potential and of redd distributions were used as input for evaluating spatial structure and diversity elements of viability (Appendix B in ICTRT 2007).

The extant population consists of a spatially complex set of five historical major spawning areas (MaSAs) in the mainstem Lower Snake River and tributaries (ICTRT 2007), each of which consists of a set of relatively discrete spawning patches of varying size (Connor et al. 2001; Groves et al. 2013). The ICTRT defined a MaSA as a stream system of one or more branches that contains sufficient spawning and rearing habitat to sustain at least 500 spawners. The ICTRT identified five MaSAs for the Lower Snake River fall Chinook salmon population (Figure 4-7):

1. Upper Hells Canyon MaSA ─ The primary (largest and most productive) MaSA in the extant Lower Snake River population, this 59.6-mile mainstem Lower Snake River reach extends 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 Hells Canyon MaSA ─ This second mainstem Lower Snake River MaSA extends 42.9 miles from mouth of the Salmon River downstream to the upper end of Lower Granite reservoir, and includes production from two adjoining tributaries, Alpowa and Asotin Creeks.
3. Grande Ronde River MaSA ─ The MaSA covers the lower mainstem reach of the Grande Ronde River. Isolated reaches in tributaries to the Grande Ronde River may have also supported fall Chinook salmon production at one time.
4. Clearwater River MaSA ─ The MaSA includes the lower mainstem Clearwater River. Historical information suggests that the Selway River and other tributaries also supported fall Chinook salmon.
5. Tucannon River MaSA ─ The MaSA covers the lower mainstem Tucannon River and contiguous mainstem Snake River habitat associated with Little Goose and Lower Monumental Dams.

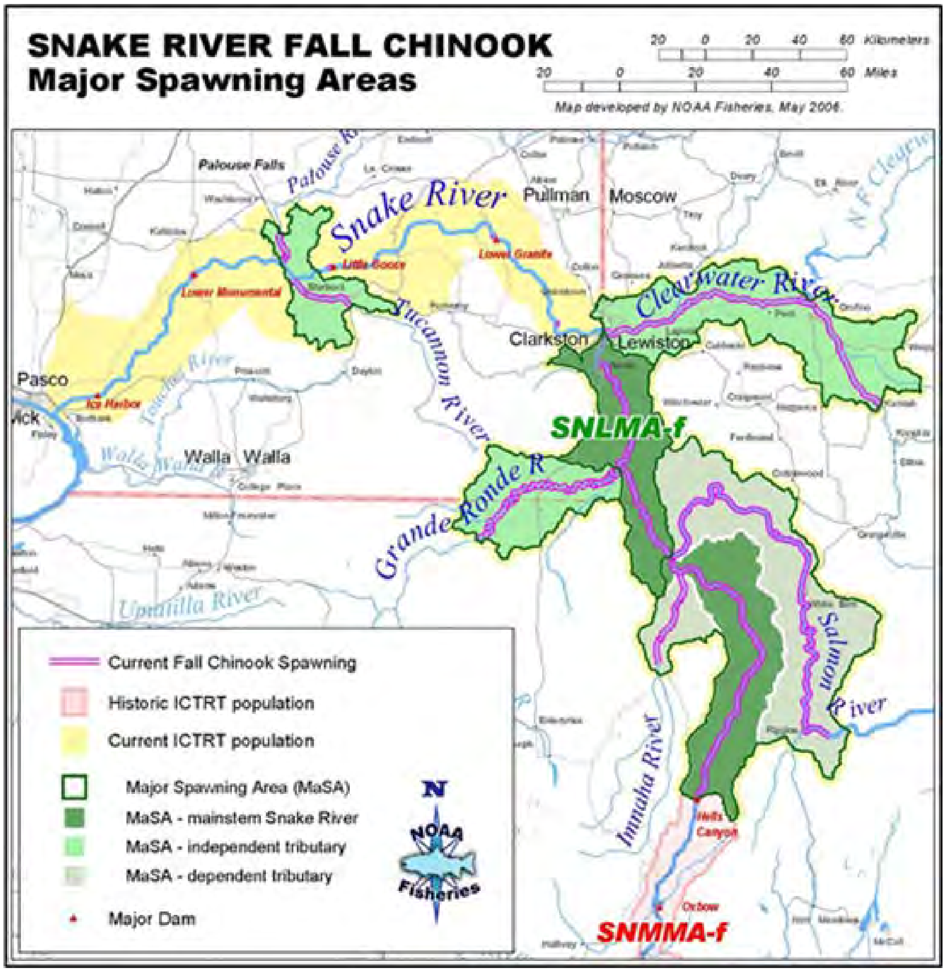


Figure 4-7. Lower Snake River fall Chinook salmon population major spawning areas (MaSAs) with core spawing habitat and associated dependent spawning areas delineated (Source: ICTRT 2007, Appendix B).

Anecdotal accounts suggest that late spawning Chinook salmon may have also existed in spatially isolated reaches of upriver tributaries in the Grande Ronde and Clearwater systems, and attempts are underway to develop a separate early-spawning component in the upper Clearwater River using the South Fork Clearwater weir as a broodstock collection point (Johnson and Hesse 2012). Late spawning Chinook salmon may have also existed in the lower mainstem of the South Fork Salmon River (Connor et al. 2016). Historically, some level of fall Chinook salmon spawning may also have occurred in the lower Snake River in the reach currently inundated by the Ice Harbor Dam reservoir (Dauble et al. 2003). Spawners using this lowest potential spawning reach 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.

Annual redd surveys show that fall Chinook salmon spawn in all five of the Lower Snake River MaSAs. However, the inability to obtain carcass samples from the mainstem MaSAs because of time of year and high flows makes it difficult to assess the distribution of natural-origin spawners. Reconstruction of natural-origin spawner abundance based on hatchery expansions and data from homing/dispersal studies on acclimated hatchery releases indicates that four of the five MaSAs are contributing to naturally produced returns (Figure 4-8). Tags from carcass samples obtained in the Tucannon River indicate that nearly all natural spawners in the Tucannon MaSA are hatchery-origin returns (Milks and Oakerman 2014).

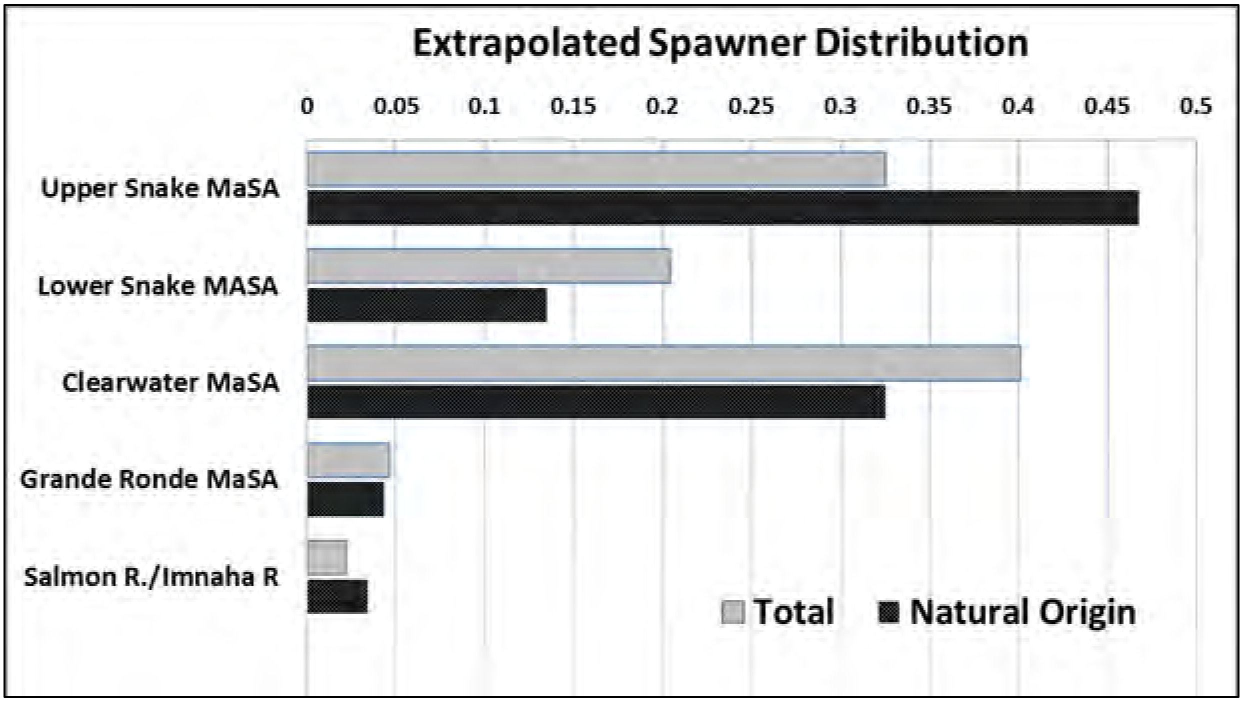


Figure 4-8. Estimated average spawner distributions (2004-2015) across major spawning areas (MaSAa) upstream of Lower Granite Dam. Total is average distribution of redds from annual multiple pass surveys, produced by combination of hatchery- and natural-origin spawners. Natural-origin estimates extrapolated from regional total redd counts, estimated hatchery returns by release area and estimated dispersal/straying patterns from Garcia et al. 2004.

The following discussions summarize spatial structure and diversity risks for the Lower Snake River fall Chinook population based on findings from the Northwest Fisheries Science Center's 2015 status review (NWFSC 2015). The discussions are organized under the nine factors that the ICTRT (2007) recommended using to determine population spatial structure and diversity risk.

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

This factor reflects the basic accessibility and distribution of MaSAs within a population. Two mainstem Snake River and three large tributary MaSAs are accessible to anadromous returns in the Lower Snake River fall Chinook salmon population. The ICTRT classified the population as trellis structured (ICTRT 2007). Applying the ICTRT guidelines for a complex (trellis-structured) population, the Lower Snake River fall Chinook salmon population is rated at very low risk for number and spatial arrangement of spawning areas.

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

The current distribution of spawning in the Lower Snake River fall Chinook salmon population is shown in Figure 4-8. Results of annual redd surveys indicate the existence of natural-origin fall Chinook salmon spawners in four of the five major spawning areas in the extant population (the Upper Hells Canyon MaSA, the Lower Hells Canyon MaSA. and the Clearwater and Grande Ronde Rivers MaSAs). Carcass sampling data from the mainstem Clearwater River MaSA also confirm the presence of natural-origin spawners. Direct sampling of carcasses in the large mainstem Snake River spawning reaches is precluded by high flows and other environmental conditions. Simple extrapolations based on known hatchery returns over Lower Granite and radio tracking studies (Connor et al. 2004) indicate the presence of both hatchery- and natural-origin spawners in both mainstem MaSAs. The Tucannon River MaSA also has fall Chinook salmon spawners, but annual surveys consistently indicate that natural spawners in the Tucannon are likely hatchery-origin returns from the Lyons Ferry Hatchery releases. As a result this MaSA does not meet the ICTRT occupancy requirements. Given that four of the five MaSAs are currently rated as occupied by natural origin spawners, the population is rated low risk for this factor (current spatial extent of natural production across MaSAs).

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

Four of the five historical MaSAs in the extant Lower Snake River population meet the ICTRT criteria for occupancy. Due to lack of evidence of natural-origin spawners, the Tucannon MaSA is not considered occupied. However, this MaSA is at the downstream end of the overall population, so the lack of occupancy does not create a gap among spawning aggregates within the population. The lack of occupancy in this MaSA, however, may increase the overall risk to the ESU 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 in the reaches supporting the extant Lower Snake River population were likely more diverse than those in the reaches supporting the extirpated Middle Snake River population. Conditions in the Upper Hells Canyon MaSA are currently the most similar to those associated with the historical Middle Snake River population (Connor et al. 2002), and data indicate that most smolts produced from this area migrate as subyearlings, which is believed to be the primary historical life-history strategy. In comparison, incubation and spring juvenile rearing temperatures in the lower Clearwater River mainstem are relatively cold. As a result, subyearling Chinook salmon must rear later into the summer before reaching sufficient size to begin active migration. Temperatures in lower sections of the Lower Hells Canyon MaSA are also colder than those in the Upper Hells Canyon reach. Out-migration timing from the Clearwater MaSA and, to a lesser extent, from the Lower Hells Canyon MaSA 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 both hatchery- and natural-origin returning adult Chinook salmon overwintered somewhere in the Columbia River system before entering the ocean (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 River mainstem below the

Salmon River confluence. These 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 or summer. Natural returns from both the subyearling 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 (yearling) life-history pattern peaked with the early 2000 broods, and has declined since then (Figure 4-9).

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 adult Snake River fall Chinook currently exhibit a subyearling life-history strategy, but an alternative yearling life-history strategy continues to exist. 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 strategies likely represent adaptations to recent environmental conditions, including changes in water temperatures. The Lower Snake River population is meeting the ICTRT guidelines for rating major life-history diversity at low risk by exhibiting positive adaptations to current conditions while also retaining historical life history patterns.

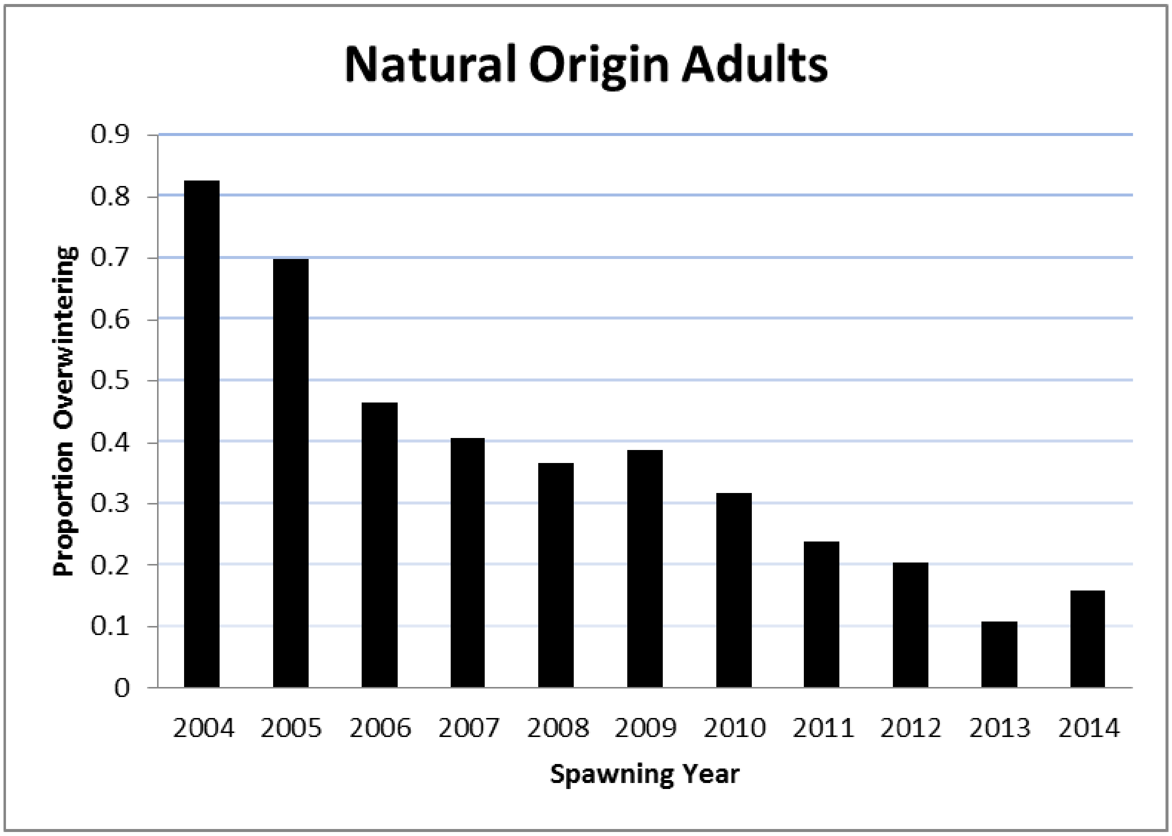


Figure 4-9. Proportion of returning natural-origin Snake River fall Chinook adults sampled at the Lower Granite Dam trap identified as yearling outmigrants. Extrapolated from age specific estimates of unmarked returns adjusted for potential contributions of unmarked hatchery fish (Young et al. 2013 for 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 (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 relative to 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 means or reduced variability for a 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 losses of traits, or significant shifts or truncated variability across multiple traits, translates to a high risk rating.

Seven phenotypic traits, each of which can be linked to natural selective forces at some life stage, were reviewed for the Lower Snake River fall Chinook salmon population (Table 4-4). Three of the traits reflect characteristics of returning adult fish. The other four traits reflect characteristics of juvenile fish. The ICTRT guidance for evaluating diversity noted that it was not appropriate to specify single point estimate targets for assessing risk for specific diversity components. Instead, assigning risk would require some level of judgment regarding 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 Lower Granite Dam, PIT-tag detections at mainstem dams (Young et al. 2012)
Age Structure (mature returns)	Trap sampling (Young et al. 2012, 2013; WDFW 2017)
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 (Connor et al. 2014)
Emigration Size Distribution	Parr seining surveys (Upper and Lower Hells Canyon Snake River reaches and Clearwater River (Connor et al. 2014)
Subyearling migrant proportions	Trap sampling, adult scale and otolith analyses, juvenile migrant timing patterns (Young et al. 2012; Connor et al. 2014; Hegg et al. 2013)

Empirical data on historical phenotypic patterns for the Lower Snake River fall Chinook salmon population are limited. Some insight into patterns that were prevalent historically can 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. These data indicate that there has been a relatively small shift in the timing of peak counts passing over Ice Harbor Dam since 1962 (the first year of counts). The seaward migration timing through the mainstem Snake and

Columbia Rivers of natural production from the Lower Snake River population 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 Snake River fall Chinook salmon population is rated 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). NMFS evaluated current genetic variation of the population from both perspectives in order to assign a risk rating for 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 to another. Altered patterns of gene flow among populations can result in increased genetic diversity in a receiving population. It can also result in outbreeding depression ─ a reduction in fitness due to altered genetic frequencies (NMFS 2012a). One of the specific factors cited in the ESA listing of Snake River fall Chinook salmon (57 FR 14653) was the potential for significant genetic introgression due to increased straying of outside stocks into natural spawning areas above Lower Granite Dam.

Recent sampling data indicate that (1) straying from the primary source of out-of-ESU returns ─ the Umatilla River releases of Priest Rapids Hatchery fall Chinook salmon stock ─ has been reduced substantially; (2) broodstock protocols have eliminated known out-of-ESU fish from the ongoing Snake River 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, managers became concerned that the natural population might become an introgressed population of upper Columbia River and Snake River gene pools (Bugert et al. 1995). Marshall et al. (2000) examined this possibility by genetically characterizing naturally produced juvenile progeny of fall Chinook salmon spawning upstream from Lyons Ferry between 1990 and 1994. They 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, recent genetic samples from returning naturally produced Lower Snake River fall Chinook salmon indicate that composite genetic diversity is being maintained. Comparative samples from returning Lyons Ferry Hatchery fish show that the Snake River fall Chinook hatchery stock is similar to the natural component of the population. This indicates that the actions taken to reduce potential introgression of out-of-basin hatchery strays have been effective.

Within-population Diversity

Given the diversity of habitats across the major spawning areas within the Lower Snake River population and evidence of relatively strong reach fidelity for released acclimated fish from hatchery programs, it is reasonable to assume that some, albeit an unknown, level of within-population diversity existed historically. Given the widespread distribution of hatchery 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. Natural-origin return levels declined substantially following the completion of the Hells Canyon Complex of dams (which completely blocked major production areas above Hells Canyon Dam, the lowermost dam in the Hells Canyon Complex) and the construction of the lower Snake River dams. Hatchery fish made up an increasing proportion of returns at Lower Granite Dam (the uppermost of the four lower Snake River mainstem dams) through the 1980s. Returns of hatchery-origin Snake River fall Chinook salmon from the Lyons Ferry Hatchery program and strays from outplanted 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, and remained low through the 1980s. Only about 78 natural-origin adults (Lavoy and Mendel 1996) returned to the Snake River in 1990. These large declines precipitated the ESA-listing of the species.

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 2000. Since 2000, hatchery returns have increased faster than natural-origin returns (Table 4-5; Figure 4-10). 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 2000s. 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 4-11). Snake River hatchery fish above Lower Granite Dam include returns from 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).

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

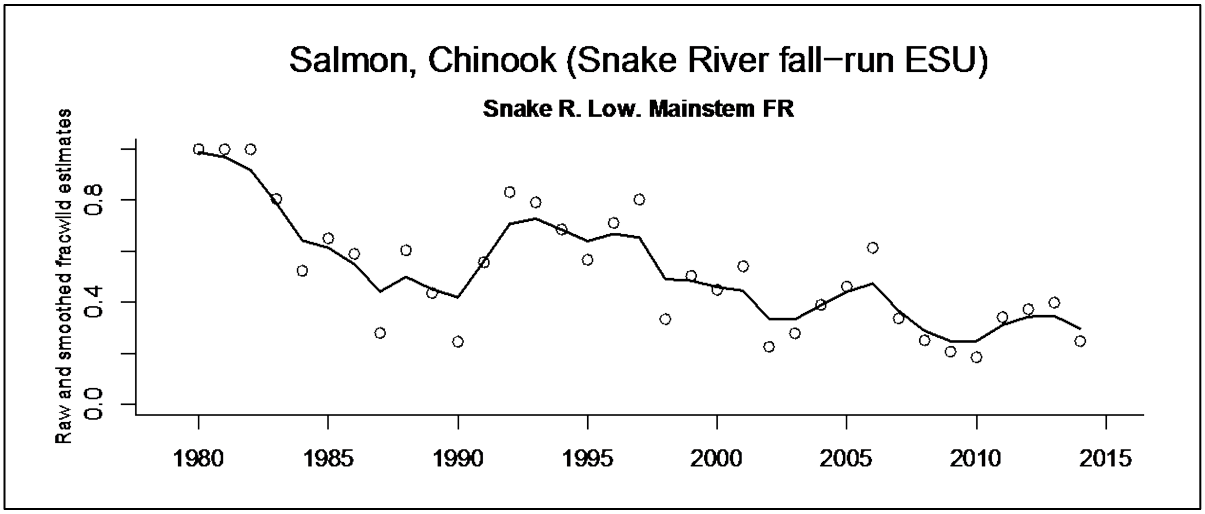


Figure 4-10. Smoothed trend in the estimated fraction of the natural spawning population consisting of fish of natural origin. Points show the annual raw estimates.

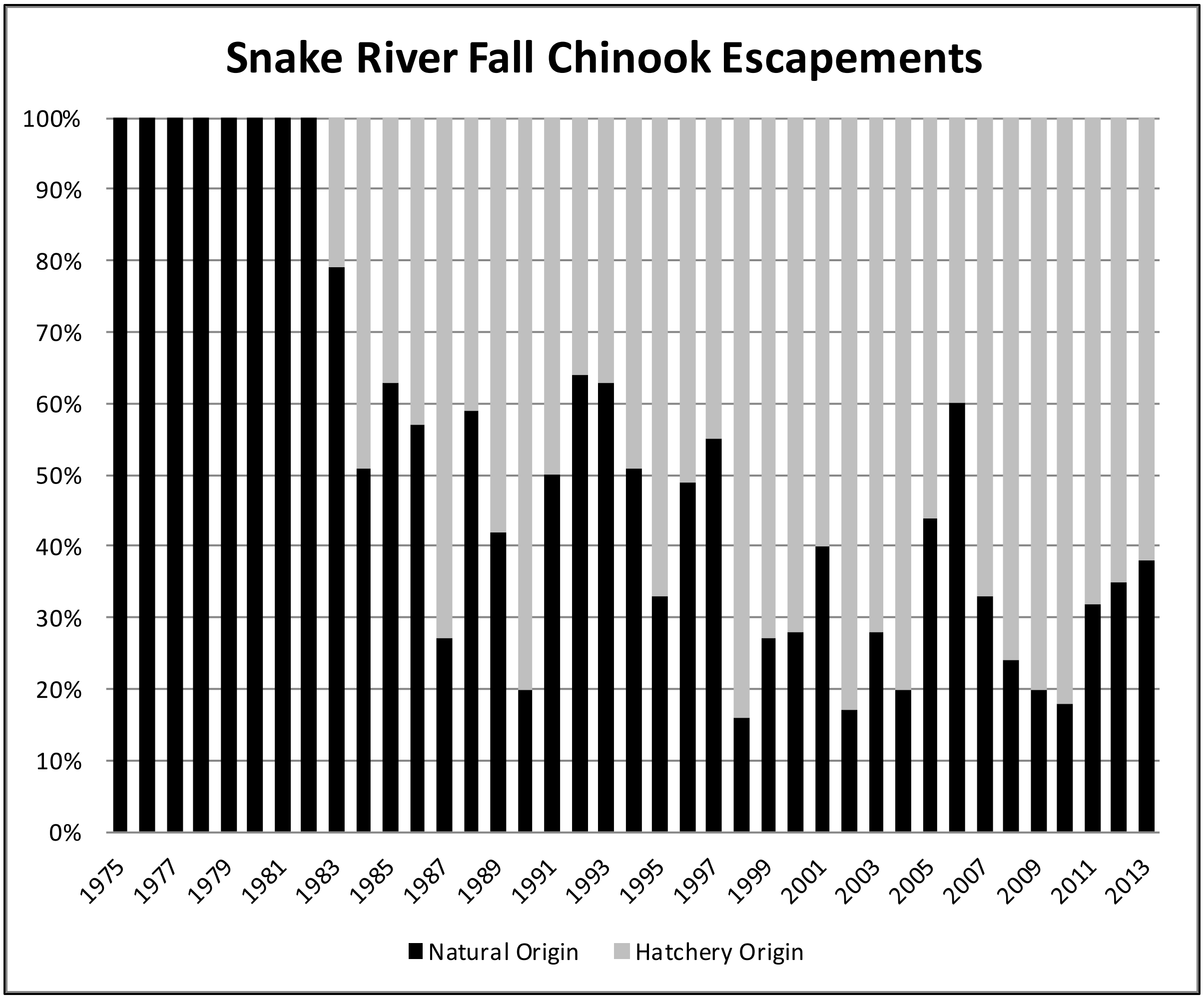


Figure 4-11. Annual adult escapement proportions natural-origin (black) and hatchery-origin (gray).

B.3. Distribution of population across habitat types

The ICTRT recognized that maintaining spawner occupancy in a 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 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 Snake River population. Therefore, the extant Lower Snake River fall Chinook salmon population is rated low risk for distribution across habitat types.

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

Human activities have the potential to result in substantial changes in phenotypes at various life stages for salmon 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 primarily spawn in the four upstream major spawning areas and must pass eight mainstem dams as both juveniles on their downstream outmigration and as adults on their return to spawn.

Juvenile migration timing: It is likely that the system of hydroelectric dams and their operations imposed differentially higher mortalities on later migrating smolts in the years leading up to, and immediately following, ESA listing. Actions have since been taken to improve outmigration survivals, including measures targeting in-river conditions affecting a substantial portion of the later-migrating component of the population. Ongoing studies of annual smolt migration timing and survivals indicate improvements in average survivals and a reduction in the potential for differential mortality across the run. Additional studies are underway 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 impact of the hydropower system on this trait is rated moderate risk.

Adult migration timing: The relatively late Columbia River entry timing of adult 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 in 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 subyearling 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 (Hard et al. 2008; Riddle 1986).

Selection caused by non-random removals of fish for hatchery broodstock: Prior to 2003, broodstock for Snake River fall Chinook salmon hatchery programs came from adult returns from previous hatchery program releases. The original broodstock was established in the 1980s and early 1990s through adult capture at lower Snake River dams (Bugert et al. 1995). Beginning with the 2003 return, natural-origin broodstock collected from across the run by trapping at Lower Granite Dam have been included in the program (Milks et al. 2006). Given current removal levels and broodstock collection 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 in 1992. Changes to operations, particularly for the Hells Canyon Complex, have generally stabilized conditions during spawning, incubation, and rearing time windows. Therefore, actions affecting 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 subyearling Chinook salmon have resulted in increased mortalities during the smolt outmigration. Northern pikeminnow, smallmouth bass, and avian predators selectively target subyearling Chinook salmon relative to larger yearling migrants. However, size frequency comparisons of subyearlings consumed by predators with in-river subyearling 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 salmon 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 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 strategies, 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. Spatial structure and diversity ratings for the Lower Snake River fall Chinook salmon population. The overall population rating is the highest risk rating among (1) spatial mechanism, (2) direct diversity mechanism, and (3) average across direct and indirect diversity mechanisms. Risk ratings represent the risk over a 100-year period: <1% (very low or VL) risk, 1−5% (low or L) risk, 6−25% (moderate or M) risk, and >25% (high of H) risk.

Metric	Risk Assessment Scores				
	Metric[d]	Factor[c]	Mechanism[b]	Goal[a]	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 Strategies	L (1)	L(1)	Moderate Risk (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 Risk 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)	Low Risk (1)		
SELECTIVE IMPACTS	M (0)	M (0)	Moderate Risk (0)		

[a] *Goals* are the biological or ecological objectives that spatial structure and diversity criteria are intended to achieve.

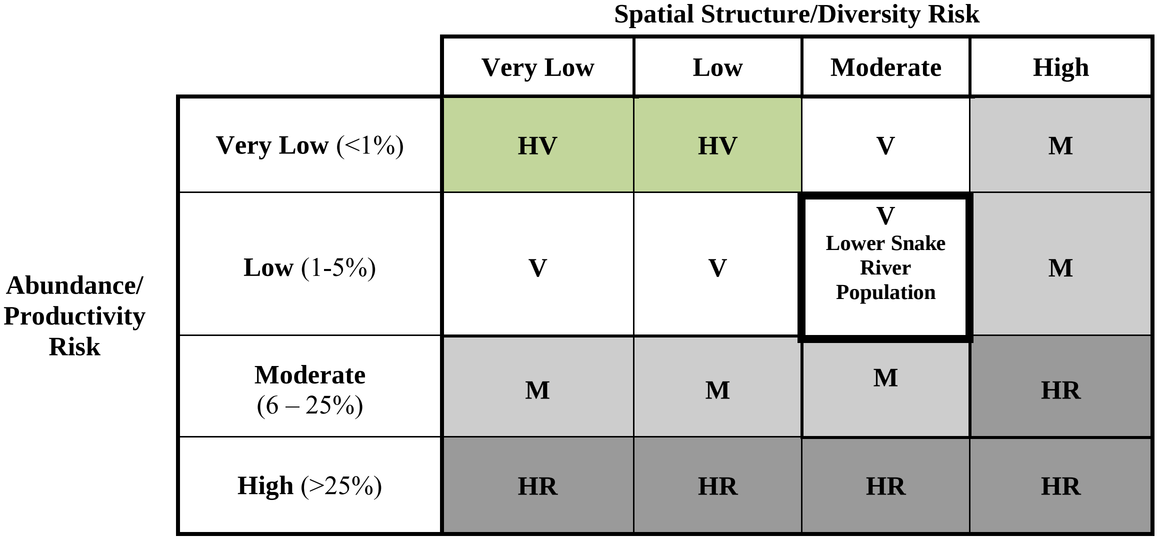
[b] *Mechanisms* are biological or ecological processes that contribute to achieving those goals (e.g., gene flow patterns affect the distribution of genotypic and phenotypic variation in a population).

[c] *Factors* are characteristics of a population or its environment that influence mechanisms (e.g., gaps in spawning distribution affect patterns of gene flow, which then affect patterns of genotypic and phenotypic variation).

[d] *Metrics* are measured and assessed at regular intervals to determine whether a population has achieved goals, or to evaluate its current risk level. Each factor has one or more metrics associated with it.

4.3 Overall Population Risk Rating

Overall population viability for the Lower 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 4-12).



		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 Snake River Population**	**M**
	Moderate (6 – 25%)	**M**	**M**	**M**	**HR**
	High (>25%)	**HR**	**HR**	**HR**	**HR**

Figure 4-12. Lower 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).***

Overall, the NWFSC (2015) found that status of the Snake River fall Chinook salmon ESU has improved compared to the time of listing and compared to previous status reviews. The single extant population in the ESU is currently meeting the criteria for a rating of viable developed by the ICTRT (2007). Nevertheless, the ESU is not meeting the ESA recovery goals described in Chapter 3. All of the potential recovery scenarios described in Chapter 3 would require the extant population to meet minimum requirements for highly viable (green-shaded combinations in Figure 4-12). The single-population viability scenarios (Scenarios B and C) require an added uncertainty buffer, i.e., the population must be highly viable with a high degree of certainty. Achieving the rating of highly viable with high certainty 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 relative to the criteria for the single Lower Snake River fall Chinook salmon population, measured in the aggregate (e.g., Scenario B described in Chapter 3). The current 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 term. The geometric mean natural-origin abundance for the most recent 10 years of annual spawner escapement estimates (2005-2014) is 6,418.

Using the ICTRT simple 20-year R/S method, the current point estimate of productivity for this population (1991-2010 brood years) is 1.53. The combination of these two estimates does not exceed the ICTRT's very low risk (1 percent in 100 years) viability curve by a sufficient amount to meet the 80 percent confidence requirement called for in Scenario B (see Section 3.2.2). Using the alternative approach of fitting stock-recruit functions to the 1991-2010 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 strategies, shifts in phenotypic traits, and high levels of genetic homogeneity in samples from natural-origin returns. In particular, the rating primarily 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 spatial distribution of hatchery- versus natural-origin spawners, the population is currently not meeting the requirements for highly viable under Scenario C, the single-population with Natural Production Emphasis Areas scenario. Under Scenario C, one or more major spawning areas would need to be producing the bulk of natural production with relatively low hatchery spawner proportions.

4.4 Gap between Current and Desired Viability Status

All of the potential recovery scenarios described in Chapter 3 would require the extant population to meet minimum requirements for highly viable status. The viability criteria for the single-population recovery scenarios, described in Chapter 3, require the extant population to achieve highly viably status (very low risk) with a high degree of certainty. Achieving this risk rating 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 Scenario C, the single population with NPEAs scenario, 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 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 survival during downstream migration. It is also possible that actions in recent years (e.g., more consistent flow-related conditions affecting spawning and rearing and increased passage survivals resulting from expanded spill programs) 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 Chapter 6 of the Plan and the research, monitoring, and evaluation strategy in Chapter 7 include provisions for further addressing these uncertainties.

Spatial structure/diversity: To achieve highly viable status with a high degree of certainty, 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 Snake River population.

Under Scenario C, 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, 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

This chapter describes the limiting factors and threats that contributed to the decline in Snake River fall Chinook salmon viability and/or currently threaten the species' viability. These limiting factors and threats are related to the five ESA section 4(a)(1) listing factors.[52] They must be addressed, in the aggregate, to the point that delisting of the ESU is not likely to result in their re-emergence. The information in this chapter was used to help identify the strategies and site-specific actions needed to recover the species and to identify potential threats where RM&E is needed to better understand whether or how they affect the species. It will also inform future analyses of Snake River fall Chinook salmon status under the five ESA section 4(a)(1) listing factors.

> **Limiting factors** are the biological, physical, and chemical conditions (e.g., inadequate spawning habitat, high water temperature, insufficient prey resources) and associated ecological processes and interactions that result in reductions in VSP parameters.
>
> **Threats** are human activities or natural events 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 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, and that can be managed in a manner that minimizes or eliminates the negative impacts. As described in Section 2.8, 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.

Limiting factors and threats operate across the entire Snake River fall Chinook salmon life cycle and have independent as well as synergistic and cumulative effects on ESU viability. Achieving recovery requires understanding both the individual and combined effects of limiting factors and threats, and addressing them throughout the life cycle. It also requires understanding how to manage activities to reduce negative impacts, and the ability to adjust actions and priorities over time as new information emerges on limiting factors and threats and their individual and synergistic effects.

Our understanding of the risks posed to Snake River fall Chinook salmon by the various limiting factors and threats continues to evolve. Information gained through RM&E and refined through use of life-cycle models and other tools will improve our understanding of how and where the different limiting factors affect the species, as well as of their relative, individual, and combined

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[52] The five ESA listing factors at section 4(a)(1) are (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. See Section 3.2.3 of this Plan for additional discussion of the section 4(a)(1) listing factors and their associated delisting criteria for Snake River fall Chinook salmon.

effects throughout the species' life cycle.[53] This information will aid our future efforts to weigh the relative impacts of the limiting factors and threats described in this chapter on the ESU's status, and identify priorities during implementation of this recovery plan to address the threats and achieve recovery as quickly and effectively as possible.[54]

Chapter Organization

This chapter contains six sections, described below, which reflect the general threats to Snake River fall Chinook salmon. These threat categories overlap with the ESA section 4(a)(1) listing factors and the threats criteria discussed in Section 3.2.3. The discussions in each section reflect the best available information, including the results of research, monitoring, and evaluation of the fish and its habitats and information presented in NMFS status reviews, ICTRT assessments, and various related ESA section 7 consultations. The discussions also reflect information from the Ocean Module (Appendix D); Hydro Module (Appendix E); Estuary Module (Appendix F); and Harvest Module (Appendix G).

- Section 5.1: Background, briefly summarizes the factors that contributed to the species' listing and those that currently affect its viability.
- Section 5.2: Hydropower and Habitat. Mainstem hydropower and other activities that affect habitat (ESA listing factor A) are discussed 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 describes hydropower- and habitat-related threats and limiting factors in different geographic areas within the species range, as well as factors related to climate change.
- Section 5.3: Harvest, identifies threats and limiting factors related to fisheries management (ESA listing factor B).
- Section 5.4: Predation, Competition, and Other Ecological Interactions. This section discusses threats and limiting factors related to predation by birds, marine mammals, and other fish. It also describes effects from other ecological interactions, including competition with hatchery fish and other species for spawning habitat and the effects of changes in the food web (ESA listing factors C and E).
- Section 5.5: Hatcheries, describes the effects of hatchery operations and programs on natural-origin fall Chinook salmon (ESA listing factor E).
- Section 5.6: Toxic Pollutants, discusses threats and limiting factors related to exposure of the fish to chemical contaminants from municipal, agricultural, industrial, and urban land uses (ESA listing factor E).

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[53] See Sections 6.1.3 and 6.2 and Chapter 7 for more on the approach to gaining new information on effects of different threats on the survival and long-term viability of natural-origin Snake River fall Chinook salmon, and integrating this information into recovery efforts across the species' life cycle.

[54] The recovery strategy (Chapter 6) discusses life-cycle models as an important tool for understanding relative and combined effects of threats and for identifying the biggest opportunities for improving survival.

5.1 Background

As discussed in Chapters 1 and 2, many human activities contributed to the steady and severe decline of Snake River fall Chinook salmon, leading to their eventual listing as threatened under the ESA in 1992 (57 FR 14653) and to subsequent determinations that the “threatened” classification remained appropriate (70 FR 37160; NMFS 2011a, 2016a). Human activities that have influenced the species are summarized in Table 5-1. NMFS has documented the factors for the ESU’s decline and continued threatened status in listing determinations, scientific assessments, and status reviews (57 FR 14653, 64 FR 50406, 70 FR 37160; Waples et al. 1991; Busby et al. 1999; Good et al. 2005; ICTRT 2007; Ford et al. 2011; NMFS 2011a, 2016a; NWFSC 2015).

Factors contributing to the decline and the subsequent listing included the loss of primary spawning and rearing habitats 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 and estuary; increases in numbers of non-local hatchery-origin fish spawning naturally and the associated possibility of significant introgression from these non-local hatchery fish; and relatively high aggregate harvest impacts from ocean and in-river fisheries (Good et al. 2005). The 1991 status review (Waples et al. 1991) and most recent status reviews (ICTRT 2010; NWFSC 2015; NMFS 2011a, 2016a) 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.

While some actions to improve the status of Snake River fall Chinook salmon were initiated before the ESA listing, the pace and magnitude of those efforts accelerated following the listing. The combined effects of management actions implemented by multiple entities have made significant progress in addressing several of the factors that led to the listing and have helped to improve the species’ abundance and productivity (see Section 2.8). These actions include the Idaho Power Company’s fall Chinook salmon spawning program to enhance and maintain suitable spawning and incubation conditions in the Snake River downstream of the Hells Canyon Complex, structural and operational improvements made to improve fish passage and survival through the FCRPS projects, as well as revisions to harvest and hatchery production programs. Consequently, while historical spawning and rearing habitats upstream of the Hells Canyon Complex remain inaccessible and too degraded to support significant anadromous fish production, actions have boosted adult and juvenile survival of the extant population downstream of Hells Canyon Dam and 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. Many more fall Chinook salmon now return to the Snake River than in the 1990s when the species was listed.

Although the extant population is currently considered viable, the ESU is not yet meeting its ESA recovery goal (see Chapter 3), and more effort is needed to reduce the effects of different threats across the life cycle and achieve recovery. Understanding the individual and combined effects of limiting factors and threats is necessary to understand the effects of actions implemented to date and to identify the additional actions needed to achieve recovery. Our understanding of effects continues to improve as a result of ongoing RM&E, including knowledge gained through life-cycle modeling, and this new information will be incorporated into recovery planning as it emerges. This chapter describes the limiting factors and threats that have affected Snake River fall Chinook salmon in the past as well as those currently affecting the ESU.

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

Time Period	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 mouth of Snake River
1890s	Commercial harvest of Columbia River salmon turns from targeting spring and summer Chinook to targeting fall Chinook salmon	Harvest peaks at nearly 80% of returning fall Chinook salmon adults	Abundance begins to decline
1901 – 1902	Swan Falls Dam constructed on Snake River (RM 457.7) First full-scale hatchery constructed, at Ontario, Oregon (1902); operated 1902-1909	Access blocked to 157 miles of mainstem habitat	Substantially reduced abundance and distribution in Middle Snake River
1904-1925	Commercial harvest effort moves from lower Columbia, where harvest was controlled, to above Celilo Falls (1904). Fish wheels outlawed in Oregon (1928) and Washington (1935)		Abundance continues to decline
1927	Lewiston Dam constructed on Clearwater River (RM 6)	Access to Clearwater River blocked, 1927-73	
1938-1947	Bonneville Dam completed on Columbia River (RM 146) in 1938	During this period, harvest rate on returning fall Chinook adults in Columbia River ranged from 64.1% to 80.2%	89,800 to 197,290 SR fall Chinook return yearly to mouth of Columbia River; 47,600 highest annual return to Snake River
1950s	McNary Dam completed on Columbia River (RM 292) in 1953 The Dalles Dam completed on Columbia River (RM 191.5) in 1957		Average annual return of 29,000 adults to Snake River
1958-1967	Hells Canyon Complex 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; 80% of total SR fall Chinook historical habitat lost.	Abundance declines further
1964-1968	John Day Dam completed on Columbia River (RM 215.6) in 1968		Average annual return of 12,720 adults to Snake River
1969-1976	Lower Snake River Compensation Plan starts egg bank program and begins producing hatchery fish to compensate for production lost due to habitat losses (1976)		2,814 adults return to Snake River in 1974; 2,558 return in 1975
1975-1980	Transportation of juvenile fall Chinook salmon past lower Snake River dams begins in late 1970s		Average annual return of 610 adults; low of 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)	Average annual return of 100 +/- natural-origin adults; stray out-of-ESU hatchery fish a major risk
1990 – 1992	Current Idaho Power Company fall Chinook salmon program initiated (1991) Snake River fall Chinook salmon listed under the ESA as threatened (1992)		Broodstock scarce; hatchery production levels very low 350 adults return low of 78 natural-origin fish (1990)
1993	Corps of Engineers begins drafting Dworshak Dam to enhance juvenile migration		
1995	Fall Chinook Acclimation Project implemented		
1996-2001	Actions in 1995 FCRPS biological opinion implemented in 1996 to improve dam passage/operations for migration		Average annual return of 2,164 adults to Snake River; includes 1,055 natural-origin fish (1997-2001)
2000-2002	Oxbow Hatchery Program begins in 2000; Nez Perce Tribal Hatchery program begins in 2002; total of four hatchery programs release up to 5.5 million fish		Abundance increases
2000-2007	Actions in 2000 FCRPS biological opinion implemented to further improve dam passage/ operations for migration (include increased summer spill from 2005 Court Order.)		Abundance increases
2003-2008	Snake River fall Chinook salmon ESA listing affirmed (2005) Agreements further reduce harvest impact from ocean/ Columbia River fisheries	Total exploitation rate on run averages 31% (2003-2010)	Average annual return of 11,320 adults to Snake River; includes 2,290 natural-origin fish
2008-2014	Actions in 2008 FCRPS biological opinion 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 NMFS determines that "threatened" status for the ESU is still warranted (2016).		50,000+ average annual adult return to Snake River; includes 6,418 natural-origin annual return (2005-2014)

5.2 Hydropower and Habitat

As discussed in Chapter 2, the loss of habitat for this ESU due to hydropower development is extensive, and the effects of mainstem hydropower from Hells Canyon through the estuary was one of the main factors leading to the ESA listing of the species. 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), a natural barrier to further upstream migration. Hydropower projects constructed on the mainstem Snake River in the early-to-mid twentieth century blocked access to, or inundated, most of this historical habitat, including the spawning grounds in the Middle Snake River mainstem, which were historically the most important for the species. Only limited spawning occurred historically downstream of RM 273 (Waples et al. 1991), where the majority of the species' spawning now occurs. Hydropower system operations associated with the Hells Canyon Complex continue to affect habitat conditions in the Lower Snake River population area.

Hydropower development and operations also affect conditions in the mainstem Columbia and Snake River migration corridors. Today Snake River fall Chinook salmon must pass up to eight large mainstem 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. In addition to passage issues, modifications to mainstem migratory and rearing habitat as a result of the hydropower projects and operations are significant, as are habitat changes in the estuary (floodplain connectivity) and in the size of the plume during smolt outmigration. Together, these various changes affect the viability of Snake River fall Chinook salmon.

Habitat conditions today in the mainstem Snake and Columbia Rivers are much different than they were historically. Sections 5.2.1 through 5.2.6 discuss the habitat conditions, threats, and related limiting factors at different stages in the Snake River fall Chinook salmon life cycle. The discussion is organized geographically as follows:

- Section 5.2.1: Middle Snake River Upstream of Hells Canyon Complex;
- Section 5.2.2: Upper Hells Canyon Reach of Lower Snake River Mainstem;
- Section 5.2.3: Lower Hells Canyon Reach of Lower Snake River Mainstem;
- Section 5.2.4: Mainstem Lower Snake and Columbia River (including FCRPS reservoirs and dams);
- Section 5.2.5: Tributary spawning areas; and
- Section 5.2.6: Estuary, plume, and ocean.

Following these geographically specific discussions, Section 5.2.7 addresses current and potential influences from climate change on habitat conditions in freshwater, estuary and plume, and coastal environments.

5.2.1 Middle Snake River Upstream of Hells Canyon Complex

As discussed in Chapter 2, the Middle Snake River was once the primary production area for Snake River fall Chinook salmon. The mainstem reach from Auger Falls (RM 606.6) downstream to near the mouth of the Burnt River (approximately RM 328) was especially productive due to the aquifer-fed thermal regime, which fostered good conditions during spawning, egg incubation, and emergence. Some fall Chinook salmon also likely spawned in the lower portions of nine major tributaries that joined the Middle Snake River 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. These tributary reaches, however, were likely less productive than the mainstream spawning areas.

Hydropower development and operations on the Middle Snake River, beginning with the construction of Swan Falls Dam in 1901, at RM 458, and followed by construction of the Hells Canyon Complex of dams from the late 1950s through the 1960s, led to the loss of this historically productive fall Chinook salmon habitat. This loss significantly affected Snake River fall Chinook salmon abundance, productivity, spatial structure, and diversity.

The successful reintroduction of fall Chinook salmon above the Hells Canyon Complex would improve the persistence probability of the ESU, and one of the potential ESA recovery scenarios (Scenario A) includes reestablishing a viable population above the Hells Canyon Complex. However, in addition to the challenges associated with providing passage above the dam complex, the mainstem habitat in the Middle Snake River upstream of the Hells Canyon Complex is currently too degraded to support significant fall Chinook salmon production. Limiting factors related to water quality 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 for Federal Power Act relicensing of the hydropower project (IPC 2003).

The following subsections review the effects on Snake River fall Chinook salmon from blocked access and inundated habitat, degraded water quality, and altered flows in the Middle Snake River upstream of the Hells Canyon Complex.

5.2.1.1 Blocked Access/Inundated Habitat Areas

As described in Chapter 2, hydropower development and operations on the Middle Snake River in the 1900s blocked access to and/or inundated the historical fall Chinook salmon production grounds in the Middle Snake River. The spawning and early-rearing areas in the mainstem Snake River above Hells Canyon were historically the most productive in the ESU as a result of both geomorphological conditions and temperature conditions. These areas of the Middle Snake River contained wide alluvial floodplains with unconsolidated sediment, bars, and islands that are favorable to spawning (Dauble et al. 2003). The areas were also productive because of inflowing springs, such as Thousand Springs, near Hagerman, Idaho. As a result of this inflow, winter water temperatures in the spring-fed Middle Snake reaches were substantially warmer during the winter and cooler during summer than in the Lower Snake River. These temperature conditions provided substantial survival benefits to pre-spawning adults, incubating eggs, fry, and rearing juveniles.

Access to these spawning grounds was first reduced in 1901 when construction of Swan Falls Dam eliminated passage to spawning reaches above RM 458, which were historically the largest and most productive aquifer-fed habitats in the Middle Snake River. Construction of the Hells Canyon Complex of dams and reservoirs, and other Middle Snake River dams and reservoirs, beginning in the mid-1950s blocked access to, or inundated, the remainder of the historically most productive spawning areas of the Middle Snake River, resulting in the extirpation of the most productive of the two historical populations in the ESU.

5.2.1.2 Degraded Water Quality

Currently, water quality in the Middle Snake River is highly degraded and not sufficient to support significant fall Chinook salmon production. These degraded water quality conditions reflect a variety of past and present land use activities. Development of the Snake River plain for irrigated and dryland agriculture, livestock grazing, confined animal-feeding operations, mining, timber harvest, and urban and residential settlement has been underway for two centuries (Buhidar et al. 1999).

Agricultural activities along many reaches of the Middle Snake River continue to degrade water quality and the potential productivity of spawning and rearing habitat. Runoff from agricultural lands and returns of irrigation water to the Snake River impair water quality by introducing pollutants and organic nutrients. 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). Aquatic habitat in the Middle Snake River is now severely degraded, with high nutrient inputs and significantly reduced spring freshet flows compared with predevelopment times (Chandler et al. 2001). These activities ─ together with livestock grazing, confined animal feeding operations, mining, and urban and residential development, and other land uses ─ have resulted in extremely large nutrient loads in the mainstem Middle Snake River that cause 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).

Many segments of the Snake River and its tributaries above the Hells Canyon Complex are listed as impaired in the state of Idaho's integrated water quality report, submitted to the Environmental Protection Agency to comply with Clean Water Action Sections 305(b), 303(d) and 314 (IDEQ 2014). Impairments to the listed river segments include problems related to sediments, nutrients, pH, bacteria, dissolved oxygen levels, temperature, and flow alterations.

Idaho must develop a water quality improvement plan, called a total maximum daily load[55] (TMDL), for water bodies not meeting water quality standards. TMDLs have been developed to address many of the listed river segments, and additional TMDLs are scheduled to be completed.

High concentrations of organic matter, chlorophyll *a*, and nutrients contributed by upstream tributaries into the Snake River accumulate in sediment in low-flow years and create eutrophic conditions in Brownlee Reservoir (the reservoir in the Hells Canyon Complex that is farthest upstream) (Myers et al. 2003). Concentrations of chlorophyll *a*, an indicator of the amount of algae growing in a waterbody, 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 explosive growth of algae in the Snake River. The nutrients and algae settle out in 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 2006; Myers et al. 2003). These hypoxic waters are eventually drawn into the turbines at Brownlee Dam during late summer and fall and then released downstream. Dissolved oxygen levels in Oxbow and Hells Canyon Reservoirs usually are approximately the same as in Brownlee Reservoir (Myers et al. 2003). The effects of these conditions downstream of Hells Canyon Dam are discussed in Section 5.2.2.1.

Summer water temperatures in the Middle Snake River can rise above the cold water aquatic life temperature standard (IDEQ 2014). The high temperatures typically occur in July and August, and historically most juvenile fall Chinook salmon in the reach likely were not exposed to the high temperatures because they migrated as subyearlings, leaving the Middle Snake River by mid-June. Early migrating adult fall Chinook salmon, however, could be exposed to the warmer temperatures in the reach, especially when returning to the area from August through October.

5.2.1.3 Altered Flows

Natural hydrologic regimes above the Hells Canyon Complex have been significantly altered to support land uses, such as irrigation for agriculture. Throughout the early to mid-1900s, the Bureau of Reclamation and some private companies constructed a number of projects to provide irrigation to Idaho farmlands on the Snake River plain. Major storage reservoirs in the upper Snake River basin included Jackson Lake (1916), Palisades (1957), and American Falls (1925). Other reservoirs were constructed for other purposes: for example, Milner Reservoir was constructed in 1905 to divert the Snake River into large canals to distribute irrigation water to southern Idaho. Historically, however, the low summer flows created by these water storage and diversion projects likely did not have an adverse effect on the now-extirpated Middle Snake River fall Chinook population. As noted earlier, most juvenile fall Chinook salmon would have migrated out of the Middle Snake River reach by mid-May, before flows dropped to low levels.

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[55] A Total Maximum Daily Load (TMDL) is a regulatory term in the U.S. Clean Water Act, describing a plan for restoring impaired waters that identifies the maximum amount of a pollutant that a body of water can receive while still meeting water quality standards.

Flows in the Middle Snake River are also altered by hydropower operations, which can dramatically alter river flows as a result of load-following. Outflows frequently fluctuate significantly on a daily basis. If fall Chinook salmon were reintroduced above the Hells Canyon Complex, load-following operations could strand or entrap rearing juvenile fall Chinook salmon in shallow-water rearing areas. This potential effect would be most pronounced nearest a dam and attenuate with distance downstream of a dam.

5.2.1.4 Summary: Middle Snake River Upstream of Hells Canyon Complex

Threats: Hydropower projects and operations, including reservoirs, flow management, and load following.

Related limiting factors: Blocked and inundated habitat, total dissolved gas levels below Brownlee and Oxbow Dams, altered hydrologic regime, potential stranding and entrapment of juveniles.

Threats: 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 limiting factors: Degraded water quality ─ excessive nutrients, sedimentation, toxic pollutants, low dissolved oxygen, and altered flows.

5.2.2 Upper Hells Canyon Reach of Lower Snake River Mainstem

The mainstem Snake River from below Hells Canyon Dam to the mouth of the Salmon River (RM 247 to 188) serves as a primary production area for the extant Lower Snake River population of Snake River fall Chinook salmon. The reach supports most of the fall Chinook salmon spawning/rearing habitat within the Upper Hells Canyon MaSA, which also includes the lower reaches of the Imnaha and Salmon Rivers.[56] This river reach is fast and narrow, characterized by high, steep canyon walls and stretches of white water. River flow and volume in this reach are dominated by the outflow of the Hells Canyon Complex, especially from storage above Brownlee Dam (Hells Canyon and Oxbow are run-of-river projects).

The thermal regime in this reach of the Lower Snake River is likely more productive for fall Chinook salmon today than it was historically due to the influence of the Hells Canyon Complex. However, other issues associated with the operation of the Hells Canyon Complex limit Snake River fall Chinook salmon viability in this reach. These factors are discussed below.[57]

5.2.2.1 Water Quality

Water quality in the mainstem Snake River from below Hells Canyon Dam to the mouth of the Salmon River affects the viability of Snake River fall Chinook salmon. The altered thermal regime has both beneficial and adverse effects. Other limiting factors include low dissolved

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[56] Limiting factors in these tributary reaches are discussed in Sections 5.2.5.4 and 5.2.5.5.

[57] In addition to the factors described in this section, the water quality and flow effects described above in Section 5.2.1.2 and 5.2.1.3 also contribute to overall conditions in this reach.

oxygen, high total dissolved gas, and changes in sediment processes and turbidity. (These factors are substantially influenced by upstream land use practices and processing of nutrients within Brownlee Reservoir – see Section 5.2.1).

Altered Thermal Regime

The current thermal regime in the Upper Hells Canyon reach is warmer in the late summer, fall, and early winter than it was historically, and cooler in the late winter and spring months due to Hells Canyon Complex operations and activities above the dam complex (Groves and Chandler 2003; Connor et al. 2016). Water temperatures in the reach typically range from 20 °C to 23 °C (68 °F to 73 °F) in early September, fall below 20 °C (68 °F) in late September, and continue to decline through the month of January (Figure 5-1). The reach does not freeze in the winter, as it sometimes did historically.

The largest reservoir in the Hells Canyon Complex is Brownlee, at the head of the complex, followed by the Oxbow and Hells Canyon Reservoirs. The Oxbow and Hells Canyon Reservoirs have little storage capacity, so most of the water released from Brownlee travels downstream through the Oxbow and Hells Canyon projects within a day. The general effect is that the large thermal mass created by the water stored in these reservoirs delays the peak summer water temperature to a later date and maintains temperatures at a higher level later into the fall relative to what would occur in a natural river condition.

While the delay in peak temperature is a consistent trend on an annual basis, a more subtle effect of reservoir operations on water temperatures exists between years. During wet years, the Hells Canyon Complex of reservoirs is drawn down for flood control. Refill of these reservoirs occurs in the spring when water temperatures have started to warm. Thus, when this water is released in the summer, it creates a warmer river environment below the projects. Conversely, in a dry year the projects are not drawn so deeply during the winter months for flood control, resulting in less refill, and the water in storage is cooler, thus creating a cooler water environment below the projects during the summer when this water is released.

Operation of the reservoirs during the late summer and fall can also have a significant effect on the temperatures that adult spawners experience. If inflow to the project is high in the late summer, then the warmer water collected during summer months is discharged and is replaced by cooler water inflow during the fall, which passes downstream, creating cooler river environment. Conversely when inflow to the project is low during the late summer and early fall, the warmer water in the reservoir is maintained, which is passed through the projects, creating warmer water conditions for fall spawning fish.

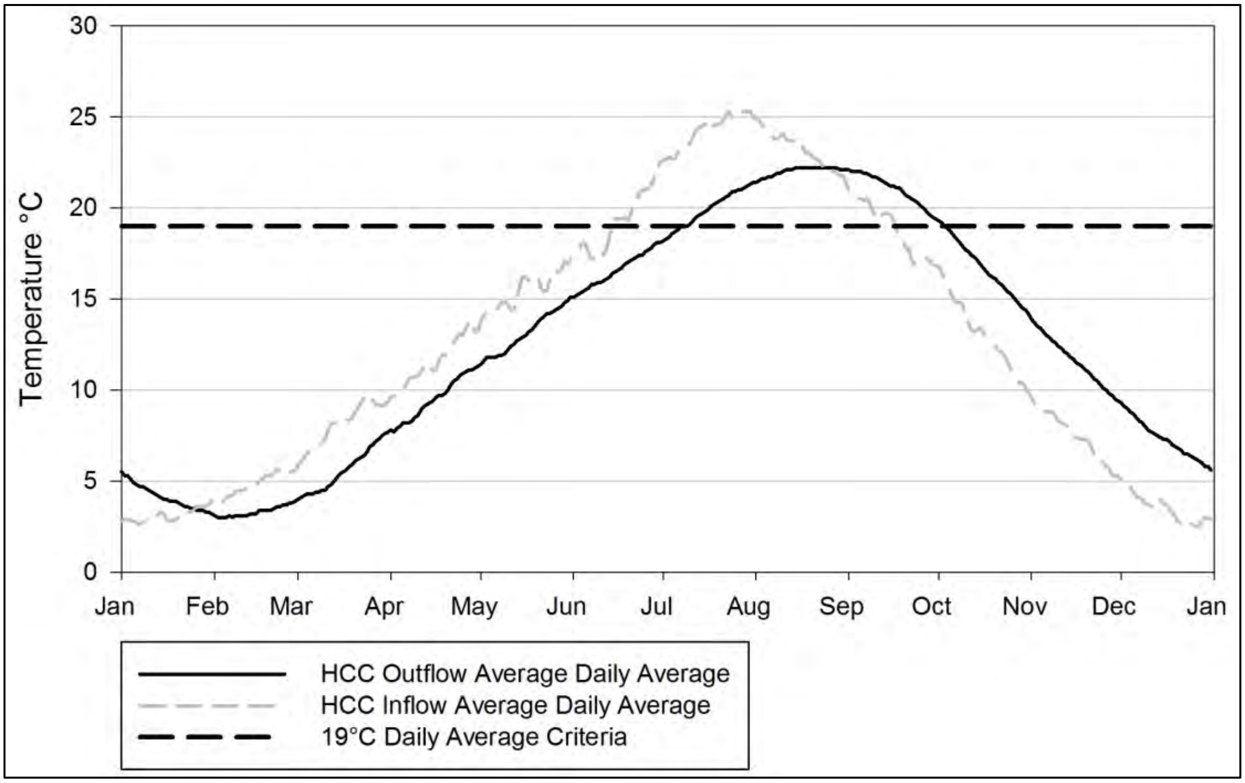

Figure 5-1. Daily average temperature in °C inflow to Brownlee Reservoir and outflow from Hells Canyon Dam for the 1996–2012 period of record compared with Idaho's daily average criteria.

Generally, the current operations of the Hells Canyon Complex make the thermal environment in this mainstem Snake River reach more conducive to fall Chinook salmon incubation and rearing than it was historically, when it sometimes froze during winter months, leading to reduced egg and fry survival. The current thermal regime, strongly influenced by Brownlee Reservoir, creates warmer conditions during the egg incubation period. These conditions foster earlier fry emergence and influence the timing of other life-history stages (parr and smolt). The altered thermal regime also favors the historically dominant Snake River fall Chinook salmon subyearling life-history strategy. Compared to historical conditions, the earlier emerging fry feed and grow in shoreline rearing areas and then outmigrate earlier, when water-temperature mediated effects such as increased mortality, disease, exposure to predators, and reduced physiological development are less severe.

In contrast to the likely beneficial effects of the warmer water temperatures in this reach on egg incubation and early rearing, the effects on adults returning to spawn in late summer/early fall are uncertain but could be negative. About 90 percent of adult fall Chinook salmon pass Lower Granite Dam and enter this reach between late August and early October, but water temperatures in the reach sometimes do not fall below the EPA-recommend criterion of 20 °C (68 °F) for migrating adult Chinook salmon until mid-to-late September. Thus, most adult fall Chinook salmon migrating, holding, and spawning downstream of Hells Canyon Dam could be 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. The warmer temperatures could affect fall Chinook salmon abundance and productivity by increasing pre-spawning mortality and reducing spawning success. It is not clear, however, that the temperature regime reduces productivity. It is also possible that the returning adults seek out cool-water refugia, such as near the mouths of the Salmon River and other smaller tributaries, and rest or hold there until temperatures in the mainstem drop. This reach of the mainstem currently produces the highest proportion of natural-origin fall Chinook salmon redds of all the major spawning areas. The effects of the altered thermal regime on fall Chinook salmon during different life stages are discussed below.

Effects on Pre-spawning Adults: Potential impacts on pre-spawning adults from water temperatures in this reach remain uncertain. Literature on all run types of Chinook salmon (used to develop the 20 °C (68 °F) water quality temperature standard) suggests that adult exposure to the current thermal regime would be associated with some level of either lethal effects (e.g., pre-spawning mortality) or non-lethal effects (e.g., decreased spawning or egg viability) (ODEQ 1995a; McCullough 1999; WDOE 2000a; EPA 2001, 2003; Mann and Peery 2005; Jensen et al. 2005).

It is not clear, however, that the current thermal regime is significantly affecting pre-spawning fall Chinook salmon in this reach. Comparisons of adult escapement estimates and fish-to-redd ratios documented in the Snake River do not suggest that substantial numbers of adult fall Chinook salmon are dying prior to spawning as a result of their exposure to elevated fall water temperatures (Appendix C). It is possible that the size and non-confined nature of the river in this reach below Hells Canyon Dam, a declining thermal regime after August, and opportunities to escape the high temperatures by moving to cool-water refugia (e.g., the confluences of the Clearwater River, Salmon River, and other tributary streams with the Snake River) make the fish less susceptible to disease and mortality than literature and laboratory studies might indicate. Further, the literature is general to all Chinook salmon run types, and there is reason to believe that fall Chinook salmon are more tolerant of higher temperatures than other stocks of Chinook salmon. Nonetheless, in some years, adults passing Lower Granite Dam in late August and early September may still be exposed to 18 to 22 °C (64 to 72 °F) water temperatures for several days or weeks prior to spawning in this reach, and the prolonged exposure of adults to elevated temperatures in the migration corridor and spawning areas could potentially result in reduced spawning success and some egg and fry mortality (Mann and Peery 2005; Jensen et al. 2005, 2006).

Recent (2007 to 2016) average migration timing of fall Chinook salmon and average daily temperatures at Lower Granite Dam are presented in Figure 5-2. 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, and near other small tributaries.

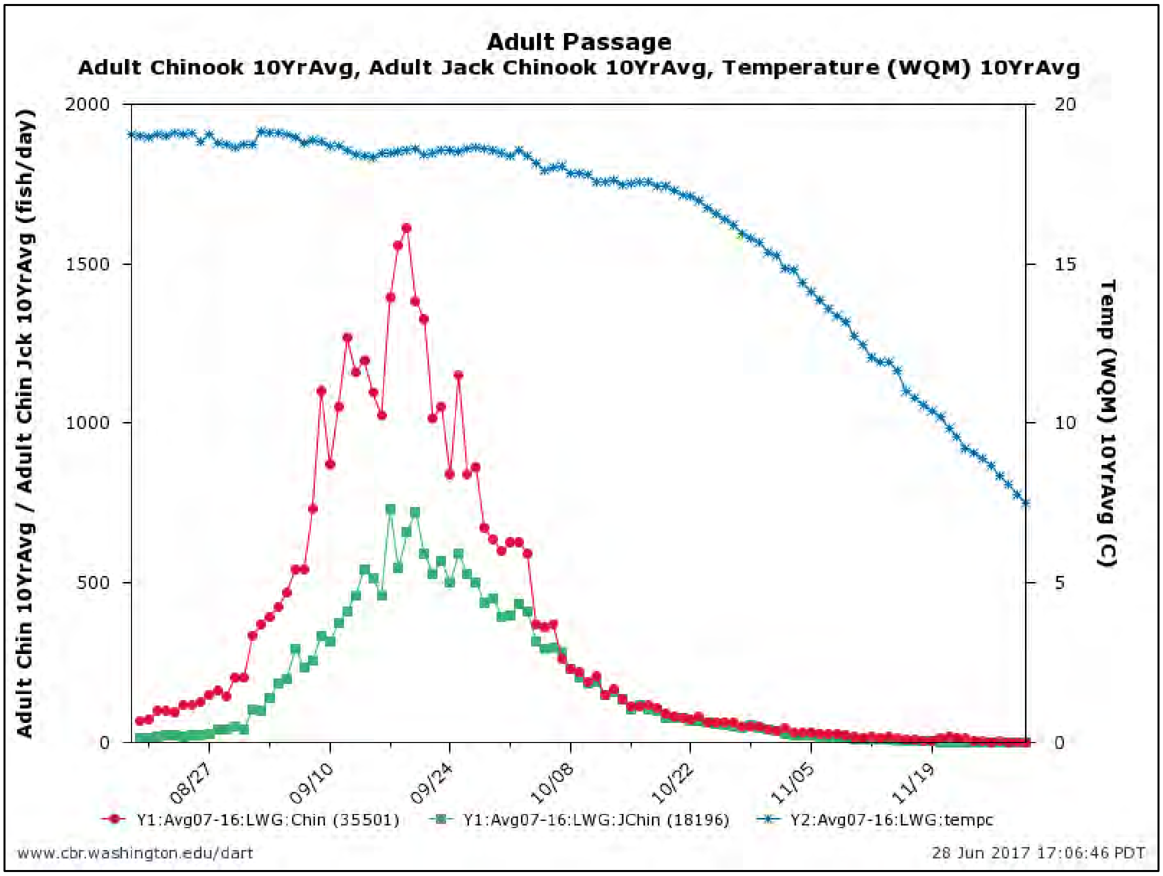

Figure 5-2. Average 10-year migration timing of adult Snake River fall Chinook salmon (red line) and adult jack fall Chinook salmon (green line) in relation to average 10-year daily temperatures (blue line) at Lower Granite Dam.

Effects on Spawning Adults: The current temperature standard in the Snake River for spawning salmon species is 13 °C (55 °F) (Oregon and Idaho have a 13 °C [55 °F] 7-day average daily maximum 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). Several studies (Seymour 1956; Olson et al. 1970; Geist et al. 2006) indicate that initial spawning temperatures greater than 16.5 °C (61.7 °F) result in substantially increased levels of egg mortality. A recent study using Snake River fall Chinook salmon suggests that spawning at initial temperatures between 14.5 °C and 16.0 °C (58 °F and 61 °F) with a declining temperature regime does not result in significant decreases in egg survival (Geist et al. 2006).[58] However, the

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[58] 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

adults in this study were held at 12 °C (54 °F) prior to spawning, a temperature that is considerably cooler than that observed in the Upper Hells Canyon reach prior to spawning

Temperature data during weekly spawning surveys in this reach of the Snake River from 2000 through 2009 show that spawning often occurred at maximum weekly maximum water temperatures in excess of 13 °C (55 °F) (Figure 5-3); however, only a small percentage of all fall Chinook salmon spawning activity occurred in the reach when water temperatures were above 16.5 °C (61.7 °F) (Appendix C). Instead, the weekly spawning surveys conducted by the Idaho Power Company, U.S. Fish and Wildlife Service, and others indicate that the majority of Snake River fall Chinook salmon in the Upper Hells Canyon reach spawn from around October 22, when water temperatures are about 16 °C (60.8 °F), through November 20, when water temperatures drop to about 12 °C (54 °F) (Appendix C). During a 13-year study period (1991-2003), only 4 percent of redds surveyed were initiated when water temperatures were greater than 16.5 °C (61.7 °F), when substantial egg and fry viability impacts would be expected. Generally, these redds represented spawners during the initial interval of spawning activity when, during the 13-year period, water temperatures peaked as high as 19.8 °C (67.6 °F) and averaged 15.5 °C (60 °F). The large majority of spawning activity began after water temperatures dropped below 16.5 °C (61.7 °F) (Appendix C). Currently, roughly 10 to 20 percent of redds are deposited between October 23 and 31, when water temperatures are 14.5 to 16 °C (58 to 61 °F) and within a range where there is still uncertainty regarding whether impacts to egg and fry viability are occurring, and if so, to what degree.

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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).

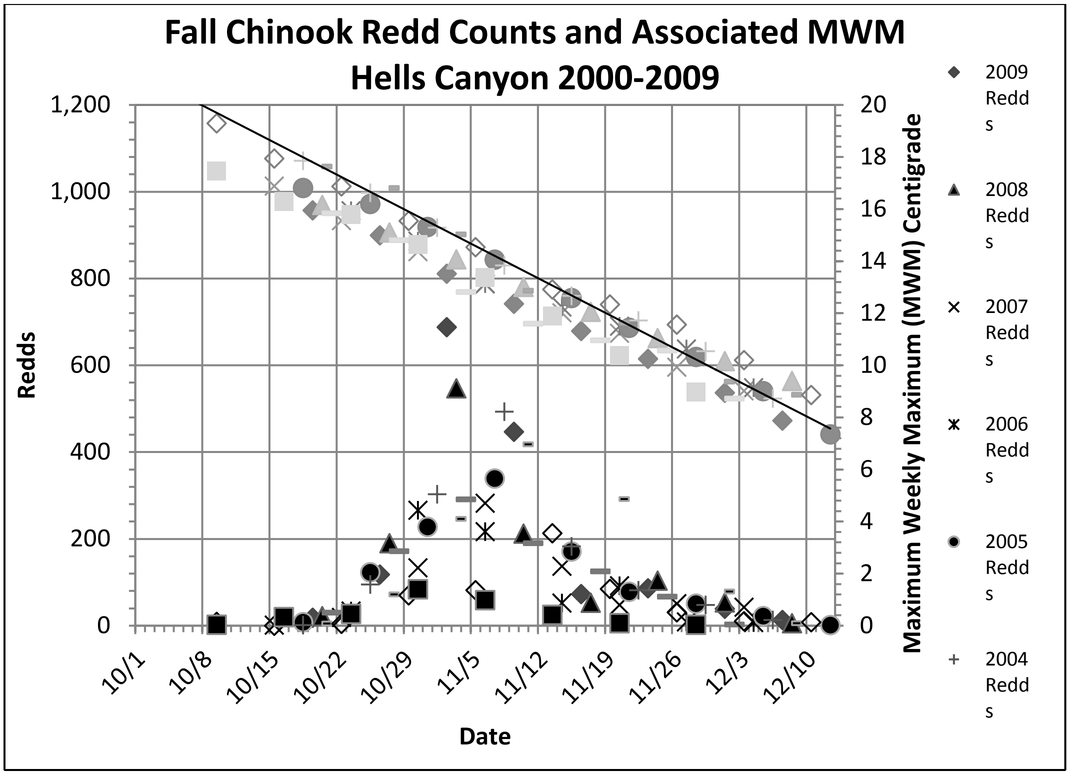

Figure 5-3. Snake River fall Chinook salmon ESU redd counts in Hells Canyon in relation to maximum weekly maximum water temperatures.

As discussed in Appendix C, Connor found that water temperatures were above 16.5 °C (61.7 °F) during the first survey interval when redds were counted in 1994, 1996, 1999–2001, 2003–2007, 2010–2012, and 2014.[59] Temperatures above 16.5 °C (61.7 °F) were also observed in the reach during the second survey interval in 2001 and 2005, and during the third survey interval in 2001. Connor estimated that the exposure to temperatures above 16.5 °C (61.7 °F) during spawning could have reduced fry production in the reach during 2014 by 2.0 (± 2.3 SD) percent, with a range from 0.2 to 7.3 percent (Appendix C).

Research shows that fall Chinook salmon that spawn in the Hanford reach of the Upper Columbia River also spawn in water temperatures in excess of 13 °C (55 °F) (Figure 5-4), though they are less exposed to elevated pre-spawning temperatures than are Snake River fall Chinook salmon. These fall Chinook salmon are part of the Upper Columbia River summer/fall Chinook salmon ESU (a robust population that is not listed under the ESA) but have genetic traits and habitat needs similar to Snake River fall Chinook (NMFS 2011d).

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[59] 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 (i.e., 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).

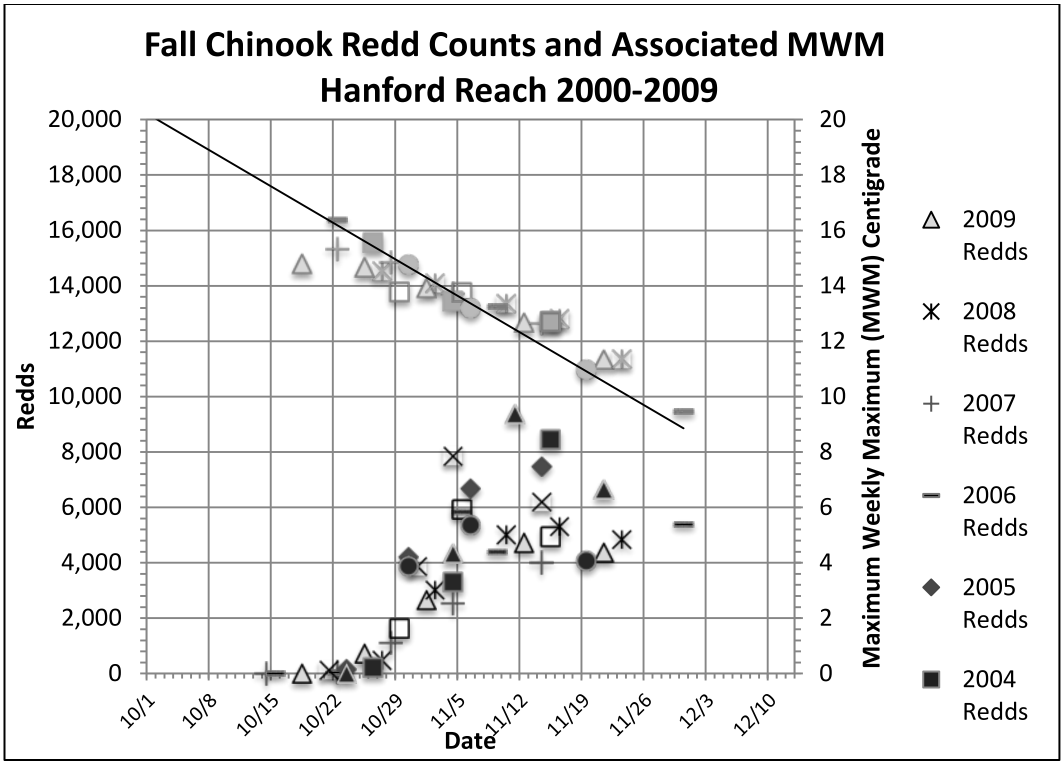

Figure 5-4. Middle Columbia fall Chinook salmon ESU redd counts at Hanford Reach in relation to maximum weekly maximum water temperatures.

Effects on Eggs and Fry: Some studies suggest that impacts to egg and fry viability might occur at water temperatures above about 13 °C (55 °F) (see related discussion in section on Effects on Spawning Adults). Studies by Geist et al. (2006), however, suggest that fall Chinook salmon eggs exposed to an initial incubation temperatures of up to 16.5 °C (61.7 °F) (and a declining temperature regime of 0.2 °C (0.36 °F) per day survive and grow at rates similar to those exposed to cooler initial incubation temperatures. These findings comport well with observations that most spawning (about 96 percent of redds counted) in the Upper Hells Canyon reach of the Lower Snake River typically does not occur until temperatures fall below 16.5 °C (61.7 °F) (Groves and Chandler 1999; Groves et al. 2013; Appendix C). Lesser impacts could be occurring to eggs deposited in late October when temperatures are usually 14.5 to 16 °C (58 to 61 °F); 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.

As previously noted, the current thermal regime in this Snake River reach is warmer than existed historically during part of the egg incubation period, until about January 1, and the warmer water temperatures foster accelerated incubation and fry emergence compared to the pre-Hells Canyon Complex era (see Section 2.6, Figure 2-14). 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) is also earlier.

Effects on Juveniles: 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. Outflows from the Hells Canyon Complex create temperature conditions in the reach that are similar to those in historically accessible upstream habitat. The conditions are conducive to the fish population's historically dominant subyearling life history, supporting early emergence and allowing the fish to migrate early before less favorable 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).

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 period of rearing in nearshore habitats influences growth rates and, consequently, the timing of dispersal from riverine habitat into downstream reservoirs. For example, in the spring of 1995, water temperature in this reach of the Snake River averaged 11.8 ºC (53 °F), and fall Chinook salmon parr along the shorelines grew an average (± SD) of 1.2 ± 0.3 mm/d, whereas parr rearing farther downstream and experiencing a mean spring temperature of 10.9 ºC (51.6 °F) grew an average of 1.0 ± 0.3 mm/d (Connor and Burge 2003). More recent work by Geist et al. (2010) indicates that while exposure of juvenile fall Chinook salmon to a naturally increasing thermal regime of 13.8 °C to 20 °C (57 °F to 68 °F) does not significantly affect growth, physiological development, and survival, exposure to 23.9 °C (75 °F) can have severe growth and physiological consequences. Temperatures above 26 °C (79 °F) are almost instantaneously lethal even if the fish are gradually acclimated to warm water (Appendix C).

Research indicates that juveniles rear in riverine habitat along this reach of the Snake River until temperatures exceed 18 °C (64.4 °F) (Connor et al. 2002), when they are likely to move closer to the thalweg (i.e., the fastest, deepest water available). Connor et al. (1999) found that the number of juveniles captured in nearshore areas along free-flowing Snake River reaches decreased markedly with increasing water temperatures (few fish were found when temperatures exceeded approximately 17 °C [62.6 °F]) 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). The behavior would improve smolt survival by reducing the duration of their exposure to predators associated with shorelines. It would also reduce their exposure to increasing water temperatures in riverine habitats through the summer, and associated effects on development and increased mortality. However, water temperature in this Snake River reach rarely exceeds the 23.9 °C (75 °F) benchmark for severely reduced growth and retarded physiological development, or the 26 °C (79 °F) benchmark for direct mortality. This is an important factor because a high rate of parr growth in this reach has a large influence on parr-to-smolt survival (Connor et al. 2012; Appendix C).

Summary of Temperature Effects

Today, operations of the Hells Canyon Complex make the downstream thermal environment in the mainstem Snake River more conducive to fall Chinook salmon incubation and rearing by providing warmer flows that allow for earlier fry emergence and higher productivity than historically. Despite these positive effects, operation of the Hells Canyon Complex may also contribute to factors that could negatively affect the viability of adult Snake River fall Chinook salmon in this reach. For example, the warmer thermal regime may negatively affect abundance and productivity by causing some pre-spawning mortality and reducing egg viability or egg-to-fry survival.

There is uncertainty regarding the effect of the altered temperature regime on Snake River fall Chinook salmon survival, and more information is needed to assess the effect of the current temperature regime in the Upper Hells Canyon reach on the abundance and productivity of fall Chinook salmon. While the temperatures are not always optimum, and while some Upper Hells Canyon reach spawners may be negatively affected, existing studies specific to Snake River fall Chinook salmon do not point to temperature as a significant limiting factor. Recent high abundance of naturally produced Snake River fall Chinook salmon spawning in the area also suggests that this is not currently one of the more significant limiting factors for the ESU.

Snake River temperatures are, however, projected to increase in the future due to global climate change. It is uncertain how, or to what extent, these changes will affect Snake River fall Chinook salmon or to what extent these fish might compensate behaviorally (e.g., later adult migration timing or earlier juvenile migration timing). This underscores the importance of continuing monitoring programs that document passage timing, redd counts, and river temperatures in order to detect changes and assess their effects on Snake River fall Chinook salmon.

Dissolved Oxygen

As described in Section 5.2.1.2, hypoxic waters from Brownlee, Oxbow, and Hells Canyon reservoirs are drawn into the turbines in the late summer and fall and released downstream. Due to these releases, dissolved oxygen (DO) levels downstream of Hells Canyon Dam often do not meet water quality criteria for cold water 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 2006). The water is re-oxygenated by rapids downstream of Hells Canyon Dam, but dissolved oxygen levels likely remain low for 10 or more miles and through important spawning habitat. The impact depends upon the initial dissolved oxygen levels in the released water, air temperatures, and mixing rates at rapids in downstream areas (Graves 2000).

Effects of exposure of pre-spawning adults to dissolved oxygen levels between 3 and 6 mg/L are not well understood but may include 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, exposure to low dissolved oxygen levels could result in the death of fall Chinook salmon eggs below Hells Canyon Dam, or in reduced fitness of 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 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.

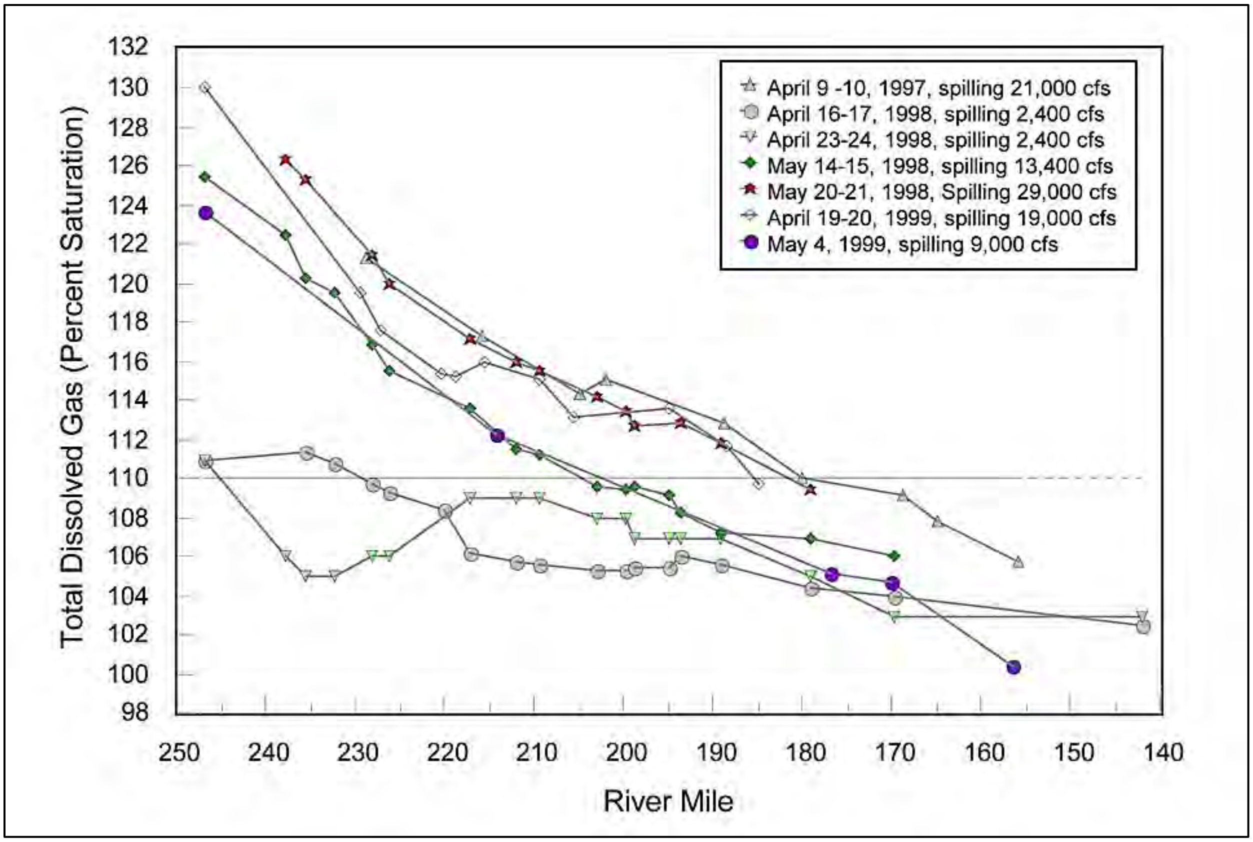

Figure 5-5. Downstream dissipation of total dissolved gas within Hells Canyon relative to the 100% saturation standard. Source: FERC 2007, Figure 34.

Figure 5-5 depicts the dissipation of the supersaturated gases downstream of the Hells Canyon Complex. Total dissolved gas (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. 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 Hells Canyon Complex.

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 shallow 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 1977; Ryan et al. 2000; McGrath et. al. 2005). However, the natural juveniles seined in the Upper Hells Canyon reach are free of external symptoms of gas bubble disease. This suggests that exposure to high TDG levels 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).

5.2.2.2 Altered Flows

Flows fluctuate on a daily and hourly basis in the Snake River below the Hells Canyon Complex in response to project operations carried out to meet changing electricity demands (i.e., load following). These flow fluctuations can result in entrapment or stranding of juveniles, or in dewatering of redds. However, since 1991, Idaho Power Company has operated the project 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 (2006) describe Idaho Power Company's management plan for preventing juvenile entrapment.

Flood control and refill operations for the Hells Canyon Complex also contribute to reduced flows in the mainstem Lower Snake and Columbia River migration corridor, Columbia River estuary, and plume during the spring outmigration (USBR 2004; NMFS 2004). Sections 5.2.4 and 5.2.6 discuss the effects of reduced spring flows in the mainstem, estuarine, and plume areas.

5.2.2.3 Geomorphic Processes, Sediment, and Turbidity

The Hells Canyon Complex prevents the downstream movement of sediments, cutting off a substantial source of these materials in fall Chinook salmon spawning habitat downstream of Hells Canyon Dam. This disruption in natural geomorphic processes may have long term impacts on maintaining the amount of functional spawning and rearing habitat in the downstream reaches of the mainstem Snake River. However, before construction of the Hells Canyon Complex, the heavy loads of sediment and organic nutrients from upstream agricultural runoff significantly reduced spawning habitat quality in downstream Snake River reaches. Today, these loads are trapped in Brownlee Reservoir (Falter and Burris 1996; Myers et al. 2003; Groves and Chandler 2005; Connor et al. 2016). 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 (Bennett and Peery 2003; Connor et al. 2016).

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 Hells Canyon reach) compared to those released at Billy Creek (in the Lower Hells Canyon 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.

5.2.2.4 Summary: Upper Hells Canyon Reach of Lower Snake River Mainstem

Threat: Hells Canyon Complex hydropower system.

Related limiting factors:

1. Degraded water quality: (a) an altered thermal regime[60] could cause some pre-spawning mortality, and reduce egg viability and egg-to-fry survival; (b) low dissolved oxygen levels in late summer and fall could result in the death of exposed fall Chinook salmon eggs below Hells Canyon Dam or in reduced fitness of fry exposed upon emergence (in redds created within the affected area below the dam); (c) elevated TDG levels in winter and spring could cause gas bubble disease in juveniles.
2. Altered flows (on a seasonal, daily, and hourly basis), resulting in altered migration patterns, juvenile fish stranding and entrapment.
3. Interruption of geomorphic processes (entrapment of sediment), resulting in reduced turbidity and higher predation.

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[60] See “Summary of temperature effects” above.

5.2.3 Lower Hells Canyon Reach of Lower Snake River Mainstem

The section of the mainstem Snake River from the mouth of the Salmon River downstream to the upper end of the Lower Granite Dam reservoir near Lewiston, Idaho (RM 188 to 147), is a primary production area for fall Chinook salmon in the Lower Hells Canyon MaSA. This MaSA also includes Alpowa and Asotin Creeks. Lower Granite Reservoir also provides temporary rearing habitat for juvenile fall Chinook salmon migrants.

The Snake River channel becomes wider in this reach, with gently sloping shorelines and a lower gradient than in the Upper Hells Canyon reach. Several tributaries also contribute flow to this reach, including the Salmon, Clearwater, Grande Ronde, and Imnaha Rivers and Alpowa and Asotin Creeks. Downstream of the Salmon and Grande Ronde Rivers, long, deep pools and runs and low-gradient rapids provide contiguous habitats for spawning and rearing (Groves and Chandler 2003).

As discussed earlier, the thermal regime in the Lower Hells Canyon reach of the lower mainstem Snake River likely provides more productive habitat for fall Chinook salmon than it did historically, as a result of the moderating effects of the Hells Canyon Complex. Potential long-term negative impacts due to disruptions in natural gravel transport are, however, also possible. Current FERC agreements on the complex call for periodic monitoring and evaluation to detect changes in the distribution and abundance of spawning and rearing habitats. In addition, several factors, discussed below, continue to limit fall Chinook salmon abundance and productivity in the reach.

5.2.3.1 Altered Temperature Regime

Water temperature in this reach of the Snake River are cooler than temperatures in the Upper Hells Canyon reach from October through January during spawning and incubation, and then are similar in the two reaches from February until roughly the third week of April depending on annual conditions. After this time, temperatures in the Upper Hells Canyon reach becomes warmer than those in this reach, and remain so through emergence.

High water temperatures in late summer and fall in the Lower Hells Canyon reach have the potential to affect abundance, productivity, and spatial structure of fall Chinook salmon. Many returning adult fall Chinook salmon, however, may miss the high water temperatures by returning to the reach after water temperatures decline. Adult fall Chinook salmon do not begin to arrive in the lower mainstem Snake River until late August after water temperatures generally begin to cool. The daily mean water temperature at the Lower Granite Dam forebay currently ranges from 20.5 °C (69 °F) in mid-August (due to releases of cool water from Dworshak Dam) to 13.5 °C (56 °F) by late October; however, temperatures occasionally exceed 20 °C (68 °F). During the peak passage of adult fall Chinook salmon in the mainstem Snake River (approximately the last two weeks in September), temperatures generally decline from 20 to 18 °C (68 to 64.4 °F) (Chandler et al. 2003).

Adult fall Chinook salmon that do experience high water temperatures in the reach often 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).

Many juvenile fall Chinook salmon outmigrate from this reach of the Snake River before water temperatures become a concern. As discussed in Chapter 2, the dates of peak dispersal from the Upper Hells Canyon reach and the Lower Hells Canyon reach into Lower Granite Reservoir were May 28 and June 4 in 1995 (Connor et al. 2002). Some juveniles, however, delay their outmigration and rear in riverine habitat along the reach. The juvenile fall Chinook salmon that remain in the reach can potentially be affected by reduced physiological development and mortality due to the high temperatures, as well as by increased exposure to potential predators whose metabolic demands rise with increasing temperature. The juvenile migrants often escape the high temperatures by returning to the thalweg and resuming their outmigration when water temperatures rise above 18 °C (64.4 °F) (Connor et al. 2002), searching out cool-water refugia, and entering Lower Granite Reservoir. Maximum daily water temperatures in Lower Granite Reservoir can exceed 20 °C (68 °F) at times during summer months, but the fish are often able to escape the high temperatures by moving to cooler areas. Young fall Chinook salmon often move up and down in the water column to maintain an optimum body temperature for growth (Tiffan et al. 2009c).

5.2.3.2 Altered Flows

Fluctuations in flow in this reach due to operation of the Hells Canyon Complex can affect fall Chinook salmon viability. Hells Canyon Complex operations alter the natural flow regime in the Lower Hells Canyon reach, although the effects of project operations in this reach are substantially attenuated due to the influence of inflow from the Salmon and Grande Ronde Rivers. (See Section 5.2.5 for discussion of habitat conditions in these tributaries.)

Water storage and releases associated with Hells Canyon Complex operations affect fall Chinook salmon in this reach by altering naturally high peak flows that historically occurred in the spring. The fish are also affected by daily and hourly fluctuations in flow releases from the Hells Canyon Complex due to project operations, which can strand fry in shallow areas when flows recede. However, as discussed in Sections 2.8.4 and 5.2.2.2, Idaho Power Company operates the project to provide stable flow from Hells Canyon Dam during the fall Chinook salmon spawning season and to support incubating eggs and emerging fry.

5.2.3.3 Loss and Degradation of Nearshore Habitat

Hydropower development and operations have reduced the amount and quality of nearshore habitat along the Lower Hells Canyon reach. These areas historically provided food and cover for juvenile fall Chinook salmon from this reach and upstream areas. Today, the remaining nearshore areas in this reach continue to provide important foraging environments for fall Chinook salmon smolts as they migrate downstream (Waples et al. 1991).

Nearshore areas in the reach are affected by both downstream and upstream hydropower systems. At the downstream end of the reach, impoundment from Lower Granite Dam has eliminated 6.2 miles of shoreline rearing habitat within the Lower Hells Canyon lower reach. Additional riverine habitat along this reach has been lost or degraded due to upstream hydropower system operations associated with the Hells Canyon Complex that alter the natural flow regime.

5.2.3.4 Loss of Spawning Habitat

The viability of the Lower Snake River fall Chinook salmon population has been affected by loss of historical spawning habitat in the area now inundated by Lower Granite Dam and reservoir. The impoundment from Lower Granite Dam eliminated 6.2 miles of spawning habitat within the Lower Hells Canyon lower reach. The upper end of Lower Granite Reservoir (near Lewiston, Idaho) is now considered the downstream limit of Snake River fall Chinook salmon spawning habitat, although limited spawning continues to occur in the lower Snake River dam tailraces. While historical habitat conditions in this mainstem reach were likely less productive than upstream spawning areas, they probably fostered phenotypic diversity in spawn timing as water temperature varied from upstream areas and tributary reaches.

5.2.3.5 Summary: Lower Hells Canyon Reach of Snake River Mainstem

Threat: Upstream dam operations.

Related limiting factors: Altered temperature regime, altered flows (seasonal, daily, and hourly), loss and degradation of nearshore rearing habitat.

Threat: Lower Granite Reservoir.

Related limiting factors: Inundation and loss of spawning and rearing habitat, altered temperature regime.

5.2.4 Mainstem Lower Snake and Columbia River

The lower Snake and Columbia River mainstem migration corridor extends from Lower Granite Dam downstream through the contiguous reservoirs formed by Little Goose, Lower Monumental, and Ice Harbor Dams on the lower Snake River, and past the four dams on the Columbia River (McNary, John Day, The Dalles, and Bonneville Dams) to the Columbia River estuary and plume. These dams and reservoirs are part of the Federal Columbia River Power System (FCRPS) and remain a threat to the viability of the Snake River fall Chinook salmon ESU. In addition to inundation of historical production areas, hydropower system development and operations have reduced mainstem habitat quality, affecting both juvenile and adult migration. The system of dams and reservoirs affects Snake River fall Chinook salmon viability by reducing abundance, productivity, spatial structure, and diversity.

5.2.4.1 Adults – Delay, Fallback, and Reduced Survival during Migration

Adult fall Chinook salmon returning to lower Snake River spawning grounds must pass six or eight of the FCRPS projects on the mainstem Columbia and Snake Rivers during their upstream journey.[61] Adult fish passage, in the form of fish ladders, is provided at each of the lower mainstem Snake and Columbia River projects. In general, the adult fish passage facilities at the dams are considered effective. Recent data (2012-2016) indicate survival for adult Snake River fall Chinook salmon migrating upstream from Bonneville to Lower Granite Dam at about 59 percent (Appendix E).[62] 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 (2012-2016) is approximately 91.0 percent, or over 98.8 percent per dam (Appendix E).

Adult passage can be delayed by effects of the hydropower system. Salmon migration can slow temporarily as fish search for fishway entrances and navigate through the fishways themselves, but they migrate more quickly through the relatively slow velocity reservoirs. The adult fish may also fall back over a dam once they have passed it. Fallback is sometimes volitional (e.g., some adults overshoot their natal stream and return downstream through a dam) and sometimes involuntary (e.g., some adults become entrained in spillway flow after exiting a fish ladder). Some adults that fall back pass through 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 (Keefer et al. 2005).

Water impoundment and hydropower system operations also influence downstream hydrologic conditions and water quality characteristics that affect adult fall Chinook salmon survival. Large storage projects like Brownlee Dam on the Snake River and Grand Coulee Dam on the upper Columbia River, because of their inertia, generally increase winter minimum temperatures, delay spring warming, and reduce maximum summer temperatures; but they also delay fall cooling, resulting in higher late summer and fall water temperatures (NMFS 2016b).

The frequency of water temperatures exceeding 20 °C (68 °F) while fall Chinook salmon are migrating during summer and fall has increased in the lower Snake River due to the combination of warmer temperatures and lower precipitation in interior subbasins (which may be associated with climate change), hydropower and water storage development, and water management operations (EPA 2001). Crozier et al. (2011) showed a rise of 2.6 °C (4.7 °F) in mean July water temperatures in the Columbia River at Bonneville Dam between 1949 and 2010; however, high water temperatures (> 20 °C [> 68 °F]) often occurred in the lower Snake River from July to mid-September prior to hydropower and water storage development (Peery and Bjornn 2002). The high water temperatures can cause migrating adult salmon to stop or delay their migration,

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[61] Most Snake River fall Chinook Fish pass eight FCRPS projects. Fish destined for the Tucannon River, which joins the Snake River downstream of Lower Granite Dam, pass six dams. A small number of fall Chinook salmon spawn in the tailraces of Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Dams; their progeny pass only four to seven of the projects.

[62] This adult survival estimate includes mortality resulting from the existence and operation of the FCPRS and unquantified levels of mortality from other potential sources (e.g., unreported or delayed mortality caused by fisheries, marine mammal attacks, etc.), and unquantified levels of "natural' mortality (i.e., levels that would have occurred without the influence of human activities).

or can increase fallback at a dam. Warm water temperatures can also increase the fishes' susceptibility to disease.

Since 1993, the U.S. Army Corps of Engineers has cooled rising water temperatures in the lower mainstem Snake River for migrating fish by drafting cooler water from Dworshak Reservoir on the North Fork Clearwater River during summer months. The U.S. Bureau of Reclamation also provides flow augmentation from the upper Snake River basin that enhances flows in the lower Snake and Columbia Rivers. The water from the upper Snake River basin is cooled as it passes through the Hells Canyon Complex (NMFS 2016b).

Goniea et al. (2006) studied relationships between water temperatures and migration rates, temporary use of tributaries as cool-water refugia, and run timing of adult fall Chinook salmon in the Columbia River below John Day Dam. They collected data on movement between Bonneville and John Day Dams from 2,121 upriver fall Chinook salmon that were radio-tagged over 6 years (1998, and 2000 through 2004). The data showed that distance traveled per day between Bonneville Dam and John Day Dam decreased by approximately 50 percent when daily mean water temperatures were above about 20 °C (68 °F). Slowed migration was strongly associated with temporary use of tributaries, which averaged 2 to 7 °C (35.6 to 44.6 °F) cooler than the mainstem river. Overall, 18 percent of all radio-tagged salmon entered Columbia River tributaries in the study reach, 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 (68 °F) to about 40 percent when temperatures neared 22 °C (71.6 °F).

Snake River adult upstream migrants are also affected by warmer summer water temperatures than would have existed historically in the Columbia River and lower Snake River mainstems. The late summer migration period 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 lower Snake River has been greatly reduced since the U.S. Army Corps of Engineers began drafting cool water from Dworshak Dam to maintain cooler summer water temperatures.

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 salmon migrants in some years when the cool water does not mix with the warmer water in Lower Granite Reservoir. For example, in late July and September 2013 a combination of low summer flows, high air temperatures, and little wind created thermally stratified conditions in Lower Granite Reservoir. 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).

In 2015, unusually hot weather, combined with low snow pack, resulted in very high tributary and mainstem temperatures in June and July. Federal project managers responded by releasing cool water from Dworshak Dam several weeks earlier than usual. In addition, the U.S. Corps of Engineers operated temporary pumps at the Lower Granite Dam adult ladder to moderate temperatures and, in coordination with NMFS and other project co-managers, altered turbine unit and spill operations in an attempt to improve passage conditions in the fishways at Lower Granite and Little Goose Dams. The U.S. Army Corps of Engineers has also recently constructed a structure at Lower Granite Dam to move cooler, deeper water (from Dworshak Dam releases) up the entrance of the Lower Granite Dam adult fishway (Appendix E). This structure will minimize temperature differentials within the fishway to improve adult passage conditions during periods of high temperatures. Figure 5-6 shows mean water temperatures at Lower Granite Dam during the 2010 through 2016 adult Snake River fall Chinook salmon migrations, as well as the average temperature at the dam during the 2007 through 2016 migration period. With the exception of 2015, and for a few brief periods of time, temperatures at Lower Granite Dam are generally held below 20 °C (68 °F) during the adult fall Chinook migration period.

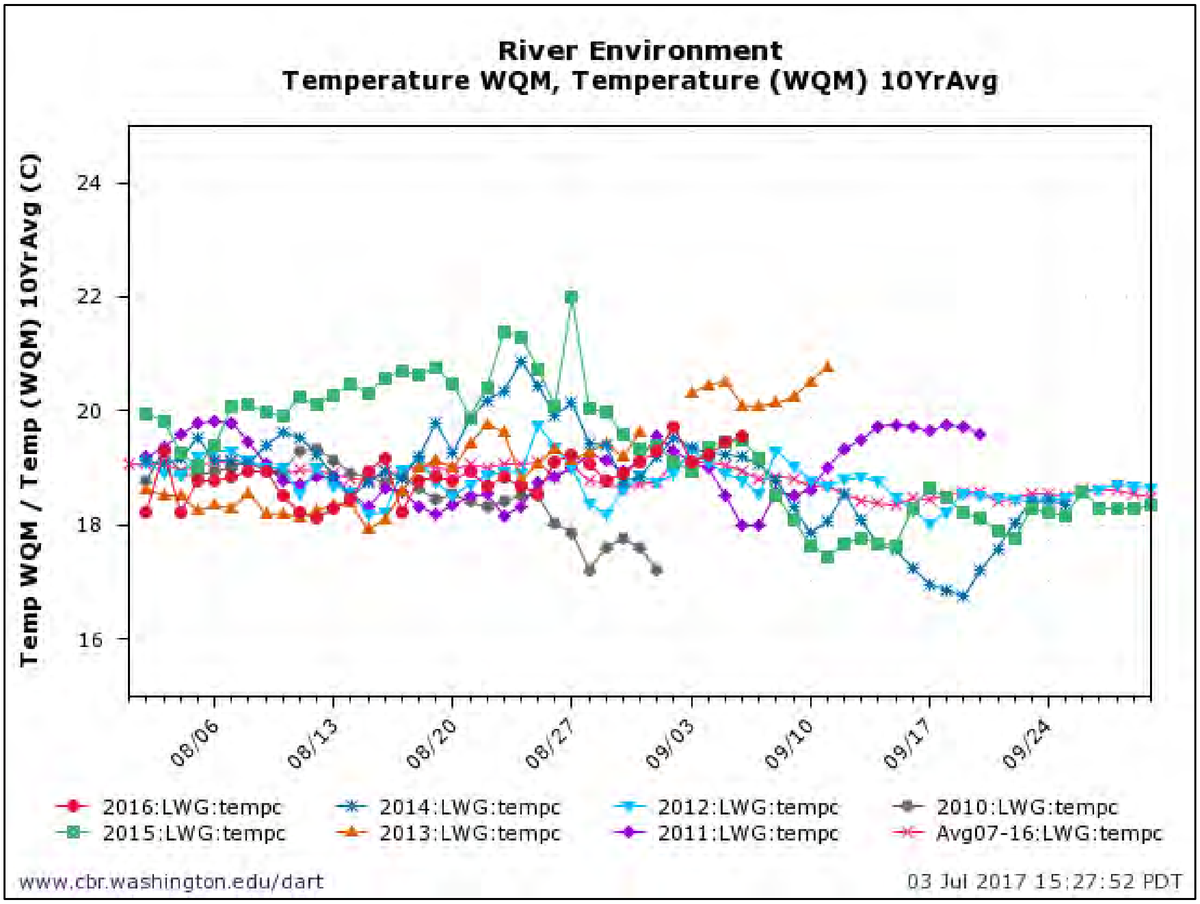

Figure 5-6. Mean water temperatures at Lower Granite Dam from 2010 through 2016 during the adult Snake River fall Chinook salmon migration.

5.2.4.2 Adults – Reduced Spawning Habitat

The viability of the Lower Snake River fall Chinook salmon population has also been affected by loss of historical spawning habitat in the area now inundated by the contiguous reservoirs formed by Little Goose, Lower Monumental, and Ice Harbor Dams. While historical habitat conditions in this mainstem reach were likely less productive than upstream spawning areas, they probably fostered phenotypic diversity in spawn timing as water temperature varied from upstream areas and tributary reaches.

5.2.4.3 Juveniles – Delay, Reduced Survival, Increased Predation and Injury

Thy hydropower system can affect migrating juvenile Snake River fall Chinook salmon by delaying downstream passage and increasing direct and indirect mortality of juvenile migrants compared to a free-flowing river reach. The hydropower projects have converted much of the migratory corridor into a stair-step series of slower pools, increasing the time it takes for juveniles to migrate through the lower Snake and Columbia Rivers. Snake River juvenile migrants pass the mainstem dams via turbines, spillway bays or weirs, or juvenile bypass systems. Juvenile salmonid survival typically is highest through spillways, followed by bypass systems, then turbines (Muir et al. 2001).

Juvenile salmon can be killed while migrating through the dams, both directly through collisions with structures and abrupt pressure changes during passage through turbines and spillways, and indirectly through non-fatal injury and disorientation that leave fish more susceptible to predation and disease, resulting in delayed or latent mortality.

A number of actions in recent years have improved juvenile passage conditions in the lower Snake and Columbia River migration corridor (see Appendix E). By 2009, each of the eight mainstem lower Snake and Columbia River dams was equipped with a surface passage structure (spillbay weirs, powerhouse corner collectors, or modified ice and trash sluiceways) to improve passage of smolts, which primarily migrate in the upper 20 feet of the water column in the lower Snake and Columbia Rivers. Other improvements include the relocation of juvenile bypass system outfalls to avoid areas where predators collect, changes to spill operations, installation of avian wires to reduce juvenile losses to avian predators, and changes to reduce dissolved gas concentrations that might otherwise limit spill operations. These and other changes, which are described in the Hydro Module (Appendix E) and 2014 supplemental FCRPS biological opinion (NMFS 2014c), have improved smolt survival in recent years but dam passage impacts remain.

Survival of Snake River fall Chinook salmon juveniles has been studied primarily with hatchery-reared subyearling fall Chinook salmon because of the methodological complications of studying the survival of both life-history types exhibited by this ESU. As discussed in 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), when both summer spill and surface passage routes were in effect, survival rates ranged from 66 to 89 percent for groups of study fish released at two-week intervals. The survival rates of all but two of the cohorts exceeded the highest average survival rate (71 percent) expected after implementation of actions in the 2008 FCRPS biological opinion.

Continued monitoring is needed to gain a better understanding of smolt migration timing and mortality rates through the lower Snake and Columbia Rivers, including the effects of spring and summer spill operations on juvenile migrants (NMFS 2016a; also see Chapter 7). We also need a better understanding of juvenile mortality that occurs before the fish produced in the Clearwater River and in the lower Grande Ronde and Tucannon systems reach the head of Lower Granite Dam reservoir and the FCRPS projects. Monitoring indicates that substantial mortality of in-river migrating juveniles occurs before the fish reach the hydropower system (Faulkner et al. 2016).

While estimates show that direct survival through spillways and bypass systems tends to be high for juvenile migrants (66 to 89 percent [see above]), there is evidence that fish bypass systems are associated with some latent, or delayed, mortality in the estuary and ocean (NMFS 2014c). It is unclear whether latent mortality reflects injury during passage through spillways and bypass systems or from predation in the vicinity of the bypass systems. Alternatively, sick or injured fish could be more likely to pass a dam through the screened bypass system. The relative magnitude of delayed or latent effects, the specific mechanisms causing these effects, and the potential for interactions with other factors (toxic pollutants, ocean conditions, habitat modifications below Bonneville Dam, etc.) remain key uncertainties (Appendix E). Answering these key questions would greatly enhance the ability of hydropower system managers to improve survival (and potentially SARs) through additional structural improvements or operational modifications at the mainstem dams in future years (NMFS 2014c).

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. Transport rates have decreased since 2005, when increased spill levels were enacted at the Snake River collector projects and dams were equipped with surface-oriented spillway weirs. Since 2008, roughly 1 to 2 million juvenile fall Chinook salmon have been collected for transport 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.

Because of the varied juvenile life-history strategies of Snake River fall Chinook salmon, 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 the proportions of hatchery-origin and natural-origin fish (NMFS 2014c). Although transportation was initiated to improve juvenile survival by avoiding losses in the mainstem migration corridor, it could potentially have negative effects (Appendix E). For example, transportation could be selective against smaller-sized migrants (ICTRT 2010). The magnitude of these potential negative effects remains unclear. A Snake River fall Chinook transportation study (Smith et al. 2017) was recently completed. Results from this study suggest that adult returns would be higher if juveniles migrating early in the season (before July 1) stay in-river and those migrating later in the summer were transported via barge or truck (Smith et al. 2017). Another study, the Comparative Survival Study, has also evaluated the relative effects of juvenile transportation versus in-river migration. As part of that study, McCann et al. (2016) assessed the likelihood of adult returns for transported subyearling fall Chinook salmon. These researchers analyzed data only for fish that migrate primarily before July. Their results showed a benefit to in-river migration for 31 of 48 adult return cohorts while 17 cohorts showed a transport benefit.

In addition, ecosystem alterations (e.g., altered temperature regimes and reduced turbidity) and associated increases in piscivorous fish and birds have increased predation on Snake River fall Chinook salmon juveniles. These threats are discussed in more detail in Section 5.2.6, Estuary, Plume, and Ocean, and Section 5.6, Predation.

5.2.4.4 Summary: Mainstem Lower Snake and Columbia River

Threats: Mainstem hydropower projects (dams and reservoirs) and juvenile transportation.

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

5.2.5 Tributary Spawning Areas

Three primary tributaries to the lower Snake River ─ the Clearwater, Grande Ronde, and Tucannon Rivers ─ likely supported fall Chinook salmon production historically. The lower reaches of these three tributaries are designated as MaSAs for Snake River fall Chinook salmon, although their production is secondary to the two mainstem Snake River MaSAs. Historically, two other tributaries, the Imnaha and Salmon Rivers, are also believed to have supported some spawning by fall Chinook salmon. The ICTRT considered spawning in the lower mainstem sections of the Imnaha and Salmon Rivers to be contiguous with and therefore part of the Upper Hells Canyon MaSA. This section discusses habitat-related limiting factors in these five tributary spawning areas.

5.2.5.1 Lower Clearwater River MaSA

The Lower Clearwater River MaSA includes the 110-mile reach of the mainstem Clearwater River upstream from its confluence with the Snake River at Lewiston, Idaho, to Selway Falls, and the lower reaches of the South Fork Clearwater, Middle Fork Clearwater, Potlatch, and Selway Rivers. The North Fork Clearwater River is not included in the MaSA because Dworshak Dam, which has no fish passage, is located on the North Fork 1.9 miles above its confluence with the mainstem Clearwater River.

The Clearwater River MaSA is one of the largest producers of fall Chinook salmon in the Lower Snake River population (27 percent of all redds are in the Clearwater, based on surveys since 1992 [see Figure 2-12]), but it produces less natural-origin fall Chinook salmon than either of the two mainstem MaSAs. It supports both a subyearling and an alternative yearling life-history strategy.

Snake River fall Chinook salmon return to the Clearwater subbasin from late August through December. Most of the fish spawn in the lower 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, the Middle Fork Clearwater River, and in the lower portions of the Potlatch, South Fork Clearwater, and Selway Rivers. In 2015 biologists counted a total of 5,082 fall Chinook salmon redds in the Clearwater River basin, including 4,666 redds on the mainstem Clearwater River, 115 on the Middle Fork Clearwater, 162 on the Selway River, and 119 on the South Fork Clearwater. From 2011 to 2016, the mean number of fall Chinook salmon redds observed in the Clearwater River basin was 2,947, ranging from 1,621 to 5,081 (Arnsberg et al. 2016).

Spawning habitat is not considered a limiting factor for fall Chinook salmon in the lower Clearwater River. Arnsberg et al. (1992) used the Instream Flow Incremental Methodology (IFIM) to quantify the amount of fall Chinook salmon spawning habitat available in the lower Clearwater River. Based on habitat suitability criteria alone, capacity was estimated at 95,000 redds; however, this was considered a liberal estimate since IFIM tends to overestimate spawning habitat in large rivers (Shrivell 1990), and other hydraulic and biological factors that may influence spawning selection were not measured (Arnsberg et al. 1992). Still, the vast amount of suitable habitat measured and the number of redds documented within and around the measured sites since redd counts began in 1988 indicate that suitable spawning habitat exists.

The lower Clearwater River is highly influenced by operations at Dworshak Dam. Operations to meet both local and regional flood control requirements during the winter and spring alter natural temperature and flow regimes (Ecovista et al. 2003). Refilling the project's reservoir in the spring reduces spring flows in the lower Clearwater, Snake, and Columbia Rivers. Since 1992, however, project operators have used summer releases from Dworshak Dam to cool water temperatures and augment flows in the lower Snake River, improving migration conditions for juvenile and adult fall Chinook salmon. Recent operations include releases of up to 14,000 cfs between late June and mid-September.

The effects of the release of cold water from Dworshak Dam in the summer are complex. Summer water temperatures in the lower Snake River can otherwise rise to harmful levels in some years, delaying or even killing both adults and juveniles. Cold-water releases from Dworshak Dam benefit Snake River fall Chinook salmon by reducing temperatures in the lower Snake River during the adult and juvenile migrations. However, the cold water released into the lower Clearwater River can also slow the growth of juvenile salmonids incubating and rearing in the lower Clearwater River and alter the pattern of increasing temperatures that can prompt downstream dispersal (Connor et al. 2001; ICTRT 2010).

The summer cold-water releases from Dworshak Dam appear to contribute substantially to an alternative life-history strategy for some juvenile fall Chinook salmon from the Clearwater River. The cooler water temperatures resulting from the releases contribute to fall Chinook salmon parr growing more slowly in the lower Clearwater River and lingering in riverine habitat longer than parr in warmer Snake River reaches. Consequently, some young Clearwater River fall Chinook salmon do not reach smolt size or migrate seaward during the first year of life because growth is out of synchronization with environmental cues such as photoperiod (Connor et al. 2001). In some years, the reduced water temperatures may also disrupt cues that prompt outmigration, causing juvenile fall Chinook salmon to hold over an extra year in freshwater.

Thus, many parr in the lower Clearwater River do not begin downstream dispersal before a partial thermal barrier forms in the east arm of Lower Granite Reservoir in July, creating temperature conditions that can disrupt downstream migration. 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 yearling 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 strategy 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.

Degraded habitat conditions in some areas of the mainstem Clearwater River and tributaries due to land use activities may also affect fall Chinook salmon. Many shoreline areas along the length of the Clearwater River used by fall Chinook salmon are riprapped to protect roads and railroads. This armoring impairs the natural filtering of sediment inputs that occurs in riparian areas and cuts off access to oxbows and side channels that could provide early rearing habitats. The subbasin also supports a variety of land uses, including agriculture, livestock grazing, timber harvest, rural residences, mining, and recreation, as well as industry in or near the city of Lewiston. These upstream activities have cumulative impacts on sediment and temperatures downstream in the reaches used by fall Chinook salmon.

While temperature impacts are generally dominated by Dworshak Dam operations (which ameliorate naturally colder temperatures during the incubation stage and naturally warmer temperatures during the late spring/early summer juvenile rearing periods), water quality effects (primarily sediment and possible toxic inputs) from degraded upstream tributary habitats are likely affecting fall Chinook salmon survival and production. Past studies have generally indicated high survivals in the Lower Clearwater, and while egg-to-parr survivals are relatively good under current conditions, they may have been even better under historical conditions.

Many streams in the Clearwater River basin do not meet various Idaho water quality standards (IDEQ 2014), with widespread problems with excess sediment, high temperatures, and nutrient enrichment. Reduced channel complexity also exists in some stream reaches. While spawning habitat in the lower Clearwater River does not appear to be limited, more information is needed to determine the impact of these degraded water quality conditions on potential fall Chinook salmon spawning and rearing in the South Fork Clearwater, Selway River, and other spawning areas.

Summary: Lower Clearwater River MaSA

Threat: Dworshak Dam.

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

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

Related limiting factors: Reduced habitat complexity and floodplain connectivity, increased water temperatures, increased sediment, excessive nutrients, pollutants.

5.2.5.2 Lower Grande Ronde River MaSA

The Lower Grande Ronde MaSA consists of the lower mainstem reach of the Grande Ronde River. Historically, fall Chinook salmon may have also spawned in some isolated tributary reaches in the Grande Ronde basin. The lower Grande Ronde River flows through northeast Oregon and southeast Washington to join the Snake River in Hells Canyon at RM 169. The lower river corridor displays rocky, exposed, arid canyons and sparely vegetated terrain.

The Lower Grande Ronde MaSA produced 5 percent of all redds in the Lower Snake River population based on surveys since 1992 (see Figure 2-12). Redd surveys conducted on the Grande Ronde River in 2015 found a total of 378 fall Chinook salmon redds in the 53-mile mainstem reach from the mouth upstream to the Wildcat Bridge past the town of Troy. Fall Chinook salmon redds have also been observed in the past in the lower Wallowa and Wenaha Rivers and Joseph Creek, but these reaches were not surveyed in 2015. From 2011 to 2016, the mean number of redds counted in the Grande Ronde River basin was 288, ranging from 154 to 378 (Arnsberg et al. 2016).

Habitat conditions in the lower Grande Ronde River that may affect fall Chinook salmon spawning and rearing include lack of habitat quantity and diversity, excess fine sediment, degraded riparian conditions, low summer flows, and water quality impairments. In some parts of the lower Grande Ronde River mainstem, past and present land use, such as livestock grazing, road development, timber harvest, and recreation have reduced habitat quantity and complexity. Activities upstream (water diversions, agriculture, channelization, roads, livestock grazing, etc.) also contribute to limiting factors in the reach. For example, sediment in the lower mainstem primarily comes from upstream tributaries and the upper mainstem. Water quality problems in the corridor due to nutrient levels also result primarily from upstream land management activities. Upstream water withdrawals contribute to low summer flows and high water temperatures in the reach (NPCC 2004; NMFS 2017b). The limiting factors may affect abundance, productivity, and spatial structure of fall Chinook salmon.

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, sediment, and temperature (ODEQ 2000; NPCC 2004; ODEQ 2010). A water quality management plan and a TMDL have been developed for the lower Grande Ronde subbasin and set TMDL goals to address 303(d) listings for temperature and bacteria (ODEQ 2000).

Summary: Lower Grande Ronde River MaSA

Threats: Timber harvest, livestock grazing, agricultural uses, channelization, water diversions, and recreation.

Related 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).

5.2.5.3 Lower Tucannon River MaSA

The Lower Tucannon River MaSA includes the lower mainstem Tucannon River and the tailrace reaches of the mainstem Snake River inundated by Little Goose and Lower Monumental Dams. The Tucannon River flows through the southeast corner of the state of Washington and joins the Snake River at RM 62.2.

While the lower Tucannon River currently supports some natural spawning of fall Chinook salmon (6 percent of all redds in the Lower Snake River population based on surveys since 1992 [see Figure 2-12]), surveys indicate that nearly all spawners in the Tucannon River are hatchery-origin returns. It is not clear whether this lack of natural-origin spawners is due to habitat conditions in the MaSA that could reduce its productivity. Starbuck Dam, built in the late 1800s about 5.5 from the mouth of the Tucannon River, blocked all fall Chinook salmon access to upstream habitats until WDFW constructed a fishway in 1992. 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. Carcass samples obtained in the Tucannon River indicate that hatchery-origin fish account for virtually all redds, suggesting negligible natural-origin returns to this MaSA (Milks and Oakerman 2014). In 2015, biologists observed a total of 506 fall

Chinook salmon redds in the lower 20-mile reach of the Tucannon River. From 2011 to 2016, the mean number of redds observed in the Tucannon River was 408, ranging from 302 to 541 (Arnsberg et al. 2016).

Limited information exists on the quality and quantity of habitat available to support additional fall Chinook salmon spawning and rearing in the river. WDFW classified sediment load and habitat quantity as primary limiting factors for fall Chinook salmon in the Tucannon River 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). Major land uses in the subbasin, including agriculture, timber harvest, and livestock grazing, contribute to habitat degradation in this lower reach.

The Lower Tucannon River MaSA also includes the adjacent inundated mainstem Snake River section associated with Little Goose and Lower Monumental Dams. Limited spawning (0.1 percent ± 0.04 percent of all redds) now occurs in the tailrace areas of these dams, where hydropower project development and operations alter flow and temperature regimes and reducing habitat diversity.

Summary: Lower Tucannon River MaSA

Threats: Agriculture, livestock grazing, timber harvest (in Tucannon River basin); hydropower development and operations (in tailrace areas of Little Goose and Lower Monumental Dams).

Related limiting factors: In Tucannon River: sediment load and habitat quantity, habitat diversity and channel stability. In mainstem Snake River tailrace areas: altered thermal regime, altered flows, reduced habitat diversity.

5.2.5.4 Lower Imnaha River

The ICTRT considered spawning in the lower approximately 20 miles of the mainstem Imnaha River to be contiguous with and therefore part of the Upper Hells Canyon MaSA. 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. Data from 2000-2014 redd counts indicate that the reach of the Imnaha River contributes a small percentage (1.8 percent ± 0.2 percent) of the basinwide redd counts. In 2015, biologists counted a total of 83 fall Chinook salmon redds on the Imnaha River from the mouth to the town of Imnaha (19 miles). From 2011 to 2016, the mean number of redds observed in the Imnaha River was 67, ranging from 24 to 103 (Arnsberg et al. 2016).

Fall Chinook salmon are present only in the mainstem Imnaha River below the town of Imnaha (Ecovista and NPT 2004). Adults enter the Imnaha River in October through the end of November, when water temperatures are dropping and base flows are increasing. Outmigration of subyearlings occurs from the end of May through the first half of July, and also coincides with a period of favorable flow and reduced stream temperatures (Ecovista and NPT 2004).

Little information exists on factors that may be limiting fall Chinook salmon in the Imnaha River, but potential limiting factors include fine sediment levels in spawning substrate and water temperatures. The ODEQ has developed a TMDL for the Imnaha River (ODEQ 2010). The ODEQ has also placed the entire Imnaha River mainstem and some stream reaches in key tributaries on the Clean Water Act section 303(d) list due to temperature limitations (based on a 50 ºF [10 ºC] standard for year-round bull trout spawning, rearing, and adult presence); however, fall Chinook salmon may not be affected by the high temperatures because of their short residency in the river system. 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, as cited in Ecovista and NPT 2004).

Summary: Lower Imnaha River

Threats: Uncertain.

Related limiting factors: Uncertain.

5.2.5.5 Lower Salmon River

The ICTRT considered spawning in the lower Salmon River to be contiguous with and therefore part of the Upper Hells Canyon MaSA. Data from 2000-2014 redd counts indicate that the lower Salmon River contributes a small percentage (0.8 percent ± 0.1 percent) of the basin-wide Snake River redd counts. During a single aerial survey conducted in 2015, biologists observed 142 fall Chinook salmon redds in the 105-mile reach of the mainstem Salmon River from the mouth to French Creek. From 2011 to 2016, the mean number of redds observed in the Salmon River was 62, ranging from 31 to 142 (Arnsberg et al. 2016). Anecdotal accounts suggest that late spawning Chinook salmon existed historically in this area. For example, Burns (1992) found anecdotal evidence for fall Chinook salmon spawning in the lowermost portion of the South Fork Salmon River during 1895–1890, the 1930s, and as recently as 1982 (Connor et al. 2016).

Limited information exists on potential factors that could be limiting fall Chinook salmon use of the lower Salmon River. The lower Salmon River flows through both private and public lands, draining steep forested mountain slopes and then shrubs and grasses along the Salmon River canyon. Habitat conditions in the lower Salmon River and lower South Fork Salmon River are affected by excess fine sediment and reduced riparian vegetation from land use activities on adjacent lands and in upstream areas. Water temperatures drop in the lower Salmon River during the fall, and the plume created by cold water from the Salmon River where it enters the Snake River can provide thermal refugia for fall Chinook salmon.

Summary: Lower Salmon River

Threats: Uncertain.

Related limiting factors: Uncertain.

5.2.6 Estuary, Plume, and Ocean

The freshwater, estuary, plume, and coastal Pacific Ocean ecosystems are all connected biologically. The management actions that take place in freshwater and the estuary are thought to affect fish numbers, as well as the size, condition, and timing of ocean entry and potentially even the survival to adulthood. Our current understanding of the use of estuarine and coastal habitats by Snake River fall Chinook salmon is summarized below. Additional information can be found in the Estuary Module (Appendix F), Ocean Module (Appendix D), and in NMFS' 2014 Supplemental FCRPS biological opinion (NMFS 2014c).

5.2.6.1 Estuary

The estuary provides important habitat where juvenile Snake River fall Chinook salmon feed and complete the process of acclimating to salt water while avoiding predators. Juveniles from this ESU enter the estuary in two timing peaks each year. The first, likely made up of yearling migrants, passes Bonneville Dam during early to mid-May; the second (subyearlings) between late June and early July. Individuals of both life-history types generally spend less than a week in the estuary (McMichael et al. 2011). Small numbers of subyearlings have been caught or detected in shallow water habitat along the margins of the estuary, including the larger "distributory" channels that provide access to floodplain wetlands (Roegner and Teel 2014).

Estuarine floodplain habitats underwent significant change over the last 100 years as a result of human development. These changes have altered the function of the estuary and plume as habitat for salmon and steelhead (Appendix F; Fresh et al. 2005). The cumulative impacts of past and current land use (including dredging, filling, diking, and channelizing) and alterations to the Columbia River flow regimes by reservoir storage and release operations have reduced the availability and quality of estuarine habitat. Most of the marshes, wetlands, and floodplain channels that provided food and refuge have been diked off from the river and converted to agriculture and industrial and urban use (Figure 5-7). Corbett (2013) estimated losses of 70 percent for vegetated tidal wetlands and 55 percent for forested uplands between the late 1880s and 2010.

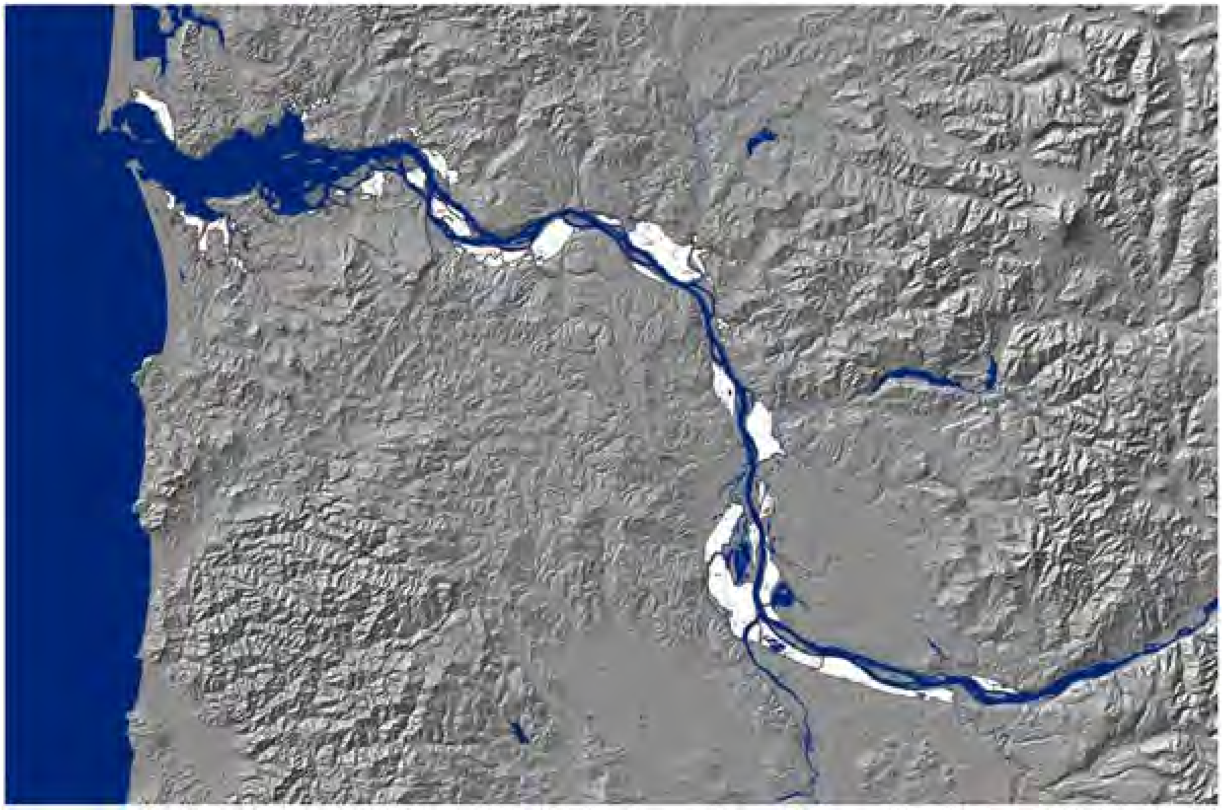

Figure 5-7. Diked areas (shown in white) of the historical lower Columbia River floodplain as of 2005 (Appendix F).

The timing and volume of river flows below Bonneville Dam has changed as a result of construction and operation of the Federal Columbia River Power 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 (Appendix F). These flow alterations, combined with diking and filling practices, have separated large sections of the lower river from its floodplain and significantly reduced the availability of prey ─ insects, crustaceans, and other particulate organic material derived from the marshes, wetlands, and shallow habitats of the estuary (Appendix F; Bottom et al. 2005; Diefenderfer et al. 2016). Sediment transport processes have also changed significantly because some materials are trapped behind dams. Where the river historically was murky with sediment, juvenile salmon may be more exposed to predatory fish and birds in the current system (Appendix F).

Water quality in the estuary 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 (Appendix F). Water temperatures above the upper end of the range tolerated by juvenile salmon occur earlier and more often, and these exceedances are likely to increase with climate change (Independent Scientific Advisory Board 2007a, as cited in NMFS 2011a). Exposure to toxic pollutants could also 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 (see Section 5.6). Other potential limiting factors and threats to salmon and steelhead in the estuary are less well understood. These include shifts in the estuarine food web and species interactions (including competition and predation), overwater and instream structures, and ship-wake stranding of juveniles (Appendix F).

5.2.6.2 Plume and Ocean

The conditions that Snake River fall Chinook salmon experience in the plume and ocean vary considerably between years. Evidence suggests that mortality during early marine residence is highly variable from year to year and can be an important determinant of year-class strength (Appendix D). Timing of ocean entry and movements of Snake River fall Chinook salmon in their first few months at sea are summarized here, as are hypotheses regarding ocean-related limiting factors. The Ocean Module (Appendix D) includes additional information 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.

While there is no specific data on the residence time of Snake River fall Chinook salmon in the Columbia River plume, data are available from telemetry studies that are not specific to individual stocks. These data show subyearling juvenile Chinook salmon present in the plume area for an average of 3.6 days, and yearling juvenile Chinook salmon present in the plume for shorter amounts of time; however, considerable variation in residence time exists among individual fish (McMichael et al. 2013).

Based on purse seine catches near the mouth of the Columbia River, yearling Snake River fall Chinook salmon enter the ocean between late April and late June with a narrower band during May for hatchery fish (Weitkamp et al. 2015). Subyearlings arrive a bit later: mid-June through early-September (through July for hatchery fish). Yearlings move north along the Washington coast and slightly closer to shore during May and June (Teel et al. 2015). Subyearlings spread out between the northern end of the Olympic Peninsula and Newport, Oregon, during June and move closer to shore by September. Teel et al. (2015) suggest that smolts are swept offshore within the plume and that the observed movements toward shore are "corrective."

Yearlings can be found along the coast of Southeast Alaska by fall. Most move off the shelf and into oceanic habitats at the start of their second year in the ocean (Appendix D). Little is known about the distribution or ecology of fish from this ESU from the time they enter the open waters of the North Pacific Ocean until they return to the Columbia River as adults.

With respect to food web interactions, Daly and Brodeur (2015) found that yearling Chinook salmon (presumably including Snake River fall Chinook) fed on early life stages of euphausiids (primarily *Thysanoessa spinifera*) and Pacific sand lance (*Ammodytes hexapterus*) during cold ocean regimes versus rockfishes (*Sebastes* spp.), decapod larvae (especially *Cancer* spp. megalopae), and flatfishes during warm ocean years. Yearlings ate more prey and more calories of prey in warm ocean years, but individuals were smaller and adult returns were much lower than in cold ocean years. Daly and Brodeur suggest that bioenergetically, juvenile salmon require more food resources during a warm ocean regime.

Subyearling fall Chinook salmon caught during late-September to early-October have been highly piscivorous; juvenile northern anchovies (*Engraulis mordax*) made up more than half the diet by weight in some years (Dale et al. 2017). Oddly, in years when invertebrates (euphausiids, *Cancer* spp. megalopae, and amphipods) were a relatively large part of the diet (e.g., 39 percent), the body condition of these juveniles was poor, but adult returns two to three years later were higher. The authors noted that ocean conditions in years with a higher percentage of invertebrates in the diet were significantly cooler from May to August.

Peterson et al. (2014) suggest that the ocean survival of yearlings from the Columbia River varies with the bioenergetics content of the food base, which in turn is driven by the predominant phytoplankton and zooplankton (especially copepod) communities. When coastal sea surface temperatures are cooler (i.e., the negative phase of the Pacific Decadal Oscillation Index, or PDO), the food chain is anchored by lipid-rich cold-water copepods. When temperatures are warm (positive phase PDO), lipid-poor warm-water copepods dominate. The PDO is linked to the copepod community and ultimately to fish through the physical processes that control water masses in the northern California Current. When the winds are primarily from the southwest, subtropical water and southern community copepods are transported onshore. Conversely, when winds are primarily from the north, upwelling in the open ocean leads to cooler conditions and the presence of the northern copepod community. The prey studies described above support this relationship although the effect may differ between yearling and subyearling migrants.

5.2.6.3 Summary: Estuary, Plume, and Ocean

Estuary

Threats: FCRPS flow management and reservoir operations; diking, filling, and other agricultural practices; forest management and industrial and urban land use practices.

Related limiting factors for subyearling and yearling migrants: Reduced habitat in the mainstem migration corridor as a result of changes in flow and sediment/nutrients; reduced floodplain connectivity as a result of reduced spring flow combined with diking for agriculture and urban and industrial development; water temperature; food source changes as a result of reduced macrodetrital inputs; altered predator/prey relationships; toxic contaminants.

Plume and Ocean

Threat: Direct or indirect effects from human actions.

Related limiting factors: Warm ocean years are related to low adult returns of many genetic stocks from the Columbia basin including Snake River fall Chinook salmon. This effect appears to be related to changes in the juvenile Chinook food web, but also may reflect the bioenergetic cost of growth during a warm ocean regime. Research is ongoing but a longer time series of data is needed to capture year-to-year variation.

5.2.7 Climate Change

Likely changes in temperature, precipitation, wind patterns, ocean acidification, and sea-level height have implications for survival of Snake River fall Chinook salmon in their freshwater, estuarine, and marine habitats. However, the magnitude of these effects on Snake River fall Chinook salmon habitats, and the species' ability to respond to the changes, remains unclear.

This section summarizes the potential climate change effects that may be pertinent to Snake River fall Chinook salmon. The information is based on findings from several recent reviews, including relevant descriptions of expected changes in Pacific Northwest climate by Elsner et al. (2009), Mantua et al. (2009), Mote and Salathe (2009), Salathe et al. (2009), Mote et al. (2010), and Chang and Jones (2010). It also reflects reviews of the effects of climate change on salmon and steelhead in the Columbia River basin by the ISAB (2007), NMFS (2010, 2014c), Hixon et al. (2010), Dalton et al. (2013), and Crozier (2016), as well as the NMFS Northwest Fisheries Science Center's 2015 *Status Review Update for Pacific Salmon and Steelhead* discussion of climate change and recent trends in marine and terrestrial environments (NWFSC 2015). The NWFSC also produces annual updates (see, e.g., Crozier 2012, 2013, 2016) describing new information regarding effects of climate change relevant to salmon and steelhead as part of the FCRPS Adaptive Management Implementation Plan (NMFS 2009).

Climatic conditions affect salmonid abundance, productivity, spatial structure, and diversity through direct and indirect impacts at all life stages. Importantly, however, the species have developed an adaptive ability over generations that has provided resiliency to a wide variety of climatic conditions in the past, and that could also help them survive and adapt to future changes in climatic conditions.in the absence of other anthropogenic stressors (NWFSC 2015).

Currently, the adaptive ability of threatened and endangered salmon in general is depressed due to reductions in population size, habitat quantity and diversity, and loss of behavioral and genetic variation. Without these natural sources of resilience that are normal in healthy populations, systematic changes in local and regional climatic conditions due to anthropogenic global climate change will likely reduce long-term viability and sustainability of populations in the Snake River basin. Species response to climate change is complex and will vary by species and population, and is context dependent (Crozier 2014; Munoz 2015; Mantua et al. 2015). Changes in phenology ─ the timing of migration out of or into a river ─ and reproduction, age at maturity, age at juvenile migration, growth, survival and fecundity are associated primarily with changes in temperature (Crozier 2014). Further research is needed regarding the strong behavioral plasticity and physiological capacity for change to help us understand the adaptive potential of Snake River fall Chinook salmon and other species in response to climate change over time. Continued development and testing of comprehensive models of climate change susceptibility based on data from Snake River species and individual populations and the watersheds in which they reside is needed to understand the biological consequences of climate change.

Adapting to climate change may eventually involve changes in multiple life-history traits and/or local distribution, and some populations or life-history variants might die out. Importantly, the character and magnitude of these effects will vary within and among ESUs and DPSs (NWFSC 2015).

5.2.7.1 Freshwater Environments

Climate records show that the Pacific Northwest has warmed about 0.7 °C (1.26 °F) since 1900 (Dalton et al. 2013). Modeling indicates that as the climate changes, air temperatures in the Pacific Northwest are expected to increase <1 °C (<1.8 °F) in the Columbia River basin by the 2020s and 2 to 8 °C (3.6 to 14.4 °F) by the 2080s, relative to a historical period of 1970 to 1999 (Mantua et al. 2010). While total precipitation changes are uncertain (-4.7 percent to +13.5 percent, depending upon the model), increasing air temperature are predicted to alter snow pack, stream flow timing and volume, and water temperatures in the Columbia and Snake River basins. Predicted changes to rivers and streams in the Columbia River basin as a result of warmer temperatures include:

- More precipitation falling as rain rather than snow.
- Declines in snowpack and total spring runoff, which could contribute to drought conditions (Mao et al. 2015).
- Higher likelihood of dry and warm years, increasing the negative impacts of drought (Diffenbaugh et al. 2015).
- Diminished snow pack and altered stream flow volume and timing.
- More winter flooding in transitional and rainfall-dominated basins.
- Lower late summer flows in historically transitional watersheds.
- A trend toward loss of snowmelt-dominant and transitional basins in Idaho and eastern Washington, including the Snake River basin.
- Continued increase in average summer and fall water temperatures.

These changes in air temperatures, river temperatures, and river flows are expected to cause general changes in salmon and steelhead distribution, behavior, growth, and survival. Climate change is anticipated to reduce the current range of native fish (Eby et al. 2014; Isaak et al. 2012; Wenger et al. 2011; Wenger et al. 2013) and could confound efforts to recover some extant populations (Munoz et al. 2014). For example, modeling of climate change scenario effects on future stream temperature suggests high elevation areas of the Snake River basin, much of which are federally managed, are likely to provide long-term cold-water refugia important for the survival and recovery of native fish (Isaak et al. 2015), including some Snake River salmon and steelhead. Since Snake River fall Chinook salmon are primarily mainstem and low-elevation tributary spawners, and since the juveniles generally spend little time rearing in their natal habitats, they would not benefit from high-elevation cold-water refugia. However, cold-water refugia lower in the tributaries could aid survival of fall Chinook salmon returning to tributary reaches, including in the Clearwater River basin. They could also help maintain the plumes of cold water at the mouths of tributaries that function as cold-water refugia in the Snake River mainstem during the adult fall Chinook salmon migration.

Potential impacts of climate change on Snake River fall Chinook salmon include the following:

Mainstem Snake River Habitat:

- Increased water temperatures in the lower Snake River could cause migrating adult Snake River fall Chinook salmon to delay passage or to fail to enter fish ladders. This situation occurred at Lower Granite Dam in late July and early August 2013, when higher than average water temperatures and associated tailrace hydraulic conditions slowed the upstream movement of adult Snake River fall Chinook salmon.
- In addition to the delay in migration described above, higher water temperatures during adult migration could also lead to increased pre-spawning mortality or reduced spawning success, increased fallback at dams, loss of energy reserves due to increased metabolic demand, or increased susceptibility to disease and pathogens. Higher mainstem temperatures during adult passage are identified in the adaptive management provisions of the 2008 FCRPS biological opinion (NMFS 2008b, 2010, 2014c) as a key concern requiring ongoing monitoring and evaluation, and possibly additional actions to improve survival.
- A delay in adult migration and spawn timing could then trigger a delay in fry emergence and dispersal. If delays in emergence timing occur and are long (i.e., weeks), then timing of smolt migration could 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 since, as explained below, warmer winter temperatures would also increase incubation rates.
- Increased water temperatures could also accelerate the rate of egg development and lead to earlier fry emergence and dispersal. Research by Connor et al. (2002, 2003, 2005) indicated that warmer water temperatures during the incubation period of fall Chinook salmon eggs also shifted the timing of emergence, parr, and smolt life stages earlier. This shift could be either beneficial or detrimental, depending upon spawning location and prey availability. If juvenile fall Chinook salmon were to move out of protected, shallow, nearshore habitats earlier, and potentially at a smaller size, their exposure and vulnerability to predators could be increased.
- If water temperatures in the lower Snake River become so warm during spring, summer, and fall that cold-water releases from Dworshak Reservoir cannot maintain temperatures suitable for salmon, then the yearling life-history pattern of the Snake River fall Chinook population could be diminished or lost. Juvenile Snake River fall Chinook salmon that exhibit a yearling life history would be particularly susceptible to the increased temperatures in the river reach and reservoirs because they generally outmigrate later in the summer than subyearlings.

- Fall Chinook salmon use of some tributary habitats may increase if winter water temperatures increase. Currently, it appears that fall Chinook salmon production in some tributary areas may be limited by low winter water temperatures. The conditions could improve if the temperatures rise.
- Sublethal thermal stress could increase vulnerability to predation (ISAB 2007). Increases in water temperatures in Snake and Columbia River reservoirs could increase consumption rates and growth rates of predators and, hence, predation-related mortality of juvenile fall Chinook salmon. Consumption of juvenile salmonids by northern pikeminnow, walleye, and smallmouth bass in Columbia and lower Snake River reservoirs is highest in July, concurrent with maximum availability of salmonid prey and high temperature (Vigg et al. 1991). Maximum daily consumption of juvenile salmonids by northern pikeminnow has also been shown to increase exponentially as a function of temperature (Vigg and Burley 1991).
- The higher temperatures could increase competition for food and/or result in changes in the food web. Warmer temperatures would increase juvenile salmonid metabolism, but would also 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. (water fleas) in Columbia River reservoirs. This could reduce the amount of food available for yearling fall Chinook salmon that prefer *Daphnia* spp. and rear in the reservoirs (Rondorf et al. 1990; ISAB 2007), however, some juvenile fall Chinook salmon prey on young shad when they are available and this predation may increase.
- Reduced flow in late spring and summer could lead to delayed migration of juvenile fall Chinook salmon and higher mortality passing dams. However, it is also possible that the juvenile outmigrants could adjust their migration timing accordingly.

Overall, the magnitude and timing of climate-related changes, and specific effects on Snake River fall Chinook salmon, remain unclear. They will depend on how increases in water temperatures and changes in river flow affect fish migration, spawning timing, emergence, dispersal, and rearing patterns. Presently, there is not a common understanding among managers about how the fish will respond. The degree to which phenotypic or genetic adaptations may partially offset these effects is being studied but is currently poorly understood. The predominant fall Chinook salmon subyearling life-history strategy allows different avoidance mechanisms than for species such as spring/summer Chinook salmon and steelhead, which remain in natal habitat areas over summer months and outmigrate as yearlings. Consequently, potential impacts on Snake River fall Chinook salmon could be reduced compared to these other fish species, if the fish adjust their migration timing accordingly. Information gained from research, monitoring, and evaluation (described in Chapter 6 [Recovery Strategy], Chapter 7 [Research, Monitoring, and Evaluation], and Appendix B) will provide information on how the species responds to increased water temperatures and other effects of climate change throughout its life cycle. This information will help determine whether these effects are significant limiting factors for species recovery and what steps could be taken to best address them.

5.2.7.2 Estuary and Plume Environments

Climate change could also negatively affect Snake River fall Chinook salmon in the estuary and plume. However, the impact could be limited since Snake River fall Chinook salmon move through the estuary relatively quickly and use the estuarine habitat less than some other Chinook salmon ESUs with subyearling life histories. Juvenile fall Chinook salmon could also be affected by changes in the plume; however, use of plume habitat by the species remains poorly understood.

Effects of climate change in the estuary and plume could include:

- Higher winter freshwater flows and higher sea levels, which could increase sediment deposition and cause wave damage, possibly reducing the quality of rearing habitat.
- Lower freshwater flows in late spring and summer, which could lead to upstream extension of the salt wedge, possibly influencing the distribution of salmonid prey and predators.
- Increased temperature of freshwater inflows and seasonal expansion of freshwater habitats, which could increase predation by extending the range of non-native, warm water fish 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 complex and not fully understood.

5.2.7.3 Marine Environment

Varying conditions in the marine environment greatly influence the status of Snake River fall Chinook salmon. The conditions affect growth and survival rates, adult returns, and population variability.

Changes in ocean conditions (shifts from good ocean years to bad ocean years) represent an important environmental factor that affects growth and survival of Snake River ESA-listed salmon and steelhead (Fresh et al. 2014). 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. The effects of environmental conditions in marine waters inhabited by Snake River fall Chinook salmon and other Pacific Northwest salmon, are influenced, in large part, by two ocean-basin scale drivers: the Pacific Decadal Oscillation (PDO) (Mantua et al. 1997) and the El Niño-Southern Oscillation (El Niño or ENSO). Since late 2013, however, abnormally warm conditions in the Central Northeast Pacific Ocean known as the “warm blob” (Bond et al. 2015) have also had a strong influence on both marine and freshwater habitats.

Globally, nationally and regionally, 2015 was a record-breaking climate year (Blunden and Arndt 2016). Di Lorenzo and Mantua (2016) describe ocean temperature variability between the winters of 2013/14 and 2014/15 during the strong North American drought, resulting in the northeast Pacific Ocean experiencing the largest marine heatwave ever recorded. Enhanced by a strong El Niño, global annual surface temperature in 2015 topped records for the second year in a row, exceeding the pre-industrial average by over 1 °C (33.8 °F) for the first time. New records were also set for global ocean heat content, sea level, and minimum sea ice extent. Climate model simulations indicate that extreme conditions such as this are likely to increase with greenhouse gas forcing (Crozier 2016).

Salmonids are particularly impacted by ocean conditions during the first weeks or months of marine life (Pearcy 1992; Pearcy and Wkinnell 2007). Accordingly, where the fish are during the first summer of ocean residence, and the conditions they experience, has a large impact on their overall marine survival. In general, salmon and steelhead from the Pacific Northwest can be grouped by their ocean migration patterns: fall Chinook salmon remain in local waters (although their location during winter months is largely unknown), while sockeye and spring Chinook salmon move rapidly north along the continental shelf to Alaskan waters and reside in the Gulf of Alaska for most of their ocean residence. Steelhead generally exhibit a unique marine migration pattern and move directly offshore and apparently west across the North Pacific Ocean (Daly et al. 2014; Hayes et al. 2012; Myers et al. 1996).

Differences in migration patterns paired with diverse ocean conditions result in species differences in survival. Since Pacific salmon are a cold water species and flourish in cold and productive marine ecosystems, elevated water temperatures can be detrimental to their growth and survival, both directly and indirectly (Crozier et al. 2008; Wainwright and Weitkamp 2013). In marine environments, temperature changes are typically associated with different environmental conditions that have their own planktonic ecosystem, including salmon prey and predators. They can have a strong effect on the available food web, and the influence of this and other indirect effects is larger than those due directly to physiological effects of changing temperatures (Beauchamp et al. 2007; Trudel et al. 2002). For example, Snake River salmon and steelhead benefit from negative PDO (cool water off the Washington/Oregon coast) as do northern copepods and anchovy, which are part of their food web. Northern copepods have much higher lipid levels than southern copepods, and therefore likely produce food webs that promote high growth and survival in salmon (juvenile salmon do not eat copepods directly) (Peterson et al. 2014). Species that prosper during positive PDOs (warmer waters) include southern copepods and sardines (Lindegren et al. 2013; Peterson and Schwing 2003; Shanks 2013).

Hypotheses differ regarding whether coastal upwelling will decrease or intensify in the future, 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 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 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.

The changing marine conditions that salmon encounter in the ocean will continue to affect species abundance and productivity. For example, Snake River fall Chinook salmon that entered the ocean in 2011 returned in record high numbers, while spring Chinook salmon entering in the same year had low returns (and below predictions). This difference is thought to be due to differences in ocean conditions encountered by the two runs: fall Chinook salmon remained off the Washington/Oregon coast, where conditions were quite productive, while spring Chinook salmon migrate rapidly to Alaska, where ocean conditions were extremely unproductive in 2011. A reverse situation to 2011 appears to have occurred in spring 2014. The exceptionally warm marine waters in 2014 and 2015 may have favored a subtropical food web that contributed to poor early marine growth and survival; however, the effects of these conditions will not be known until the fish return as adults.

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 is poorly understood. A mismatch between earlier smolt migrations (because of earlier peak spring freshwater flows and decreased incubation period) and altered upwelling could 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, there is currently a paucity of research directly related to the effects of ocean acidification on salmon and their prey. 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.

5.2.7.4 Summary: Climate Change

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

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. As a result, adult mortality could increase or spawning success decrease due to combined effects of water temperature, migration and spawning delay, increased fallback at dams, loss of energy reserves due to increased metabolic demand, and 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 yearling life history and rears in the lower Snake River reservoirs could 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 susceptible to changes in the estuary, plume, and ocean environments. Analysis of salmon and steelhead species' vulnerabilities to climate change by life stage will be available in the near future, upon completion of the *West Coast Salmon Climate Vulnerability Assessment* by the Northwest Fisheries Science Center.

To the extent that climate change results in substantial effects to fall Chinook salmon and challenges their phenotypic or genetic ability to adapt, additional survival improvements in any stage of their life cycles would be beneficial. Remaining uncertainty regarding the effects of climate change reinforces the importance of monitoring to document climatic effects on freshwater, estuary, and ocean productivity, and adjusting actions accordingly through adaptive management.

5.3 Harvest

Snake River fall Chinook salmon encounter fisheries in the ocean from Alaska to California, and in the mainstem Columbia River and some tributaries. Fisheries do not directly target ESA-listed natural-origin fall Chinook salmon. Instead they target marked hatchery fish (fall Chinook salmon and other species) and non-listed natural fish (fall Chinook salmon and other species). Natural-origin Snake River fall Chinook salmon are caught in these fisheries, which are managed to limit impacts on natural-origin Snake River fall Chinook salmon and other ESA-listed species, while optimizing harvest of healthier stocks to the extent possible within constraining limits for weak stocks. This section summarizes harvest-related threats and limiting factors affecting Snake River fall Chinook salmon. The Harvest Module (Appendix G) provides more detail on the various fisheries, management processes, analyses, and other related information.

Harvest has the potential to affect abundance, productivity, spatial structure, and diversity of Snake River fall Chinook salmon. Direct harvest effects on natural Snake River fall Chinook salmon include mortality of fish that are targeted for harvest, as well as mortality of fish that are incidentally harvested and mortality of fish that are caught and released or injured by fishing gear but not landed. Indirect effects can occur when fishing rates are high and selective by age, size, or run timing and might include selective pressure on migration timing, maturation timing, and size characteristics as well as genetic, growth, or reproductive changes.

5.3.1 Direct Effects

Due to their patterns of ocean distribution and adult migration timing, Snake River fall Chinook salmon are subject to harvest in a wide range of 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. Adult migration timing of Snake River fall Chinook salmon overlaps with fish that are targeted for harvest, including the Hanford Reach upriver bright Chinook salmon returns and returns of several large hatchery runs in the lower mainstem Columbia River. In locations where fish are harvested, it is infeasible to distinguish listed natural-origin (and therefore unmarked) Snake River fall Chinook salmon from the large numbers of natural unlisted (and unmarked) fish that are targeted for harvest. This difficulty in distinguishing Snake River fall Chinook salmon from other, healthier fish runs contributed to past high harvest rates.

While relatively high aggregate harvest impacts in ocean and in-river fisheries was one of the factors that led to the ESA listing of Snake River fall Chinook salmon, since listing, fisheries have been managed to reduce morality of ESA-listed fish, and impacts have remained relatively constant in recent years (Good et al. 2005).

5.3.1.2 Harvest Exploitation Rates

Total harvest mortalities for combined ocean and in-river fisheries are often expressed in terms of exploitation rate, which is the proportion of a total run that is harvested by the combined fisheries. This term provides a common currency for comparing ocean and in-river fishery impacts. In comparison, harvest mortalities that occur in a particular region are expressed in terms of harvest rates. For example, the harvest rates on fisheries in the Columbia River are expressed as the proportion of the run returning to the river that is killed in river fisheries.

The total exploitation rate on Snake River fall Chinook salmon has declined significantly since the ESA listing. Although no direct estimates of ocean harvest impacts on natural-origin Snake River fall Chinook salmon are available, the Pacific Salmon Commission Chinook Technical Committee (CTC) estimates total exploitation rates for Snake River fall Chinook salmon based on analysis of coded-wire tag recoveries for subyearling releases of Lyons Ferry Hatchery fish. Average total exploitation rates from 1989 to 1992 were 70 percent, and from 2003-2012 they were 46 percent (there were too few tag recoveries during the intervening years to conduct the necessary analysis).[63] Ocean fisheries have been required since 1996, through ESA consultation, to achieve a

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[63] Exploitation rate analysis of Lyons Ferry fingerling coded-wire tags by CTC modified by Snake River fall Chinook salmon wild in-river harvest rates form run reconstruction, March 2015.

30 percent reduction in the average exploitation rate observed during the 1988 to 1993 period (Appendix G).

Figure 5-8 shows how the average total exploitation rate on Lyons Ferry Hatchery fall Chinook salmon is distributed among ocean and Columbia River fisheries. Fishery managers use coded-wire tag recoveries of fall Chinook salmon from Lyons Ferry Hatchery subyearling releases as a surrogate to estimate mortalities on natural-origin Snake River fall Chinook salmon in ocean fisheries because no direct estimates of ocean harvest impacts on natural-origin Snake River fall Chinook salmon are available.

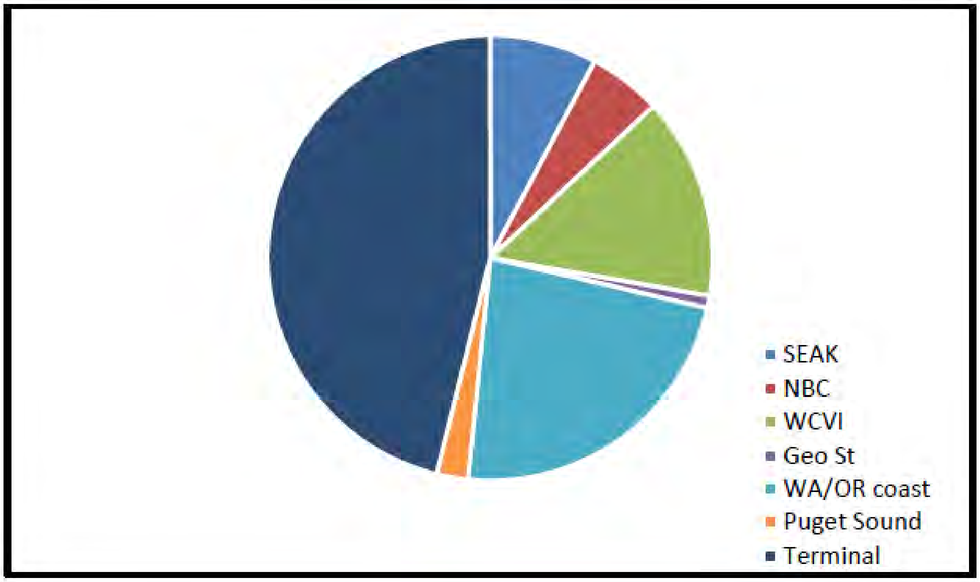

Figure 5-8. Percentage distribution of Lyons Ferry Hatchery average total fishing exploitation rate among ocean and Columbia River fisheries (1999-2011) (Appendix G). The fisheries are the Southeast Alaska (SEAK) fishery; northern British Columbia (NBC) fishery; west coast of Vancouver Island (WCVI) fishery; Georgia Strait (Geo St) fishery; Washington/Oregon coastal (WA/OR coast) fishery; Puget Sound fishery; and the non-treaty and treaty Indian (terminal) fisheries in the Columbia River.

In recent years, about 10 percent of the harvest mortality 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 2012). In-river gillnet and sport fisheries are managed in time and space to maximize the catch of harvestable hatchery and natural (Hanford Reach) stocks while minimizing impacts on the intermingled ESA-listed Snake River fall Chinook salmon.

As described in Section 2.6.7, ocean fishery impacts on Snake River fall Chinook salmon are managed through agreements negotiated through the Pacific Salmon Treaty, which was first ratified in 1985. The most recent Chinook salmon agreement under the Pacific Salmon Treaty was completed in 2008 and covers the period from 2009 through 2018. The 2008 agreement is similar to the previous agreement with certain refinements, including harvest reductions of 15 percent in Southeast Alaskan fisheries and 30 percent in fisheries off the west coast of Vancouver Island relative to the previous agreement.

As also noted in Section 2.6.7, fisheries in the Columbia River basin, particularly in the mainstem Columbia River, are managed pursuant to the *U.S. v. Oregon* Management Agreement (2008-2017). Under this agreement, non-treaty commercial and recreational fisheries and treaty Indian fisheries in the Columbia River are managed subject to an abundance-based harvest rate schedule (see Table 5-2). Under this schedule, allowable harvest in any given year depends on the abundance of unlisted upriver fall Chinook salmon and natural-origin Snake River fall Chinook salmon combined (this aggregate group of fish is called the Upriver Bright fall Chinook salmon stock, or URB). The allowable harvest rate ranges from 21.5 percent to 45.0 percent.

Table 5-2. Abundance-based harvest rate schedule for Snake River fall Chinook salmon under the 2008-2017 *U.S. v. Oregon* Management Agreement (TAC 2008, as cited in Appendix G).

State/Tribal Proposed SR Fall Chinook Harvest Rate Schedule					
Expected URB Columbia 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
>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.

The harvest rate schedule in Table 5-2 modifies the past practice of managing fisheries subject to a fixed harvest rate and provides a management structure that is more responsive to the status of the species.[64] 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 5-3. Observed harvest rate (HR) in the Columbia River on Snake River fall Chinook salmon compared to the maximum allowable harvest rate limit used in the 2008-2017 *U.S. v Oregon* Management Agreement going back to 1996.

Year	Observed HR (%)*	Allowed HR (%)	Difference between Allowed and Observed
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%
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%

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[64] 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 2008-2017 *U.S. v. Oregon* Agreement.

5.3.3 Indirect Effects

In addition to direct effects (i.e., mortality), harvest has the potential to have indirect effects on migration timing, maturation timing, size, and other factors. Information based on CWT recoveries of Lyons Ferry Hatchery fall Chinook salmon indicates that timing and distribution of ocean harvest of Snake River fall Chinook salmon has an impact on both maturing and immature fish (Chinook Technical Committee 2007). This means that the cumulative impact of ocean harvest would be higher on components of the run maturing at older ages, as size regulations focus fisheries on mature fish. Snake River fall Chinook salmon are also harvested incidentally in in-river fisheries directed at healthier, more abundant fall Chinook salmon runs, such as the un-listed upriver bright fall Chinook salmon. These fisheries intercept both jacks (primarily age-2s, some smaller age-3s) and adults (dominated by age-4 and age-5 returns) but are managed based on impacts to adults. Annual in-river harvest rates are reported for both jacks and adults.

These potential indirect effects are not considered a limiting factor at this time. In addition, such indirect effects could occur not just from harvest but from the collective effects of hydropower, hatchery, and harvest influence. Time series of size, growth, and age should be monitored to further investigate potential combined indirect effects of hydropower, hatcheries, and harvest influences on Snake River fall Chinook salmon.

5.3.4 Summary: Harvest

Threat: Fisheries.

Related limiting factors: Direct effects (harvest mortality).

Potential limiting factors: Indirect effects (selection for age, size, or run timing).

5.4 Predation, Competition, and Other Ecological Interactions

Predation, competition, and other ecological interactions affect Snake River fall Chinook salmon in the mainstem Columbia and Snake Rivers and in the tributaries where spawning occurs. These factors reduce species viability by influencing abundance, productivity, spatial structure, and diversity.

5.4.1 Predation

Ecosystem alterations attributable to the construction and operation of hydropower dams and modification of estuarine and other mainstem habitat have increased predation on Snake River fall Chinook salmon. However, Snake River fall Chinook juvenile salmon typically migrate through the Snake and Columbia River system in the early to late summer months (although some fish migrate as yearlings in early spring), and adults move into the Columbia River in August and September, with peak numbers passing Bonneville Dam in early to mid-September. This migration timing helps fall Chinook salmon avoid much of the bird and marine mammal predation incurred by spring migrating salmon and steelhead stocks. Predation effects on fall Chinook salmon are summarized below.

5.4.1.1 Bird Predation

Primary bird predators of Snake River fall Chinook salmon are double-crested cormorants and Caspian terns, with gulls and pelicans having relatively insignificant impacts. In general, as described below, rates of predation on Snake River fall Chinook salmon are relatively low.

Two primary populations of double-crested cormorants prey on juvenile Snake River Fall Chinook: Foundation Island, in the mainstem Columbia River near the mouth of the Snake, and East Sand Island, in the Columbia River estuary. The Foundation Island colony and its estimated impacts are relatively small. Colony size was estimated at 300 to 400 pairs over the years 2004-2010 (Roby et al. 2011) and at 390 pairs in 2014 (Evans et al. 2015). The colony has been estimated to consume 0.8 percent of in-river Snake River fall Chinook salmon migrants, or about 0.4 percent of all migrants (with transported fish added to the total) (Lyons et al. 2011). These effects are low enough that managers have not implemented management actions to reduce them. Some cormorants from the Foundation Island colony disperse into the lower Snake River after breeding, where yearling migrants from the Clearwater River would be particularly vulnerable. However, estimates of these impacts have also been low (Roby et al. 2011).

The East Sand Island colony was estimated at 11,000 nesting pairs in 2016 (Appy et al. 2017). An average for all the years of PIT-tag derived consumption data (2000 to 2016) indicates an average consumption of Snake River fall Chinook salmon of approximately 3.3 percent of the PIT-tagged population passing through Bonneville Dam (calculated from data in Table 3.4 of Skalski and Townsend 2016). The FCRPS action agencies are in the third year of management of this colony. Actions have focused on reducing the colony numbers through culling, with habitat modification actions projected to start in 2018. The overall goal is to reduce the size of the colony to 5,380 to 5,939 pairs and to reduce Snake River fall Chinook salmon predation by about 1.1 percent (NMFS 2014c).

Two primary Caspian tern colonies prey on juvenile Snake River fall Chinook salmon. The colony at East Sand Island contained about 5,200 pairs in 2016 and was estimated to consume 0.7 percent and 0.8 percent of Snake River fall Chinook salmon in 2015 and 2016, respectively. This compares with a pre-management (2000-2010) estimate of 2.5 percent and a post management (2011-2016) average of 0.9 percent (Evans et al. 2016a, 2016b). Management of the East Sand Island tern colony began in 1999 and has included relocation from Rice Island to East Sand Island in an effort to increase reliance on marine prey and reduction of the colony's nesting habitat from several acres down to one acre.

The second Caspian tern colony is located on the Blalock Islands in the mainstem Columbia River below McNary Dam. This colony has increased in size recently from a 10-year average of about 58 pairs per year to 500 to 700 pairs annually in 2015 and 2016, respectively. This increase is largely due to management efforts to relocate colonies from Goose Island in Potholes

Reservoir and Crescent Island in the Columbia River near the mouth of the Walla Walla River. In 2015 and 2016, estimated consumption of Snake River fall Chinook salmon by the Blalock colony was 0.4 percent and 0.6 percent, respectively, of the run that passed McNary Dam (based on data from Collis et al. 2016a and b, and Roby et al. 2017). There are no management efforts to address the Blalock Island tern colony at this time; however, discussions among the Walla Walla District Corps and other management agencies are ongoing through the Inland Avian Predation Management Program.

Large gull colonies are present in the mid-Columbia River, on the Blalock Islands near Boardman and on Miller Island near the mouth of the Deschutes River. In 2014, the Miller colony was estimated at 4,000 nesting individuals and over 6,000 nesting individuals were counted on the Blalock Islands (Evans et al. 2015). In 2015, Snake River fall Chinook salmon consumption by the Miller colony was estimated at 2.4 percent of the PIT-tagged fish detected at McNary Dam (Roby et al. 2017). At present, no management actions are in place for these gull colonies. There is, however, a bird predator deterrent program in place at McNary, John Day, The Dalles, and Bonneville Dams aimed at reducing gull presence in dam tailrace areas, although these effects have not been measured.

There is one large colony of American white pelicans on Badger Island in the Columbia River near the mouth of the Snake River. This colony was estimated at 2,447 breeding individuals in 2014 (Evans et al. 2015). Food habit studies indicated a low consumption (~0.1 percent) of all juvenile salmonids passing through the McNary Pool (Lyons et al. 2011). There have been no management actions on the colony to date.

5.4.1.2 Marine Mammal Predation

Marine mammals (pinnipeds) are a substantial source of adult salmonid mortality in general, although less is known about specific impacts to Snake River fall Chinook salmon. Until about 2010, most of the sea lions in the vicinity of Bonneville Dam were California sea lions and left the area near the end of May. As a result, adult fall Chinook salmon generally avoided encountering these predators below Bonneville Dam. However, since 2011, an increasing number of Steller sea lions has been moving up the river to the Bonneville Dam tailrace area and feeding on adult salmon starting in late August when adult fall Chinook salmon start passing the project (USACE 2016). Mean daily numbers of Steller sea lions in the tailrace at Bonneville Dam increased from 3 per day in October 2011 to 22 per day in 2015. This species is now present in the lower Columbia for 10 months of the year (USACE 2017).[65] Steller sea lions are assumed to intercept adult Snake River fall Chinook salmon, but estimates of consumption are not available at this time, and there are needs for continued monitoring.

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[65] California sea lions have occasionally been observed at Bonneville Dam in the fall, but unlike Steller sea lions their numbers have remained low, averaging less than one per day (USACE 2017).

5.4.1.3 Fish Predation

Both native and non-native fish prey on salmon in the Columbia and Snake River basins. Snake River fall Chinook salmon may be vulnerable to fish predation because of their relatively small size and because their mainstem rearing habitats often overlap with or are in close proximity to habitats used by predators (Curet 1993; Nelle 1999; Naughton et al. 2004).

The primary native fish predator of Snake River fall Chinook salmon is the northern pikeminnow, which preys on juvenile salmon throughout the mainstem Snake and Columbia Rivers. Beamesderfer et al. (1996) estimated that over 16 million salmonids were consumed by northern pikeminnows each year in the mainstem Columbia and Snake Rivers before BPA initiated a bounty reward fishery, the Northern Pikeminnow Management Program (NPMP), in the early 1990s. Impacts at the time this program was implemented were concentrated from The Dalles Reservoir downstream, where about 80 percent of these salmonids were estimated to have been consumed. This was an estimated loss of 8 percent of the 200 million hatchery and wild juvenile salmonid migrants in the system. The goal of the NPMP is to facilitate sport fisheries such that between 10 and 20 percent of the population of large adult pikeminnow is harvested each year, with a resulting reduction of predation on salmon and steelhead smolts by about 50 percent over historical levels. Modeling predicts that following the 2016 sport reward fishery season, for example, predation on salmonids in 2017 will be about 29 percent below predation levels prior to implementation of the sport reward fishery (Carpenter et al. 2017).

Non-native game fish (smallmouth bass, walleye, etc.) also feed on migrating salmon smolts, and smallmouth bass (*Micropterus dolomieu*) and juvenile salmon use many of the same habitat types (Bennett and Naughton 1999). Past studies of smallmouth bass predation in the Snake River documented relatively low consumption of juvenile fall Chinook salmon (0 to 11 percent 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 a historic low, which may explain why consumption rates were relatively low. Since then, the number of subyearlings in the Snake River basin has increased substantially due to a variety of recovery actions and, 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 of 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).

Recent research indicates that current consumption of Snake River fall Chinook salmon by smallmouth bass is significantly higher than it was in the past. In Hells Canyon during 2012–2016, mean annual consumption rates ranged from 0.05 to 0.08 Chinook/bass/day, with peak consumption ranging from 0.13 to 0.23. In contrast, Nelle (1999) reported mean consumption rates that ranged from 0.0015 to 0.003 Chinook/bass/day and a peak rate of 0.027 Chinook/bass/day. In the upper portion of Lower Granite Reservoir, consumption rates were over an order of magnitude higher than previously reported (0.08 to 0.16 Chinook/bass/day at present comparted to .002 to 0.004 Chinook/bass/day reported by Naughton et al. 2004). The highest consumption rates observed were for bass sampled in the lower portion of Lower Granite reservoir, which ranged from 0.21 to 0.35 Chinook/bass/day. These are substantially higher than those reported by Anglea (1997), which ranged from 0.007 to 0.017 salmonids/bass/day (Tiffan and Erhardt, unpublished). The increased per capita smallmouth bass consumption rates in recent years correspond to large increases in the abundance of both hatchery- and natural-origin juvenile fall Chinook salmon in reaches above Lower Granite Dam. It is not known if the increased consumption levels by smallmouth bass reflect a higher proportional morality rate on juvenile fall Chinook salmon.

While not specific to Snake River fall Chinook salmon, a study in the Yakima River found that smallmouth bass appear to have a preference for fall Chinook salmon, which constituted to 47 percent of their diet in May (Fritts and Pearsons 2004). In the Columbia River near Richland, Washington, salmonids made up nearly 60 percent of the diet of smallmouth bass (Tabor et al. 1993).

Walleye (*Sander vitreus*), the largest member of the perch family, also prey on fall Chinook salmon. Walleye can grow up to 20 pounds, are extremely piscivorous, and, in the Columbia Basin, are most abundant in dam tailraces, where the potential for impacts on juvenile salmonids is high (NMFS 2000). 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. Poe et al. (1991) stated that walleyes and smallmouth bass were much less important predators on salmonids than pikeminnows and appeared to select subyearling Chinook salmon only in August when the distribution of this prey overlapped with that of the predators. 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).

Channel catfish (*Ictalurus punctatus*), another predator, can weigh up to 35 pounds. They are omnivorous and opportunistic in feeding, and have been known to eat almost anything, dead or alive. Large channel catfish feed almost exclusively on fish. Fish was the most important component of the diet by weight in John Day Reservoir during 1983 to 1986 (Poe et al. 1991). Salmonids were the single most important item, comprising about 33 percent of the stomach contents by weight (NMFS 2000). However, predation rates have not been developed.

Fishing regulations in Oregon and Washington have recently been modified to eliminate size and daily limits on the catch of smallmouth bass and walleye in the Columbia and Snake Rivers. This could potentially help control non-native fish predator populations.

5.4.1.4 Summary: Predation

Threats: Dam operation, reservoirs, alterations to estuary (particularly creation of dredged material islands).

Related limiting factors: Increased predation by marine mammals, birds, and native and non-native fish.

5.4.2 Competition and Other Ecological Interactions

Competition and other ecological interactions can affect fall Chinook salmon abundance, productivity, and diversity. The productivity of juvenile Snake River fall Chinook salmon depends in part on the food web and prey communities that support their growth and survival, and on competition for food and space with other fish. Juveniles exhibit a transitory rearing strategy, using a continuum of riverine and reservoir habitats for rearing and migration, and are generalists and opportunistic in their feeding behavior. They can be affected by changes in the composition and capacity of the food webs and prey communities that support them in riverine and reservoir habitats. They are also affected by the intensity and magnitude of competition from other fish for food and space in habitat areas. Competition can escalate when habitat capacity is limited and unable to support the number of salmonids and/ or other fishes competing for key resources at the same time. For example, the growth rate of fall Chinook salmon rearing in Lower Granite Reservoir has declined in recent years compared to when the juvenile population was at low abundances in the 1990s (Connor et al. 2016). Increased competition or changes in food resources may be contributing to this decline in growth rate.

5.4.2.1 Altered Food Web and Prey Community

The food web and prey community has changed through time in the lower Snake River since development of the four lower Snake River dams and reservoirs, and the associated increase in 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, however, *Corophium* spp. compose a large portion of the subyearling diet at certain times. The cause for this change is not known. *Neomysis mercedis*, an estuarine mysid native to the Columbia River estuary, also were not present in the lower Snake River about 15 years ago, but have expanded their range upstream and today are abundant in the Snake River. The ecological effect of the increased abundance of this species on juvenile fall Chinook salmon is not known, but the species has the potential to alter the food web in either a positive or negative way.

Tiffan et al. (2014) examined prey availability, prey consumed, and diet energy content as sources of variation in growth of natural-origin fall Chinook salmon subyearlings rearing in riverine and reservoir habitats in the Snake River. Subyearlings in riverine habitat above the confluence with the Clearwater River primarily consumed aquatic insects (e.g., *Diptera, Ephemeroptera, Trichoptera*). In Lower Granite Reservoir, subyearlings consumed aquatic insects but also preyed heavily at times on nonnative lentic amphipods (*Corophium* spp.) and the mysid *Neomysis mercedis*; these species were absent in drift samples from riverine habitats. Overall, study results showed that the availability of prey was typically much higher in the reservoir, largely because *N. mercedis* often composed over 90 percent of the biomass. When this taxon was removed from consideration, biomass estimates were often higher in the riverine habitat. Subyearling diets during 2009–2011 were generally 17 to 40 percent higher in energy and observed growth (both length and weight) was also significantly higher in the riverine habitat than in the reservoir.

The situation is further complicated due to 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 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 (Haskell et al. 2013), and, if they become abundant in the Snake River, may also affect prey availability for Snake River fall Chinook salmon. Haskell et al. (2017) collected subyearling Chinook salmon in open water in John Day Reservoir during July and August 2013. While juvenile American shad are considered a potential competitor of subyearling Chinook salmon, this study showed that the Chinook salmon consumed the small juvenile shad in August after switching from eating *Daphnia*. By switching to this prey, which has a higher energy density, the subyearling Chinook salmon gained greater growth opportunity.

5.4.2.2 Competition among Salmonids and Between Salmonids and Other Native Fish

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 recovery and mitigation actions may increase competition for food and space between conspecifics, other salmonids, and other 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.

Competition for food resources or rearing habitat among salmonids, and between salmonids and other fish species, may also 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.

In addition, competition may occur on the spawning grounds between hatchery-origin and natural-origin fall Chinook salmon. For instance, 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).” The 2015 5-year status review assessment (NWFSC 2015) and the life-cycle modeling efforts that are underway for Snake River fall Chinook salmon (Peery et al. 2017) have found stronger evidence of density-dependent effects in the Lower Snake River fall Chinook salmon population. More study is needed to better understand the causal mechanisms and extent of these effects.

Fall Chinook salmon may also compete with other salmonids in Snake River tributaries but the extent of such competition 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 RM&E.

5.4.2.3 Competition with Non-Native Fish Species

Competition can also occur between salmonids and non-native species. The effects of introduction of non-native species in the estuary, including invertebrates, plant species (such as Eurasian water milfoil), and non-native fish (such as shad) are poorly understood. The impact of American shad in particular may be significant, because of the sheer tonnage of their biomass. 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. As discussed in Section 5.4.2.1, 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. Additional research is needed to more fully understand the effects of competition on the viability of Snake River fall Chinook salmon

5.4.2.4 Summary: Competition and Other Ecological Interaction

Threats: Increased abundance of non-native species, alterations to estuarine and mainstem Columbia and lower Snake River habitats (including conversion to reservoirs), altered food web and prey community, high density of fish on spawning grounds due to large numbers of hatchery fish.

Related limiting factors: Competition for space in spawning and rearing areas, competition for food, increased predation.

5.5 Hatcheries

Hatchery production of salmon can affect all four VSP parameters and be a source of both benefits and 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 their spawning grounds can benefit salmonid viability by increasing abundance, thus reducing extinction risk and conserving genetic variability that would otherwise be lost through genetic drift. On the other hand, as abundance of natural-origin spawners increases 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 hatchery releases are unmarked; however, the presence of 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 by increasing or decreasing stream flow through the use of wells or direct water withdrawals from streams, and by creating migration barriers, such as weirs used for broodstock collection.

The sections below discuss the effects of the Snake River fall Chinook salmon hatchery programs on the four VSP parameters, and then summarize the primary hatchery-related threats and related 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; Appendix F). For a more comprehensive treatment of these and all other hatchery program issues, see the biological opinion on the Snake River fall Chinook salmon hatchery programs (NMFS 2012a).

5.5.1 Abundance

As described in Chapter 4, based on estimates made at Lower Granite Dam, the proportion of natural-origin fish in the population from 2007 to 2016 has averaged only 30 percent, based on post-harvest, post-broodstock collection estimates above Lower Granite Dam (Young, personal communication, 2017). However, during the same period, annual abundance of natural-origin fish was in the thousands, which represents a dramatic improvement over abundance levels in the 1990s.

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). Snake River fall Chinook salmon hatchery programs have also grown during this time. 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 increase in natural-origin abundance 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. In the 1990s, the hatchery programs were limited by measures imposed to reduce the inclusion of stray fish from other programs. With these limitations no longer in place, the hatchery programs have now reached their full intended sizes, and under this more stable situation, the relative contribution of the hatchery programs to abundance and other factors should be easier to determine (NMFS 2012a).

5.5.2 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. 1996). 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.

5.5.3 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) (NMFS 2012a). Ecologically, hatchery fish on the spawning grounds can potentially benefit productivity to some extent by conditioning spawning gravel (Montgomery et al. 1996) and adding marine-derived nutrients to the ecosystem (Cederholm et al. 1999), but can depress productivity through competition and possibly predation (Kostow 2009). The larger the number of hatchery-origin fish relative to natural-origin fish, the greater the genetic and ecological risk.

5.5.3.1 Genetic Effects

The current hatchery programs (see Section 2.8.8), 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 biological opinion on Snake River fall Chinook salmon hatchery programs (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 and demonstrating that fitness consequences can be large, NMFS' view is that 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 (NMFS 2012a). An additional consideration in the case of Snake River fall Chinook salmon is that perceptions of risk are largely based on studies of the reproductive success of hatchery-origin fish relative to that of natural-origin fish. No empirical information of this sort is available for this population and almost all the data available from studies of this type are based on fish that are released as yearling smolts (spring Chinook salmon, Coho salmon, and steelhead) (reviewed in Christie et al. 2014). 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 than in those with yearling 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 (NMFS 2012a). However, some aspects of fish culture in the programs may affect life history, and 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. Since 2007, the estimated proportion of hatchery-origin fish in the broodstock of the Snake River fall Chinook salmon hatchery programs has averaged 22 percent, although estimates based on parentage-based tagging,[66] which became available for the first time in 2016, indicate that the earlier figures may be underestimates (Young et al. 2017). Over the same period, the estimated proportion of hatchery-origin fish on the spawning grounds has averaged around 70 percent (Young, personal communication, 2017). 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 (HSRG) (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. NMFS has not adopted the HSRG guidelines but uses them as a screening tool, considering that hatchery programs that meet them pose acceptably low levels of risk. Using the estimates above, the Snake River fall Chinook salmon population currently has a PNI of approximately 22 percent, which is considerably below the level recommended by the HSRG.

5.5.3.2 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. Estimating 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

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[66] Parentage-based tagging consists of matching genotypes (DNA patterns) of fish to patterns of possible parents. Currently, DNA samples are taken from all Snake River fall Chinook salmon used as hatchery broodstock. Unmarked adults can be compared to the broodstock samples to see if they can possibly be the progeny of the broodstock fish, and thus hatchery fish.

migrating. However, indirect predation (i.e., predation by other species attracted by the large releases of hatchery juveniles), could be significant In addition, the increased level of juvenile fall Chinook salmon available because of hatchery production could cause increases in predator populations. These indirect predation effects have not been quantified.

5.5.4 Diversity

5.5.4.1 Subpopulation Structure

A major concern about current hatchery programs for Snake River fall Chinook salmon is that they may be adversely affecting diversity by preventing development or maintenance of subpopulation structure. This concern arises because hatchery managers collect broodstock primarily at Lower Granite Dam and release the 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.[67] However, it is quite possible that a completely naturally reproducing Snake River fall Chinook salmon population could have significant subpopulation structure: the primary areas used by Snake River fall Chinook salmon for spawning and rearing are located far apart (e.g., Lower Granite Dam and Hells Canyon Dam are 129 river miles apart), spawning occurs in a range of habitat conditions, and limited information on homing (Cleary et al. 2017; Garcia et al. 2004) indicates that adult hatchery fish in some areas have a strong tendency to home to the areas where they were released. In addition, a genetic study by Marshall and Small (2010) presents some data suggesting some level of existing substructure. This subpopulation structure could factor significantly in the viability of the population, and thus in recovery strategies.

5.5.4.2 Life-History Strategies

Typically, the goal of mating protocols at salmon hatcheries is to mate fish randomly in an effort to maximize genetic diversity. 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. These practices are currently under review and their future is unclear.

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 in the early years of the program were considerably higher than those of subyearlings (Bugert et al. 1997). In recent years, however, survival rates of the two life-history types have been much more similar (Rosenberger et al. 2017). Although the dominant

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[67] A Nez Perce tribal effort to develop a program component for the South Fork Clearwater is an exception.

life-history strategy 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, 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 (Waples et al. 2017). The practice of releasing “forced” yearlings is currently under review and may be discontinued.

5.5.5 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 hatchery 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 level of Snake River fall Chinook salmon hatchery-origin fish on the spawning grounds, although high, is not atypical. However, Snake River fall Chinook salmon differ from most other listed hatchery-influenced salmon populations in a number of ways that pose challenges for recovery planning and monitoring, and the major ones are worth highlighting here.

Size of the spawning population and the proportion of consisting of hatchery-origin fish are critical pieces of information because much of the concern about the effect of the hatchery programs is the perception that the proportion of hatchery-origin spawners is quite large compared to the natural production, but the absolute number and hatchery/natural composition of spawners is subject to considerable uncertainty. Most of our information on abundance and hatchery/natural mix comes from monitoring at Lower Granite Dam, far below (~100 river miles)[68] where most of the spawning occurs. The redd counts are imprecise because in many places the water is so deep that many redds are not visible. Carcasses are difficult to collect. Monitoring of the population is also made more difficult and costly by the sheer geographical extent of spawning, which is likely larger than that of any other listed salmon ESU.

Another critical uncertainty is natural productivity of the population, both overall and in major population segments. For any population to be considered recovered, natural productivity must be sufficient to assure a high probability of population persistence. In this case, the size and extent of the hatchery programs make estimation of natural productivity highly uncertain. Indeed, one of the main motivations for recovery Scenario C is that natural productivity will be more accurately estimated if an area of reduced hatchery influence is available for monitoring.

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[68] Distance between Lower Granite Dam and Pittsburgh Landing.

A third critical uncertainty related to the Snake River fall Chinook salmon hatchery programs is the impact of the programs, both ecological and genetic, on population productivity. This uncertainty is not limited to Snake River fall Chinook salmon, of course, but it is a special concern here because of the challenges to implementing measures to control hatchery influence in Snake River fall Chinook salmon that may be available elsewhere (e.g., removal of hatchery fish at a downstream weir, implementation of selective fisheries, or greatly increasing the number of natural-origin fish used for hatchery broodstock). Although information on genetic effects of hatcheries continues to grow, making population-specific predictions about short- and long-term effects is very speculative. The considerable amount of information available from relative reproductive success (RRS) studies indicates clearly that hatchery fish are generally less fit reproductively than natural-origin fish (Christie et al. 2014). The same type of studies shows that the fitness deficit may have a substantial non-genetic component. Also, RRS studies have been directed almost exclusively at fish that produce yearling smolts. Ecological impacts are also a concern, but detailed information is lacking, especially on a population-specific level, and they do not have the same potential for long-term effects that genetic impacts have. We expect studies elsewhere, not specifically focused on Snake River fall Chinook salmon, to provide guidance on dealing with these issues in recovery of the Snake River fall Chinook salmon ESU.

5.5.6 Summary: Hatcheries

Threat: High proportion of hatchery fish as juveniles.

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

Threat: High proportion of hatchery-origin spawners.

Related limiting factors: Genetic change, loss of fitness; competition for resources, including spawning areas.

5.6 Toxic Pollutants

Throughout their migration corridor and in some rearing and spawning 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 related limiting factors for the ESU.

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 copper, have received attention from NMFS because of their potential effects on listed salmonids (NMFS 2008e, 2011a, 2011b). 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. They 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 used 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 biological 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 copper 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 smell. 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, tributyltin, 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.

5.6.1 Summary: Toxic Pollutants

Threats: Agricultural runoff, legacy mining contaminants, urban and industrial runoff, effluent, and wastes; accumulation of toxic pollutants in reservoirs.

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

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6. Recovery Strategy, Site-Specific Management Actions, and Adaptive Management Framework

This chapter describes the recovery strategy for the Snake River fall Chinook salmon ESU. It contains three sections. Section 6.1 describes the overall approach for recovery of the Snake River fall Chinook salmon ESU and the strategies for recovering the extant Lower Snake River population and the extirpated Middle Snake River population. It includes an adaptive management framework for prioritizing and updating future efforts. Section 6.2 provides further detail, identifying management strategies and site-specific management actions for recovery of the extant population and extirpated population. Section 6.3 describes processes that will be used to identify contingency actions for the ESU if it does not continue to move towards recovery objectives in a timely manner and/or if there are significant declines in the species' status.

6.1 Recovery Strategy

The recovery goal for Snake River fall Chinook salmon is to ensure that the ESU and the ecosystems upon which it depends have been conserved to a point that the ESU is self-sustaining in the wild and no longer needs the protections of the ESA.[69] The recovery strategy is designed to achieve this recovery goal and the objectives identified in Chapter 3 by closing remaining gaps between the species' current status (see Chapter 4) and its desired status (see Chapter 3). This will be accomplished by addressing the threats and limiting factors identified in Chapter 5, through implementation of the management strategies and site-specific actions identified in Section 6.2, all within an adaptive management framework (Section 6.1.3) and bolstered by a robust RM&E plan (Chapter 7).

The overall approach to recovery of the Snake River fall Chinook salmon ESU is threefold. First, the recovery strategy aims to maintain recent improvements in the species' status through ongoing implementation of actions that have contributed to those improvements. Second, continued RM&E will be designed and implemented to confirm the driving factors for the recent improvements in abundance and productivity, and to evaluate other critical uncertainties regarding the status of the Lower Snake River population and the combined and relative effects of limiting factors and threats. Third, the recovery strategy calls for an adaptive management framework and using the information gained through RM&E to identify and implement additional actions needed to address the limiting factors and threats to the species and achieve recovery.

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[69] A self-sustaining, viable ESU depends on the status of its component populations and major population groups 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 artificial propagation measures to achieve its viable characteristics (see Chapter 3).

The recovery strategy is intended to be consistent with the broad sense goals identified in Section 3.1.2 to meet hatchery mitigation goals and tribal treaty and trust responsibilities related to harvest, and to maintain long-term opportunities to achieve goals that go beyond ESA delisting. These long-term goals include reestablishing natural production of Snake River fall Chinook salmon above the Hells Canyon Complex and the broad goals identified in subbasin plans developed under the NPCC's Fish and Wildlife Program.

Chapter 3 identifies three potential recovery scenarios designed to meet the ESA recovery goal and objectives. It also describes biological viability and threats criteria (i.e., ESA de-listing criteria) that NMFS will use in determining whether ESA recovery has been achieved. While one of the potential scenarios would require reestablishing a viable population above the Hells Canyon Complex; the other two would achieve ESA recovery with the single extant population. Each scenario has attendant uncertainties and tradeoffs, discussed in Chapter 3. In Chapter 3, we also noted that the most likely and most timely path to recovery is the single-population scenario that would focus natural production in Natural Production Emphasis Areas (Scenario C). We recognize there are uncertainties about this approach, however, and so the strategy also stresses the importance of continuing to explore opportunities for reestablishing natural production above the Hells Canyon Complex in the event that achieving a single-population scenario consistent with ESA recovery proves infeasible or unsuccessful.

Accordingly, and consistent with the ICTRT's recommendation,[70] this recovery strategy focuses on recovery for the extant population, concurrent with scoping efforts for reintroduction above the Hells Canyon Complex. In the event that achieving ESA recovery with the single extant population proves feasible, NMFS will continue to support efforts, in cooperation with state and tribal agencies, to reintroduce fall Chinook salmon to the area as a broad sense goal. Reestablishing natural production of fall Chinook salmon upstream of the Hells Canyon Complex would address tribal treaty and trust responsibilities and also further reduce risk to the species by increasing geographic distribution and abundance and reducing risks associated with catastrophic events.

The strategy takes a comprehensive, all-H and life-cycle approach. It emphasizes the importance of continuing the full suite of actions that has contributed to the improvements in abundance and productivity of the ESU since listing. It also emphasizes the importance of implementing a robust and strategic RM&E plan to inform critical uncertainties, and using life-cycle modeling to enhance our understanding of the combined and relative effects of factors affecting the species and of the actions that will be most effective in ensuring recovery.

This approach recognizes that recovery of the Snake River fall Chinook salmon ESU poses unique scientific and management challenges but also presents significant opportunities. The ESU has lost substantial habitat upstream of the Hells Canyon Complex, resulting in the

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[70] Because there are "significant difficulties in reestablishing fall Chinook salmon populations above the Hells Canyon Complex…initial effort [should] 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" (ICTRT 2007).

extirpation of one of two historical populations. Fish from the one extant population must pass six to eight mainstem Snake and Columbia River dams and survive other effects of the FCRPS hydropower system. Upriver hydropower system operations associated with the Hells Canyon Complex and Dworshak Dam also influence habitat conditions in the Lower Snake River area. Snake River fall Chinook salmon are also subject to harvest in both ocean and in-river fisheries. While hatchery production has increased fish abundance and contributed to improving the status of the ESU, there are uncertainties related to the effects of high proportions of hatchery-origin spawners on species productivity and diversity. At the same time, the ESU has shown significant improvements since listing. Natural-origin abundance and productivity of the extant Snake River fall Chinook salmon population have increased since ESA listing, and the extant population is now considered to be at low risk of extinction (NWFSC 2015; NMFS 2016a). Our goal is to capitalize on the substantial improvements since ESA listing, identify additional actions that will be most effective in closing remaining gaps, and achieve an ESU that will be self-sustaining in the wild.

6.1.1 Recovery Strategy for the Extant Lower Snake River Population

In 1990, only about 78 natural-origin fall Chinook salmon returned to the one remaining Lower Snake River fall Chinook salmon population to spawn (Lavoy and Mendel 1996). NMFS listed the ESU as threatened under the ESA in 1992 (57 FR 14653). After the listing, efforts by federal, state, and tribal co-managers and other entities to conserve the species intensified. Since that time the ESU's abundance and productivity have increased significantly. Our working hypothesis is that the combined effect of the management actions implemented since listing has contributed to these improvements. These actions have improved survivals through the hydropower system, reduced other impacts of hydropower operations, reduced ocean and mainstem harvest, and increased natural production through hatchery supplementation. But the ESU is not yet meeting the ESA recovery goal and objectives.

As described in Chapter 4, the overall status of the extant Lower Snake River population has improved to viable, with a low risk rating for abundance/productivity and a moderate risk rating for spatial structure and diversity. To meet recovery criteria, however, the population needs to be highly viable with a high degree of certainty (see Chapter 3). There are also key uncertainties about whether the population can sustain recent high abundance levels and productivity across a range of environmental conditions, including the occurrence of years with poor ocean conditions, and about the effects on the natural population of a high proportion of hatchery-origin spawners. These uncertainties leave NMFS with inadequate confidence that the ecosystem and the extant population have improved to a point where the ESU would meet the ESA recovery goal and objectives and could be naturally self-sustaining over the long term.

The recovery strategy described in more detail below for the Lower Snake River population addresses effects across the life cycle. It aims to maintain the recent improvements in population status since listing by continuing the full suite of actions that have contributed to those improvements. The strategy also calls for RM&E to confirm the driving factors for the recent improvements in abundance and productivity, reduce uncertainties about the status of the Lower Snake River population, and evaluate action effectiveness. Then the strategy calls for using information gained through RM&E in an adaptive management framework to identify and implement the additional actions needed to achieve recovery.

Section 6.2 identifies these ongoing and potential additional actions.[71] In addition to continuing the ongoing actions that have contributed to improvements in the ESU's status, the potential additional actions identified in Section 6.2.1.7 for hatchery management are explicitly highlighted as key component of this recovery strategy, given their potential to inform key questions about the species productivity and to improve diversity. The life-cycle models (described in Section 6.1.1.1) will also be a key tool to help inform understanding of the additional actions that will be most beneficial.

6.1.1.1 Life-Cycle Approach to Evaluate and Improve Viability

The recovery strategy calls for developing tools, including life-cycle models, for evaluating and improving our understanding of the combined and relative effects of limiting factors and recovery actions across the life cycle. These efforts will help achieve a major focus of the overall recovery strategy for the Lower Snake River fall Chinook salmon population ─ to confirm the driving factors for the recent increase in abundance and productivity, and to validate or update management provisions to sustain long-term population viability through an adaptive management framework. The effectiveness of most ongoing actions is being evaluated through RM&E associated with the ESA section 7 consultations that require the actions (see Section 2.8). These actions operate across the life cycle and address various threats (e.g., hydropower, harvest, hatcheries, and estuary habitat).

Multi-stage life-cycle models are in development for Snake River fall Chinook salmon that will improve our understanding of the combined and relative effects of actions addressing different threats across the life cycle. These models incorporate empirical information and working hypotheses on survival and habitat capacity relationships at different life stages. The models will 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. This information will inform decisions about the most effective management strategies and direct future RM&E priorities to improve future decision making. The information will also be used to assess the status of the ESU as a whole, and interactions between different spawning areas. Accordingly, our ability to evaluate the combined and relative effects of actions across the life cycle will continue to improve.

6.1.1.2 Mainstem and Tributary Habitat and Hydropower

The recovery strategy for mainstem tributary habitat and hydropower is to maintain and improve spawning, incubation, rearing, and migration conditions by continuing ongoing actions and

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[71] See footnote 27, in Section 2.8.1 regarding the state of Oregon's position that additional or alternative actions in the FCRPS biological opinion should be taken in mainstem operations of the FCRPS to advance the persistence and recovery of ESA-listed salmon and steelhead.

implementing additional actions as appropriate in the lower mainstem Snake and mainstem Columbia Rivers and in the lower Snake tributaries.

Actions to maintain and improve mainstem Snake and Columbia River habitat are being implemented primarily under the 2008 FCRPS biological opinion and through the Hells Canyon Project Federal Power Act relicensing process. Continued implementation of these actions through these existing processes represents the centerpiece of the mainstem hydropower and habitat recovery strategy for Snake River fall Chinook salmon. Another priority is to improve understanding of the mechanisms that have led to the recent increases in survival through the mainstem Snake and Columbia River hydropower system. This will help managers identify key actions to maintain those improvements and elucidate the potential for further improvement through adapting ongoing actions or identifying additional actions.

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. For instance, recent evaluations of the efficacy of juvenile transport (McCann et al. 2016; Smith et al. 2017) may result in modifications to juvenile transport strategies. Other potential opportunities for gaining improvements in ESU viability from actions addressing limiting factors in mainstem and reservoir reaches from below the Hells Canyon Complex through the mainstem lower Snake and Columbia Rivers include: addressing temperature issues that may affect adult passage at Lower Granite Dam; modifying Hells Canyon Complex operations to further minimize stranding and entrapment below Hells Canyon Dam and to improve water quality; reducing predation on juvenile fall Chinook salmon in the Lower Granite Reservoir by reducing predator levels or predation opportunities; and exploring density-dependent effects, particularly those associated with recent increases in fall Chinook salmon spawning levels above Lower Granite Dam (studies are underway to evaluate how those patterns are influenced by environmental conditions – see Chapter 7 and Appendix B).

The recovery strategy also aims to protect and improve spawning and rearing habitats in tributary major spawning areas. While mainstem Snake River reaches contain most of the current and potential spawning habitat for the extant population, opportunities exist to expand natural production in the tributary major spawning areas.

State of Oregon Position regarding Hydropower Operations

It is the state of Oregon’s position that additional or alternative actions to the FCRPS biological opinion should be taken in mainstem operations of the FCRPS to advance the persistence and recovery of ESA-listed salmon and steelhead. Some additional or alternative actions recommended by Oregon, while considered, were not included in NMFS’ FCRPS biological opinion. At this time, Oregon is a plaintiff in litigation against the FCRPS action agencies and NMFS, challenging the adequacy of the measures contained in the current (2008 as supplemented in 2010 and 2014) FCRPS biological opinions.

6.1.1.3 Estuary Habitat

The recovery strategy for estuary habitat is to continue ongoing actions and implement additional actions as appropriate to help maintain and improve fall Chinook salmon survival in the estuary. The actions ─ which are identified in the Estuary Module (Appendix F), FCRPS biological opinion (NMFS 2008b, 2010, 2014c), and this recovery plan ─ include actions to increase off-channel habitat in the floodplain and improve the food web.

6.1.1.4 Climate Change

The recovery strategy for climate change is to continue ongoing actions and implement additional actions as appropriate to gain a better understanding of the potential magnitude and severity of climate change effects during freshwater, estuarine, and ocean life stages; and to implement actions that support Snake River fall Chinook salmon adaptation and resilience in response to climate change.

6.1.1.5 Harvest Management

The recovery strategy for harvest management is to continue to implement abundance-based harvest management and to update harvest management frameworks as appropriate to contribute to rebuilding and achieving recovery goals. NMFS will work with harvest managers through the existing forums that manage harvest in ocean and in-river fisheries to implement this strategy. As described in Section 2.8.7, ocean fishery impacts are managed through the Pacific Salmon Commission and the U.S. regional fisheries management councils. Columbia River mainstem harvest of Snake River fall Chinook salmon is managed through the *U.S. v. Oregon* Management Agreement. Regulations for recreational fisheries are developed by Idaho, Washington, Oregon, and tribal governments in their respective jurisdictions. This strategy includes implementing abundance-based harvest regimes according to the Pacific Salmon Treaty, *U.S. v. Oregon* Management Agreement, and other fishery management frameworks authorized under the ESA, and conducting assessments of the performance of these management regimes to ensure accuracy of reported estimates of harvest impacts. The strategy also identifies potential additional actions that should be implemented as appropriate.

6.1.1.6 Predation, Competition, Changes in Food Web, and Other Ecological Interactions

The recovery strategy for predation, competition, food web changes, and other ecological interactions is to continue ongoing efforts and implement additional actions as appropriate to reduce predation and competition, and address other ecological interactions that affect Snake River fall Chinook salmon. This strategy includes actions described in the 2008 FCRPS biological opinion (NMFS 2008b, 2010, 2014c), the Estuary Module (Appendix F), and other potential additional actions identified in Section 6.2.1.6 of this Plan. The actions are intended to reduce or disperse bird colonies that prey on juvenile Snake River fall Chinook salmon in both the interior Columbia and the estuary, improve fishery management to reduce non-native fish predator populations, and evaluate plume and ocean conditions that influence predator fish populations and predation rates during the early ocean life stage. The strategy also includes evaluating and addressing impacts on natural-origin fall Chinook salmon due to competition with non-native fish for limited food and rearing habitat.

6.1.1.7 Hatchery Management

The recovery strategy for hatchery management is to continue ongoing actions and implement additional actions that will inform key uncertainties related to hatchery risk and reduce the short- and long-term detrimental impacts of hatchery-origin fish on natural-origin Snake River fall Chinook salmon.

The recent increases in natural-origin returns of the Lower Snake River population have been accompanied by substantial increases in hatchery-origin returns. While these high numbers of hatchery-origin returns can boost fall Chinook salmon abundance, they also have the potential to diminish Snake River fall Chinook salmon productivity and diversity. In addition, although the risk of hatchery-influenced selection is reduced somewhat by recent increases in the proportion of natural-origin fish used as broodstock, the presence of large numbers of unmarked hatchery fish on the spawning grounds poses a risk of loss of productivity, and also adds uncertainty to our understanding of the status of the natural-origin population. A high-priority element of the recovery strategy involves evaluating and adapting the hatchery programs for Snake River fall Chinook salmon to address these uncertainties and risks and to achieve the full range of ESA recovery objectives identified in Chapter 3 for the naturally spawning population.

Production goals and details regarding releases of fish from Snake River fall Chinook salmon hatchery programs (e.g., size at release, release location, life-stage of released fish, and marking strategies) are established through the *U.S. v. Oregon* management process. NMFS participates in this process and conducts ESA section 7 consultations on HGMPs developed to implement the *U.S. v. Oregon* Management Agreement (see, e.g., the 2012 biological opinion on Snake River fall Chinook salmon hatchery programs [NMFS 2012a]). The strategy includes working through the *U.S. v. Oregon* forum to identify and assess potential management frameworks that would achieve delisting by creating one or more Natural Production Emphasis Areas (NPEAs) (see Scenario C) or reducing hatchery-origin spawners in the population overall (see Scenario B).

For example, under Scenario C some hatchery releases would be shifted to targeted areas, while other areas would be managed as NPEAs to maintain within-population diversity, with high levels of natural-origin spawners and low levels of hatchery-origin spawners. Preliminary evaluations (Cooney 2017) indicate that, given current information on dispersal rates, implementation of this approach could result in significant natural production from natural-origin spawners in one or more major spawning areas (NPEAs). Shifts in release locations could include targeting some hatchery returns into tributary reaches where occupancy by natural-origin Snake River fall Chinook is currently low. Further work is underway to develop details of how such a scenario would be implemented and evaluated. It is important in the near term to explore potential management actions that could achieve ESA recovery objectives for a single population through this approach. Implementation of this approach will require development of specific monitoring efforts to allow for the evaluation of how shifts in release locations influence natural-origin returns to NPEAs (as well as to other MaSAs).

6.1.1.8 Toxic Pollutants

The recovery strategy for toxic pollutants is to continue RM&E to gain a better understanding of potential negative impacts from exposure to toxic pollutants and to develop management actions to reduce the potential effects of toxic pollutants on natural-origin fall Chinook salmon. Snake River fall Chinook salmon are exposed to toxic pollutants in the mainstem Columbia and Snake Rivers, the estuary, and some tributary reaches. Elements of the strategy include revising water quality criteria and implementing existing programs to reduce toxic contaminant levels and adverse effects.

6.1.2 Recovery Strategy for Extirpated Middle Snake River Population

This Plan includes a potential ESA recovery scenario that would require reestablishing a viable population above the Hells Canyon Complex (see Chapter 3). As noted in Chapter 3 and previously in Section 6.1, at this time the most likely path to ESA recovery is a single-population scenario that would focus natural production in NPEAs (Scenario C). However, because there are uncertainties related to that approach, it is important to continue to explore opportunities for reintroduction above the Hells Canyon Complex in case a reestablished Middle Snake River population is needed for ESA recovery.

In the event that reestablishing a viable population above the Hells Canyon Complex is not needed for ESA recovery, NMFS will continue to support reintroduction of fall Chinook salmon to the area as a broad sense goal. Successfully reestablishing significant natural production upstream of the Hells Canyon Complex would restore lost fishing opportunities for Upper Snake River tribes and address tribal treaty and trust responsibilities. In addition, it would further reduce risk to the species by increasing geographic distribution and abundance and reducing risks associated with catastrophic events.

Many of the recovery actions identified for the Lower Snake River population, particularly those addressing passage, migration and rearing habitat, and predation in the mainstem Snake and Columbia Rivers, will also create conditions that would benefit a reestablished population above the Hells Canyon Complex. However, there are multiple and significant obstacles and uncertainties associated with reestablishing a population above the Hells Canyon Complex. Habitat conditions 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.

Under Scenario A (see Chapter 3), the long-term recovery strategy for the extirpated Middle Snake River population, which spawned historically in habitats above the Hells Canyon Complex, is to reestablish the population to a point that it is considered viable. The initial step in the recovery strategy, reflected in this Plan, is to complete feasibility studies for upstream and downstream passage to and from spawning and rearing areas above the Hells Canyon Complex, for restoration of habitat conditions above the Hells Canyon Complex, and for eventual reintroduction of the species.[72] The timing of the feasibility studies and implementation of their results will be determined through the ongoing Hells Canyon Project Federal Power Act relicensing proceedings. In the meantime, actions that protect and restore passage, migration, and rearing habitat for the Lower Snake River population below the Hells Canyon Complex would also benefit a potential reintroduced population above the Hells Canyon Complex.

The Hells Canyon Fisheries Resource Group, representing affected tribes, states, and federal fish and wildlife agencies, has developed initial phases of a draft outline of a fisheries restoration plan for passage and reintroduction of anadromous fish above the Hells Canyon Complex dams and reservoirs. This considerable effort shows the commitment of the parties to forge a pathway forward to restore anadromous fish passage and eventually provide fisheries above the Hells Canyon Complex. While the Fisheries Resource Group has not yet achieved complete consensus among the parties, the fisheries restoration plan contains three main goals for a phased approach for reestablishing anadromous fish, including fall Chinook salmon, upstream of these dams. This plan could inform future steps to reestablish passage and sustainable fish runs above the Hells Canyon Complex, and will subsequently be used as a reference document.

6.1.3 Adaptive Management Framework

Implementation of this recovery plan will be based on an adaptive management framework in which site-specific actions will be implemented based on best available science, research and monitoring will be conducted to inform key uncertainties and evaluate action effectiveness, and actions will be updated based on new knowledge (see Figure 6-1). Monitoring results will also be used in evaluating progress in closing the gap between the species' status and the ESA recovery goals and objectives. A life-cycle context is essential to this adaptive approach. The use of multi-stage, life-cycle models and other tools will improve our understanding of the combined and relative effects of limiting factors and recovery actions across the life cycle.

In addition, NMFS will evaluate the status of the ESU at least every five years, consistent with ESA requirements. If necessary, managers can also develop additional contingency actions if the species does not make progress toward recovery as we expect and/or if it has a significant decline.

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[72] Carrying out this strategy will also contribute to the broad sense goals described in Section 3.1.2.

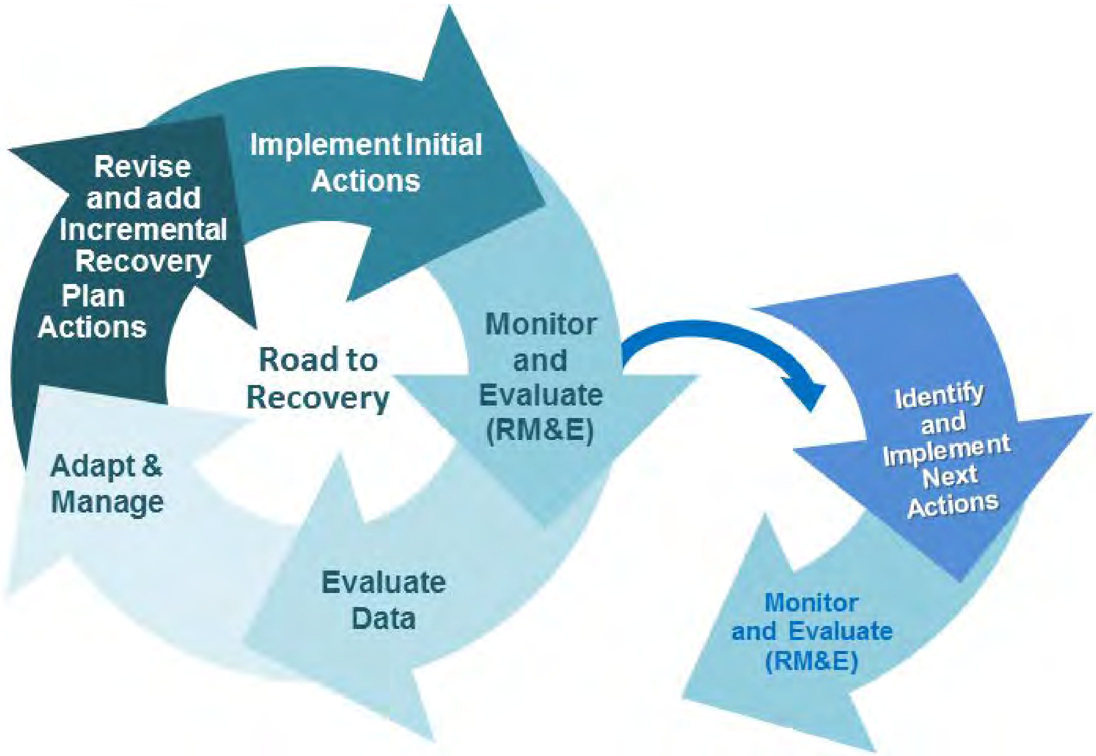

Figure 6-1. Adaptive Management Process Framework

The Snake River fall Chinook salmon ESU adaptive management framework includes the following structure of decision making so we can alter our course strategically as we gain new information:

1. Establish recovery goals, objectives, and biological viability and threats criteria for delisting (Chapter 3).
2. Determine the species' current status and the gaps between the current status and the recovery objectives and biological viability criteria (Chapter 4).
3. Assess limiting factors and threats throughout the life cycle (and in the context of variable ocean conditions and emerging information on climate change) that are contributing to the gaps between current status and recovery objectives (Chapter 5).
4. Identify, prioritize, and implement recovery strategies and management actions (Chapter 6) that target the limiting factors and threats (Chapter 5).
5. Prioritize and implement RM&E to evaluate the status and trend of the species, the status and trend of limiting factors and threats, and the implementation and effectiveness of actions (Chapter 7).
6. Establish contingency actions to be implemented in the event of significant decline in species status or lack of continued progress toward recovery (Chapter 6).
7. Regularly review implementation progress, species response, and the results of research and monitoring and adjust management actions through an implementation structure that

recognizes the interests of different stakeholders and the best opportunities to improve viability (Chapter 8).

8. Continue adaptive management in a continuous loop of action implementation, monitoring and evaluation, assessment of new information, and updated actions.

6.2 Site-Specific Management Actions

The site-specific management actions in this Plan address the threats and related limiting factors described in Chapter 5. Actions are identified separately for the extant Lower Snake River population and for the extirpated Middle Snake River population. The actions are organized under ten management strategies. The management strategies describe broadly what needs to be accomplished to protect and restore Snake River fall Chinook salmon, while the corresponding site-specific management actions detail how to implement the strategies. Where relevant, we have included a brief summary of the limiting factors and threats a group of actions is designed to address, based on the material in Chapter 5. For most management strategies, both ongoing and potential additional actions to achieve ESU viability are identified.

> *Ongoing management actions,* as discussed in Section 2.8, have contributed to improvements seen in the extant population's status since listing. It is essential that these actions continue as presently designed unless new information demonstrates that changes are warranted to maintain or continue to improve the species status. As described in Chapter 7 and Appendix B, these actions should be paired with monitoring to help evaluate whether changes are needed.
>
> *Potential additional actions* identify additional actions in each sector across the life cycle that may be needed to achieve and maintain ESA recovery goals and objectives. The adaptive management framework will be used to evaluate these actions and identify the most effective opportunities to close the gap between the species' current status and the recovery objectives.

Together, the management strategies and actions are designed to evaluate and improve viability across the life cycle. They address limiting factors in all threat categories: hydropower; mainstem, tributary, and estuary habitat; harvest; predation, prey base, competition and other ecological interactions; hatcheries; and toxic pollutants. They also propose strategies to mitigate and/or adapt to potential effects of climate change. Since Snake River fall Chinook salmon are primarily mainstem spawners and significantly influenced by hydropower operations, mainstem habitat and hydropower factors are considered together.

Research, monitoring, and evaluation (RM&E) actions are also an essential part of the recovery strategy. Information gained through evaluating the status of Snake River fall Chinook salmon, examining the effectiveness of actions implemented to improve the species' status, and addressing critical uncertainties will help us better understand how best to achieve and maintain recovery. While a few key RM&E actions are identified in the following sections as ongoing or potential additional actions, most RM&E actions are discussed in Chapter 7 and in Appendix B.

Site-specific management actions for the extant Lower Snake River population are described in Section 6.2.1, while Section 6.2.2 contains site-specific management actions for the extirpated Middle Snake River population. Table 6-1 summarizes the actions and includes, for each action, information on VSP parameters, limiting factors, and threats addressed, as well as estimated costs, potential implementing entities, and whether the action is an “ongoing essential” or a “potential additional” management action. In addition, the table includes preliminary information on prioritizing and sequencing of potential additional actions by categorizing them as “most likely to provide opportunities for ESU viability” or “warrants additional evaluation.”

Prioritizing and Sequencing Actions

An important step in implementation of this recovery plan will be to further prioritize and sequence the site-specific management actions and RM&E actions within an adaptive management framework. Prioritizing the actions will also help in coordinating funding and implementation of the actions across existing programs.

Many of the ongoing management actions identified in this Plan are being implemented through other existing forums, each with their own distinct mandates. It is essential that these actions continue as presently designed until or unless effectiveness monitoring or other information demonstrates that changes are warranted to maintain or continue to improve the species status. The FCRPS biological opinion (NMFS 2008b, 2010, 2014c), the *U.S. v. Oregon* Agreement for 2008-2017 (U.S. District Court 2008), and the 2012 biological opinion on Snake River fall Chinook salmon hatchery programs (NMFS 2012a) ─ the agreements through which many of these are being implemented ─ are scheduled to be updated in 2017 or 2018. We anticipate that the actions benefitting Snake River fall Chinook salmon in those agreements will be evaluated based on new RM&E results and that their implementation will either continue or be updated as appropriate and in consideration of recovery goals.

In general, the potential additional actions require further evaluation. We need to determine which potential additional actions provide the best and most timely opportunities for achieving ESA recovery and to then prioritize their implementation accordingly. (Some of the potential additional actions have already been evaluated and implementation is proceeding, although the effects of these additional actions have not yet been realized or demonstrated in species status).

The sequencing and rate at which additional actions are implemented are key variables that will influence how quickly the Snake River fall Chinook salmon ESU moves from its current status to achieving ESA recovery goals and objectives. The Plan (see Table 6-1) suggests 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 (2018-2022), although additional evaluation and prioritization will be needed. This 5-year 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. For additional discussion of the time needed to achieve recovery, see Section 9.1.

6.2.1 Management Strategies and Actions for the Extant Lower Snake River Population

6.2.1.1 Life Cycle Approach to Evaluate and Improve Viability

Uncertainty remains regarding the driving factors for the recent increases in Snake River fall Chinook salmon abundance and productivity, and whether those increases will persist into the future across a range of changing environmental conditions. There is also uncertainty about the effects of the high proportions of hatchery-origin spawners on species productivity and diversity. Multi-stage life-cycle models and other tools will improve our understanding of these and other uncertainties, and of the combined and relative effects of actions addressing different threats across the life cycle. This information will help us target and prioritize recovery actions and RM&E accordingly.

Management Strategy 1: *Develop tools, including life-cycle models, for evaluating and improving our understanding of the combined and relative effects of limiting factors and recovery actions across the life cycle.*

Ongoing Actions:

1-1. Continue relevant actions under the life-cycle modeling initiative being carried out under the FCRPS Adaptive Management Implementation Plan.

Potential Additional Actions:

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' current status and recovery objectives.

1-3. Develop a multi-stage life-cycle model that incorporates estimates of survival through various stages of the salmon life cycle to assess changes in population viability.

1-4. Use life-cycle modeling to assess the ESU as a whole, and interactions between the different spawning areas.

6.2.1.2 Mainstem and Tributary Habitat and Hydropower

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 being implemented through existing processes, including the FCRPS biological opinion and the Hells Canyon Project Federal Power Act relicensing process. 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.

Currently, pursuant to a court order (discussed in Section 2.8.1), BPA, the Corps, and the USBR are preparing a new Environmental Impact Statement (EIS) under the National Environmental Policy Act (NEPA). This EIS will address the operation, maintenance, and configuration of 14 federal projects that are part of the FCRPS and operated as a coordinated water management system.[73] The EIS is referred to as the Columbia River System Operations EIS. As part of this process, BPA, the Corps, and the USBR (i.e., the "co-lead agencies" for the EIS) will evaluate a range of alternatives, including a no-action alternative (current system operations and configuration). Other alternative actions will also be developed, and will likely include an array of alternatives for different system operations and additional structural modifications to existing projects to improve fish passage, including breaching one or more dams. Alternatives will include those within the EIS co-lead agencies' current authorities, as well as certain actions that are not within the co-lead agencies' authorities, based on the court's observations about alternatives that could be considered and on comments received during the scoping process. In addition, the EIS will evaluate alternatives to ensure that the prospective management of the Columbia River System is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of designated critical habitat, including evaluating mitigation measures to address impacts to ESA-listed species. The EIS will allow federal agencies and the region to evaluate the costs, benefits, and tradeoffs of various alternatives as part of reviewing and updating the management of the Columbia River System.

The Corps has previously evaluated breaching the four lower Snake River dams, in the Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement (USACE 2002). In 2010, the Corps prepared the Lower Snake River Fish Passage Improvement Study: Dam Breaching Update Plan of Study (USACE 2010), which describes the process for initiating an evaluation of dam breaching in the event salmon populations significantly declined. Since breaching of a dam at the scale of the lower Snake River dams has not yet occurred, many of the effects considered in those evaluations and described below are estimates or preliminary assessments. Further, the previous assessments do not take into account the most current information.

However, if lower Snake River dams are breached, some effects are fairly certain to occur for Snake River fall Chinook salmon, especially for actively migrating smolts. Juvenile travel time through the Snake River would be faster (although the difference would be less than previously

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[73] These 14 projects are: Bonneville, The Dalles, John Day, McNary, Chief Joseph, Albeni Falls, Libby, Ice Harbor, Lower Monumental, Little Goose, Lower Granite, and Dworshak Dams (operated and maintained by the Corps) and the Hungry Horse Project and Columbia Basin Project, which includes Grand Coulee Dam (operated by the USBR). Also see Section 2.8.1.

estimated, given current spill levels and the fact that surface passage were not contemplated in the original analysis), juvenile fish transportation would no longer occur or would be greatly reduced depending on how many dams were breached, total dissolved gas would be reduced, and spawning habitat would be increased.

Effects with greater uncertainty include the duration of high turbidity levels after dam breaching. Turbidity would increase dramatically for the first several years after breaching, as material was flushed from the reservoirs behind the dams, but much of the sediment transport would occur during the high spring flows. Since Snake River fall Chinook salmon juveniles migrate in the late spring and summer, turbidity may have little impact on this life stage. A similar, relatively low impact from turbidity is anticipated for adults because they migrate upstream through this reach under the low flows of late summer and early fall, during which time sediment transport should be low.

Temperature effects are uncertain. Large reservoirs, because of their thermal inertia, generally alter water temperatures (compared to an unimpounded river) by reducing summer maximum temperatures, increasing winter minimum temperatures, and delaying warming in the spring and cooling in the fall (see Section 5.2). Breaching the Snake River dams would diminish these effects and likely cause an increase in peak maximum summer temperatures. Breaching of the lower Snake River dams would shift the timing of peak temperature earlier in the summer and may also increase the magnitude of the peak. The magnitude of the peak temperature could be ameliorated by releasing cool water from Dworshak Dam (in the North Fork Clearwater River), but the extent to which these cool-water releases would mix with the warmer water of the mainstem Snake River with breached dams has not been thoroughly evaluated. Temperature models are being developed that should give some insight into these effects.

The rearing environment for juvenile fall Chinook salmon would change. The reservoir environment provides juvenile rearing habitat for fall Chinook that migrate both as subyearlings in the summer as well as winter rearing habitat for fish that express a yearling life history and leave for the ocean the following spring. It is likely this yearling life history would be diminished without reservoir conditions. The effect on the subyearling rearing life-history type is uncertain, as is the effect of how these changes in juvenile rearing life histories would affect the magnitude of adult returns.

The effect of predation by birds on juvenile salmonids during and after dam breaching is unknown. Effects in the estuary would probably not change. Caspian terns and cormorants at inland roosting and nesting sites are effective predators in free-flowing river systems and would likely also continue to have an effect on juvenile salmonids. Gulls, however, are opportunistic feeders that would likely have a reduced impact in a free-flowing river. The response of predatory fish (native pikeminnow as well as non-native smallmouth bass, channel catfish, and walleye) is even less certain. Migrating smolts would be less exposed to such predation due to decreased travel times through the lower Snake River, but, at least initially, the large existing population of predators would be concentrated into the smaller volume of the unimpounded river, potentially increasing predation rates.

The effect that dam breaching would have on adult migration success would be influenced by temperature of the river in late summer. Temperature modeling would help inform this question.

Life-cycle modeling that incorporates expected effects on the river environment will help inform the question of how the Snake River fall Chinook salmon might respond to breaching of the lower Snake River dams, although uncertainties regarding the combined effects on this population will remain.

In conjunction with development of the EIS, NMFS will work with the co-lead agencies to identify actions to be analyzed that could benefit Snake River fall Chinook salmon and other affected ESA-listed species. Future actions may include the potential additional actions identified below in this section.

Threats: Hydropower projects and operations; reservoirs; predation; 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 improve spawning, incubation, rearing, and migration conditions by continuing ongoing actions and implementing additional actions as appropriate in the lower mainstem Snake and Columbia Rivers and lower Snake 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 (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).

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 (NMFS 2014c).

2-4. Continue summer spill at mainstem lower Snake River and 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 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 are intended to maintain and improve spawning and rearing potential for Snake River fall Chinook salmon and to help maintain cold-water plumes at the mouths of tributaries that provide thermal refugia. NMFS' ESA Recovery Plan for Snake River Spring/Summer Chinook Salmon and Snake River Steelhead (NMFS 2017b) includes as appendices three management unit plans (for Southeast Washington, Northeast Oregon, and Idaho) that describe specific tributary habitat actions for Snake River spring/summer Chinook and steelhead.[74] Although actions for spring/summer Chinook salmon and steelhead tend to be implemented higher in the tributaries than where Snake River fall Chinook salmon spawn and rear, the actions may 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.

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[74] A management unit is a geographic area defined for recovery planning purposes on the basis of state boundaries that encompasses all or a portion of the range of a listed species, ESU, or DPS. Some ESU and DPS-level plans contain multiple management units, as in the case of Snake River spring/summer Chinook salmon and steelhead.

Potential Additional Actions:

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 (and at other Snake and Columbia River mainstem dams as needed) 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 Project Federal Power Act relicensing (NMFS 2006; 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. Identify locations of seasonal use of cold-water refugia and research reasons for loss of fish using these cold-water refugia sites. Based on research, identify actions to protect and restore cold-water refugia to improve survival of fish using this habitat.

2-20. 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.[75]

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[75] 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.

2-21. Federal agencies will complete a NEPA process that will consider innovative approaches for increasing the survival of salmon and steelhead in the Columbia Basin which pass through the FCRPS. The result of this effort should result in feasible and effective actions, which, once implemented, will improve the survival and productivity of Snake River fall Chinook salmon, as well as other salmon and steelhead species in the basin.

Tributary Habitat

2-22. Complete and implement TMDLs to improve water quality in tributary habitats that affect Snake River fall Chinook salmon spawning and rearing habitats.

2-23. Improve tributary major spawning area (MaSA) habitat.

   2-23.1. 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.

   2-23.2. 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.

   2-23.3. 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.

2-24. Target high priority opportunities to restore October spawning life-history patterns.

   2-24.1. Evaluate potential spawning and rearing habitats in the lower reaches of the Selway, Lochsa, and South Fork Clearwater Rivers.

2-25. Evaluate whether water quantity 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.

2-26. Evaluate the potential to reduce sediment impacts on lower Tucannon River mainstem historical spawning and rearing area.

6.2.1.3 Estuary Habitat

The Estuary Module (Appendix F) identifies and prioritizes habitat-related management actions that, if implemented, would reduce the impacts of limiting factors that reduce salmon survival and condition in the estuary and plume ecosystems. The following threats and limiting factors affect Snake River fall Chinook salmon in the estuary:

Threats: FCRPS flow management and reservoir operations; diking, filling, and other agricultural practices; forest management and industrial and urban land use practices.

Related limiting factors for subyearling and yearling migrants: Reduced habitat in the mainstem migration corridor as a result of changes in flow and sediment/nutrients; reduced floodplain connectivity as a result of reduced spring flow combined with diking for agriculture and urban and industrial development; water temperature; altered predator/prey relationships (addressed under Management Strategy 6); reduced food and food source changes as a result of reduced macrodetrital inputs (addressed under Management Strategy 6); toxic contaminants (addressed under Management Strategy 8).

Management Strategy 3: *Address loss of off-channel habitat in the estuarine floodplain and altered food web by continuing ongoing actions and implementing additional actions identified in the Estuary Module (Appendix F), FCRPS biological opinion (NMFS 2008b, 2010, 2014c) and this recovery plan, as appropriate.*

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.

Potential Additional Actions:

3-3. Continue to breach, lower, or relocate dikes and levees to improve connectivity to off-channel floodplain 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.

6.2.1.4 Climate Change

Potential effects from climate change on Snake River fall Chinook salmon abundance, productivity, spatial structure, and diversity remain poorly understood. Because the species primarily spawns and rears in the lower Snake and Columbia Rivers and has a dominant subyearling life history, it is possible that it may be among those salmonids either least affected by, or most likely to adapt to, climate change effects on mainstem and tributary habitat. However, it is also possible that changes such as increased water temperatures in the mainstem Columbia and lower Snake Rivers or in the ocean could adversely affect viability.

Threat: Climate change.

Related limiting factors: Warmer water temperatures, changes in precipitation and flow patterns, and increased acidification in the Pacific Northwest and ocean. Passage delay; egg and fry survival; pre-spawn mortality; shift in fry emergence and outmigration timing; reduced prey availability; increased predation by non-native species.

<u>Management Strategy 4:</u> *Continue ongoing actions and implement additional actions as appropriate to gain a better understanding of potential impacts from climate change during freshwater, estuarine, and ocean life stages, and to support Snake River fall Chinook salmon adaptation and resilience in response to climate change.*

Mainstem Snake/Columbia Rivers:

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.

Estuary:

4-6. Breach, lower, or relocate dikes and levees to establish or improve access to off-channel habitats.

6.2.1.5 Harvest Management

Harvest is currently managed under an abundance-based harvest management framework. NMFS will work with harvest managers through existing harvest management forums to implement this framework and to monitor and update it as appropriate.

Threat: Fisheries.

Related Limiting Factors: Harvest mortality.

Potential Limiting Factors: Indirect effects (selection for age, size, or run timing).

<u>Management Strategy 5:</u> *Implement harvest management 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, 2008c, 2008f).

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:

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 ESA recovery objectives.

5-6. Consistent with results of the evaluations described in RM&E, update harvest management plans through negotiations within appropriate fishery management forums.

6.2.1.6 Predation, Competition, Changes in Food Web, and other Ecological Interactions

Predation, particularly by other fish, is a 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, can also adversely affect Snake River fall Chinook salmon, especially when habitat capacity is limited and unable to support the number of salmonids and/ or other fishes competing for key resources at the same time.

Threats: Increased abundance of non-native species, alterations to estuarine and mainstem Columbia and lower Snake River habitats (including conversion to reservoirs), altered food web and prey communities, high density of fish on spawning grounds due to large numbers of hatchery fish.

Related Limiting Factors: Competition for space in spawning and rearing areas, competition for food, increased predation.

Management Strategy 6: *Continue ongoing actions and implement additional actions as appropriate to reduce predation and competition and address other ecological interactions that affect Snake River fall Chinook salmon.*

Ongoing Actions:

6-1. Continue efforts to reduce or disperse colonies of Caspian terns, double-crested cormorants, and other birds 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:

6-3. Improve Oregon and Washington fishery management of non-native fish predator populations including 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 spawning site competition and 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 mussels, quagga mussels, New Zealand mud snails, Siberian prawns, and other invasive species from extending into Snake River fall Chinook salmon habitat and depleting available nutrients in the river.

6.2.1.7 Hatchery Management

While hatchery programs have increased abundance and spatial structure of Snake River fall Chinook salmon, they remain a concern because the high proportion of hatchery-origin fish on the spawning grounds raises concerns about the productivity and diversity of the natural-origin fish.

Threats: High proportion of hatchery fish as juveniles and as adults.

Related Limiting Factors: Loss of genetic diversity and phenotypic traits; 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 additional actions that will improve ESU viability by reducing the impacts of hatchery-origin fish on natural-origin Snake River fall Chinook salmon.*

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 Snake River fall Chinook salmon hatchery programs (NMFS 2012a).

7-2. Continue current actions to minimize fish from outside the ESU being included in hatchery broodstocks (NMFS 2012a).

7-3. Continue to improve estimates of natural- and hatchery-origin fish over Lower Granite Dam (NMFS 2012a).

    7-3.1. Review and update as warranted estimates 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 other existing and 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:

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 ESA recovery 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.

  7-10.1 Develop methods/indices for the estimation of the relative contribution of naturally spawning hatchery Snake River fall Chinook salmon across major spawning areas to productivity and diversity.

7-11. Identify and implement additional methods to measure effects of high levels of hatchery-origin spawners on natural population of Snake River fall Chinook salmon productivity, diversity, and response to natural-selective processes.

7-12. Assess the expense, logistical difficulty, and consequences (e.g., to fisheries) of implementing NPEA frameworks.

6.2.1.8 Toxic Pollutants

Snake River fall Chinook salmon are exposed to toxic pollutants and chemical contaminants in the migration corridor and in some rearing and spawning areas, and this exposure can have lethal or adverse sub-lethal effects.

Threats: Agricultural runoff, legacy mining contaminants, urban and industrial runoff, effluent, and wastes; accumulation of toxic pollutants in reservoirs.

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

Management Strategy 8: *Continue RM&E to gain a better understanding of potential negative impacts from exposure to toxic pollutants and develop actions to reduce potential effects of toxic contaminants on natural-origin Snake River fall Chinook salmon.*

8-1. Continue to identify and reduce toxic contaminants at the sources, including, but not limited to, pollutants from agricultural, mining, and urban and industrial sources; also reduce accumulation of toxic contaminants in reservoirs.

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.

8-4. Continue to restore or mitigate contaminated sites.

6.2.2 Management Strategies and Actions for the Extirpated Middle Snake River Population

The successful reintroduction of fall Chinook salmon above the Hells Canyon Complex would improve the persistence probability of the ESU ─ and one of the potential ESA recovery scenarios in this Plan (see Chapter 3, Scenario A) includes a reestablished, viable population above the Hells Canyon Complex. Passage to historical habitat above the Hells Canyon Complex remains blocked and the mainstem habitat is too degraded to support significant natural production. These limiting factors are being addressed through the Hells Canyon Project Federal Power Act relicensing process, and related fish passage discussions are occurring between Idaho and Oregon with respect to the states’ 401 Water Quality Certification authorities.

Initial actions under this management strategy focus on completing feasibility studies for upstream and downstream passage to and from spawning and rearing areas above the Hells Canyon Complex. The feasibility studies also identify needed efforts to restore water quality and other habitat conditions in the Snake River upstream of the Hells Canyon Complex. The timing of these feasibility studies and implementation of their results will be determined through the ongoing Hells Canyon Project Federal Power Act relicensing proceedings. These actions are needed to support any future effort to restore a viable population or significant natural production of fall Chinook salmon about the Hells Canyon Complex.

The actions also support the implementation of existing Total Maximum Daily Load (TMDL) implementation plans for the Middle Snake River to reduce pollutants to levels that achieve water quality standards adopted under the federal Clean Water Act. The Idaho Department of Environmental Quality works with soil conservation districts, tribes, and public and private landowners to develop and implement these plans. For example, IDEQ is working with the Idaho Association of Soil Conservation Districts, BLM, Idaho Department of Lands, and agricultural producers to implement resource management systems and best management practices to reduce the amounts of nutrients entering the Mid Snake River system and, where feasible, to decrease stream temperatures by increasing shading along stream corridors.

In addition, many of the recovery actions identified for the Lower Snake River population ─ particularly those that improve passage, migration and rearing habitat, and reduce predation in the mainstem Snake and Columbia Rivers ─ will also create conditions that would benefit a reestablished population above the Hells Canyon Complex.

Threats: Hydropower projects and operations; land uses that alter river habitat: irrigated and dry land agriculture, livestock grazing, confined animal-feeding operations, mining, and 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 providing adult and juvenile fish passage to and from spawning and rearing areas above the Hells Canyon Complex.*

9-1. Complete the Hells Canyon Project Federal Power Act relicensing process and develop biological and engineering fish passage and migration feasibility studies.[76]

Management Strategy 10: *Restore habitat conditions that can support Snake River fall Chinook salmon spawning and rearing above the 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 TMDLs and FERC licensing conditions to improve water quality in the mainstem Snake River to support adequate spawning and rearing habitat.

10-2. Continue to implement and develop habitat restoration programs or incentive programs for land owners and water users that promote protecting and improving habitat conditions.

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[76] Once the Federal Power Act relicensing process is 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.

Table 6-1. Site-specific management actions, costs, and potential implementing entities.

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Timing of Potential Additional Actions (near, mid, or long-term)[77]	Estimated Costs	Potential Implementing Entity(ies)	Comments
Management Strategy 1: Develop tools, including life-cycle models, for evaluating and improving our understanding of the combined and relative effects of limiting factors and recovery actions 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 uncertainties and the relative and combined effects of actions across the life cycle.	Tools lacking to adequately evaluate uncertainties and determine species response to actions at stages & across lifecycle.	Category: Ongoing essential.	Baseline action	BPA, NMFS, USFWS, USGS, co-managers	2008/2010 FCRPS biological opinion (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 uncertainties and the relative and combined effects of actions across the life cycle.	Tools lacking to adequately evaluate uncertainties and 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[78]	NMFS, state and tribal co-managers, BPA, USFWS, USGS	

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[77] The near-term time frame corresponds roughly with the next five years of implementation (2018-2022). The mid-term time frame corresponds generally to the succeeding twenty years.

[78] 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	Timing of Potential Additional Actions (near, mid, or long-term)[77]	Estimated Costs	Potential Implementing Entity(ies)	Comments
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 uncertainties and the relative and combined effects of actions across the life cycle.	Tools lacking to adequately evaluate uncertainties and 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	
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 uncertainties and the relative and combined effects of actions across the life cycle.	Tools lacking to adequately evaluate uncertainties and 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 improve spawning, incubation, rearing, and migration conditions by continuing ongoing actions and implementing additional actions as appropriate in the lower mainstem Snake and Columbia Rivers and lower Snake 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

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Timing of Potential Additional Actions (near, mid, or long-term)[77]	Estimated Costs	Potential Implementing Entity(ies)	Comments
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, reduced thermal refugia.	FCRPS reservoirs and dams.	Category: Ongoing essential	Baseline action	COE	2008 FCRPS biological opinion
2-3	Continue summer flow augmentation (at Dworshak and Brownlee Reservoirs, 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 migration, injuries stress, mortality, reduced thermal refugia.	FCRPS reservoirs and dams.	Category: Ongoing essential	Baseline action	COE, BOR, Idaho Power Company	2008 FCRPS biological opinion
2-4	Continue summer spill at mainstem lower Snake River and 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, reduced thermal refugia.	FCRPS reservoirs and dams.	Category: Ongoing essential	Baseline action	COE	2008 FCRPS BiOp

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Timing of Potential Additional Actions (near, mid, or long-term)[77]	Estimated Costs	Potential Implementing Entity(ies)	Comments
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 biological opinion
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 biological opinion
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.[79] Additional cost: $750,000[80]	COE, BPA	2008 FCRPS biological opinion
2-9	Continue to implement measures identified in the Lower Snake River Programmatic Sediment	A, P, SS	Altered flow and sediment regimes,	Dam operations and reservoirs.	Category: Ongoing essential	Baseline action	COE	Preferred alternative from Lower Snake River Programmatic Sediment

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[79] 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 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.

[80] 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	Timing of Potential Additional Actions (near, mid, or long-term)[77]	Estimated Costs	Potential Implementing Entity(ies)	Comments
	Management Plan (PSMP) to reduce impacts of reservoir and river channel maintenance dredging and disposal on Snake River fall Chinook salmon.		increased predation, competition, loss of rearing area.					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 biological opinion; 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.	All parameters	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								
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	A, P	Juveniles: slowed migration, increased mortality, stress, injury, predation, impaired homing ability.	FCRPS dams, operations, reservoirs.	Category: Most likely to provide opportunities for achieving ESU viability. Timing: Near term	Baseline action	COE	2008 FCRPS biological opinion

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Timing of Potential Additional Actions (near, mid, or long-term)[77]	Estimated Costs	Potential Implementing Entity(ies)	Comments
	consideration of terminating or modifying transport at one or more collector projects if warranted, depending on results.							
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, increased mortality, injury, impaired 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 biological opinion
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.	A, P, D	Altered thermal regime, slowed migration, increased 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 (and at other Snake and Columbia River mainstem dams as	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 biological opinion

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Timing of Potential Additional Actions (near, mid, or long-term)[77]	Estimated Costs	Potential Implementing Entity(ies)	Comments
	needed) to more reliably address adult passage blockages caused by warm 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.[81] Any follow-up actions would depend on outcome of study and costs would be to be determined.	Idaho Power, BOR	

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[81] 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	Timing of Potential Additional Actions (near, mid, or long-term)[77]	Estimated Costs	Potential Implementing Entity(ies)	Comments
2-18	Evaluate effects of winter dredging and of in-water dredge sediment disposal on predator-prey relationships and adapt management actions as appropriate.	A, P	Increased predation, competition, loss of rearing area.	FCRPS system dams and reservoirs.	Category: Warrants additional evaluation Timing: Mid-term	Baseline action	COE	Lower Snake River PSMP EIS Preferred Alternative
2-19	Identify locations of seasonal use of cold-water refugia and research reasons for loss of fish using these cold-water refugia sites. Based on research, identify actions to protect and restore cold-water refugia to improve survival of fish using this habitat.	A, P	High water temperatures, altered thermal regime, climate change.	Land uses, hydro system dams and operations.	Category: Warrants additional evaluation Timing: Mid-term	Baseline action	EPA	Biological Opinion on EPA's Proposed Approval of Certain Water Quality Standards Including Temperature and Intergravel Dissolved Oxygen (November 3, 2015)
2-20	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
2-21	Federal agencies will complete a NEPA process that will consider innovative approaches for increasing the survival of salmon and steelhead in the Columbia Basin which pass through the FCRPS. The result of this effort should result in feasible and effective actions, which, once	All parameters	Juvenile and adult migration impairments, altered flow, sediment, and temperature regimes, reduced spawning and rearing habitat quantity and quality, increased predation.	FCRPS system dams and reservoirs.	Category: Most likely to provide opportunities for achieving ESU viability. Timing: Near term	Baseline action	BPA, Corps, BOR	Scheduled to be completed in March 2021.

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Timing of Potential Additional Actions (near, mid, or long-term)[77]	Estimated Costs	Potential Implementing Entity(ies)	Comments
	implemented, will improve the survival and productivity of Snake River fall Chinook salmon, as well as other salmon and steelhead species in the basin.							
Potential Additional Actions to Achieve ESU Viability – Tributary Habitat								
2-22	Complete and implement TMDLs to improve water quality in tributary habitats that affect Snake River fall Chinook salmon spawning and rearing habitats.	All parameters	Degraded water quality (high summer temps, toxic pollutants, nutrients, low dissolved oxygen), disease, reduced fitness.	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
2-23	Improve tributary major spawning area (MaSA) habitat.							
2-23.1	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 conditions.	Land uses that affect river corridor habitat conditions.	Category: Warrants additional evaluation. Timing: Mid term	$50,000[82]	WA, OR, ID, NPT	Addresses RM&E appendix gaps 4B and 4C.
2-23.2	When carrying out actions to mitigate for declining tributary flows by evaluating, protecting, and restoring	All parameters	Low summer flow, degraded water quality (high summer temps, nutrients,	Water withdrawals and land uses that affect river	Category: Warrants additional evaluation. Timing: Mid term	N/A[83]	WA, OR, ID, NPT	

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[82] 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.

[83] 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.

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Timing of Potential Additional Actions (near, mid, or long-term)[77]	Estimated Costs	Potential Implementing Entity(ies)	Comments
	wetlands, floodplains, or other landscape features that store water (primarily to benefit spring Chinook), consider downstream benefits to fall Chinook.		etc.), reduced habitat quantity/ diversity, excess fine sediment.	corridor habitat conditions.				
2-23.3	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.	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 [84]	WA, OR, ID, NPT	
2-24	Target high priority opportunities to restore October spawning life-history patterns.	All parameters	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 [85]	NPT, ID	
2-24.1	Evaluate potential spawning and rearing habitats in the lower reaches of the Selway, Lochsa, and South Fork Clearwater Rivers.	All parameters	Degraded water quality: high temp, sediment, nutrients, and 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	

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[84] 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.

[85] 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	Timing of Potential Additional Actions (near, mid, or long-term).[77]	Estimated Costs	Potential Implementing Entity(ies)	Comments
2-25	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, low dissolved oxygen, 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	
2-26	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, grazing, 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 loss of off-channel habitat in the estuarine floodplain and altered food web by continuing ongoing actions and implementing additional actions identified in the Estuary Module, FCRPS biological opinion, and this recovery plan, as appropriate.								
Ongoing Actions								
3-1	Protect recent gains in acquisitions of functioning floodplain habitat below Bonneville Dam.	A, P	Reduced floodplain habitat and connectivity, reduced food.	FCRPS flow management, land use practices that affect floodplain connectivity – 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.[86]	COE, BPA, OR, WA, local governments, tribes, NGOs, Lower Columbia Estuary Partnership, et al.	Estuary Module, CRE 1, 9

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[86] 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	Timing of Potential Additional Actions (near, mid, or long-term).[77]	Estimated Costs	Potential Implementing Entity(ies)	Comments
3-2	Protect restored areas so that juvenile Snake River fall Chinook salmon can benefit from increased habitat capacity and quality.	A, P	Reduced floodplain habitat and connectivity, reduced food.	FCRPS flow management, land use practices that affect floodplain connectivity -- 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, 9, 10
Potential Additional Actions to Achieve ESU Viability								
3-3	Continue to breach, lower or relocate dikes and levees to improve connectivity to off-channel floodplain habitats.	A, P	Reduced off-channel floodplain habitat and connectivity, reduced food.	FCRPS flow management, land use practices that affect habitat connectivity -- 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 biological opinion, Estuary Module CRE-10
3-4	Continue to protect remaining high-quality off channel floodplain habitat from degradation and restore degraded areas with high intrinsic potential for high quality habitat.	A, P	Reduced off-channel floodplain habitat and connectivity, reduced food.	FCRPS flow management, land use practices that affect habitat connectivity -- 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 biological opinion, Estuary Module CRE- 9

Action No.	**Action**	**VSP* Parameter Addressed**	**Limiting Factors Addressed**	**Threats Addressed**	**Timing of Potential Additional Actions (near, mid, or long-term)[77]**	**Estimated Costs**	**Potential Implementing Entity(ies)**	**Comments**
Management Strategy 4: Continue ongoing actions and implement additional actions as appropriate to gain a better understanding of potential impacts from climate change during freshwater, estuarine, and ocean life stages, and to support Snake River fall Chinook salmon adaptation and resilience in response to 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.)*	All parameters	High water temperatures, delayed migration, reduced spawning and rearing area.	FCRPS reservoirs and dams, climate change.	Category: Ongoing essential	Baseline action	COE	2008 FCRPS biological opinion
4-2	Maintain surface passage routes that reduce travel time through forebays.	All parameters	Delayed migration, injuries stress, mortality.	FCRPS reservoirs and dams, climate change.	Category: Ongoing essential	Baseline action	COE	2008 FCRPS biological opinion
4-3	Continue to reduce warm water predators in reservoirs (for example, as in action 5-3, above).	A, P, D	Increased predation, competition for space/ food.	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 patterns, slowed migration, mortality.	FCRPS reservoirs and dams, climate change.	Category: Ongoing essential	Baseline action	Corps, BPA, ID Power/FERC, BOR, USGS	2008 FCRPS biological opinion, FERC licenses and Biological opinions 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	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 biological opinion

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Timing of Potential Additional Actions (near, mid, or long-term)[77]	Estimated Costs	Potential Implementing Entity(ies)	Comments
	fish ladders and 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.)	A, P	Reduced off-channel habitat and floodplain connectivity, 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 biological opinion, 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 biological opinions

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Timing of Potential Additional Actions (near, mid, or long-term)[77]	Estimated Costs	Potential Implementing Entity(ies)	Comments
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.	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 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 biological opinions
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 biological opinions
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 biological opinions

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Timing of Potential Additional Actions (near, mid, or long-term)[77]	Estimated Costs	Potential Implementing Entity(ies)	Comments
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 biological opinions
Management Strategy 6: Continue ongoing actions and implement additional actions as appropriate to reduce predation and competition and address other ecological interactions that affect Snake River fall Chinook salmon.								
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, 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 biological opinion In the estuary, this action overlaps with actions 3-7 and 3-8 above.
6-2	Continue pikeminnow 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 biological opinion
Potential Additional Actions to Achieve ESU Viability								
6-3	Improve Oregon and Washington fishery management of non-native fish predator populations including 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	

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Timing of Potential Additional Actions (near, mid, or long-term)[77]	Estimated Costs	Potential Implementing Entity(ies)	Comments
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[87]	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	
6-5.1	Evaluate effect of spawning site competition and redd superimposition on juvenile productivity.	A, P	Competition for space in spawning and rearing areas.		Category: Warrants additional evaluation. Timing: Mid term	$500,000[88]	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.	A, P	Competition for space in spawning and rearing areas, competition for food.		Category: Warrants additional evaluation. Timing: Mid term	$2.5 million[89]	BPA, USGS, USFWS	Could be implemented as expansion/reprogram of currently funded work related to predation under project 200203200 funded by BPA.

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[87] 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.

[88] 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.

[89] 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	Timing of Potential Additional Actions (near, mid, or long-term)[77]	Estimated Costs	Potential Implementing Entity(ies)	Comments
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.	All parameters	Mortality and disease, increased competition, 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 additional actions that will improve ESU viability by reducing the impacts of hatchery-origin fish on natural-origin Snake River fall Chinook salmon.								
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 Snake River fall Chinook salmon hatchery programs.	A, P, D	Genetic changes, loss of fitness, disease transfer, competition for spawning areas and other resource, higher mortality from incidental harvest.	High proportion of hatchery fish as juveniles and adults.	Category: Ongoing essential	Baseline action	NMFS, NPT, WDFW, IDFG, ODFW	biological opinion
7-2	Continue current actions to minimize fish from outside the ESU being included in hatchery broodstocks.	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	biological opinion
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	WDFW, IDFG, NPT, ID Power (IPC), USFWS, NMFS	

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Timing of Potential Additional Actions (near, mid, or long-term)[77]	Estimated Costs	Potential Implementing Entity(ies)	Comments
						implementation – see action 7-3.1.		
7-3.1	Review and update as warranted estimates 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[90]	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. Additional cost: $370,000[91]	WDFW, Nez Perce Tribe, USFWS, Idaho Power Company	
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, Idaho Power Company	

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[90] Support for one analyst and coordination with the existing run reconstruction group.

[91] 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	Timing of Potential Additional Actions (near, mid, or long-term).[77]	Estimated Costs	Potential Implementing Entity(ies)	Comments
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 with a low proportion of hatchery-origin spawners or (2) reducing hatchery-origin spawners in the population overall.	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	
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 ESA recovery objectives for highly viable population status	All parameters	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.

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Timing of Potential Additional Actions (near, mid, or long-term)[77]	Estimated Costs	Potential Implementing Entity(ies)	Comments
	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.	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[92]	Nez Perce Tribe, NMFS, USFWS, ODFW, WDFW, Idaho Power	
7-10.1	Develop methods/indices for the estimation of the relative contribution of naturally spawning hatchery Snake River fall Chinook salmon across major spawning areas to productivity and diversity.	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	Nez Perce Tribe, NMFS, USFWS, ODFW, WDFW, Idaho Power	
7-11	Identify and implement additional methods to measure effects of high levels of hatchery-origin spawners on natural		Lack of tools to evaluate VSP status.	High proportions of hatchery fish as adults and juveniles in some areas;	Category: Warrants additional evaluation. Timing: Mid term	To be determined.	Nez Perce Tribe, NMFS, USFWS, ODFW, WDFW, Idaho Power, BPA	

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[92] Task would be completed with existing staff resources.

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Timing of Potential Additional Actions (near, mid, or long-term).[77]	Estimated Costs	Potential Implementing Entity(ies)	Comments
	population of Snake River fall Chinook salmon productivity, diversity, and response to natural-selective processes.			carrying capacity; competition.				
7-12	Assess the expense, logistical difficulty, and consequences (e.g., to fisheries) of implementing NPEA frameworks.	P, SS, D	Lack of information to complete assessment.	Competition; high proportion of hatchery fish as adults and juveniles; higher mortality due to incidental harvest.	Category: Most likely to provide opportunities for achieving ESU viability. Timing: near term	To be determined	BPA, Nez Perce Tribe, NMFS, USFWS, ODFW, WDFW, Idaho Power	
Management Strategy 8: Continue RM&E to gain a better understanding of potential negative impacts from exposure to toxic pollutants and develop actions to reduce potential effects of toxic contaminants on natural-origin Snake River fall Chinook salmon.								
8-1	Continue to identify and reduce toxic contaminants at the sources, including, but not limited to, pollutants from agricultural, mining, and urban and industrial sources; also reduce accumulation of toxic contaminants in reservoirs.	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

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Timing of Potential Additional Actions (near, mid, or long-term)[77]	Estimated Costs	Potential Implementing Entity(ies)	Comments
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
8-4	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 biological opinion, Estuary Module CRE-22
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.	All parameters	Fish passage to historical upstream habitats.	Hydropower projects.	Category: Action to reestablish a population above the Hells Canyon Complex Timing: near term	Baseline action	FERC, Idaho Power Company	
Management Strategy 10: Restore habitat conditions that can support Snake River fall Chinook spawning and rearing above the 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) and FERC licensing conditions to improve water quality in the mainstem Snake River to	All parameters	Excessive nutrients, sedimentation, toxic pollutants low dissolved oxygen, total dissolved gas, reduced hyporheic conditions in reservoirs.	Reservoirs; Land uses that affect river habitat.	Category: Action to reestablish a population above the Hells Canyon Complex Timing: near term	Baseline action	State water quality agencies in OR, WA, ID; Idaho Power Company	Clean Water Act; FERC licensing conditions

Action No.	Action	VSP* Parameter Addressed	Limiting Factors Addressed	Threats Addressed	Timing of Potential Additional Actions (near, mid, or long-term)[77]	Estimated Costs	Potential Implementing Entity(ies)	Comments
	support adequate spawning and rearing habitat.							
10-2	Continue to implement and develop habitat restoration programs and incentive programs for land owners and water users that promote protecting and improving habitat conditions.	All parameters	Excessive nutrients, sedimentation, toxic pollutants, low dissolved oxygen.	Land uses that affect river habitat.	Category: Action to reestablish a population above the Hells Canyon Complex Timing: near term	To be determined	OR, WA, ID, NGOs; Idaho Power Company	FERC licensing conditions

6.3 Contingency Processes

As discussed in Section 6.1.3, this recovery plan is based on an adaptive management framework. Under that framework, management actions will be implemented based on best available science; RM&E will be conducted to improve our understanding of species status, action effectiveness, and critical uncertainties; and management actions will be updated based on new knowledge. Implementation of the site-specific management actions identified in Section 6.2 (including modification of those actions as appropriate based on emerging RM&E information) will likely be adequate for achieving recovery. However, it is important to have contingency processes in place if the species does not continue to move towards recovery objectives in a timely manner and/or if there are significant declines in the species' status.

During implementation of this recovery plan, NMFS will work with co-managers and other appropriate entities, through the implementation framework described in Chapter 8, to consider and adopt appropriate contingency processes. These processes might be triggered, for example, in the event that the Snake River fall Chinook salmon ESU does not continue to trend towards recovery in a timely manner through implementation of the management actions identified in this Plan, or in the event of a significant decline in population parameters. Managers may also identify specific contingencies that might occur under a particular management scenario (e.g., implementation of Scenario C ─ Single Population with Natural Production Emphasis Areas), and actions to take in the event of those contingencies.

These contingency processes might be modeled, to some extent, on the FCRPS Adaptive Management Implementation Plan (AMIP). NMFS worked with the FCRPS action agencies to develop the AMIP as part of the 2010 FCRPS Supplemental biological opinion and incorporated it into the RPA for the 2008 FCRPS biological opinion (NMFS 2008b, 2009, 2010). The AMIP incorporates early warning indicators and significant decline triggers. If a trigger is tripped, then processes within existing management frameworks will be used to identify and implement response actions, most of which would be short-term in duration, in the hydro, predation, harvest, and hatchery sectors. Similarly, in implementation of this recovery plan, triggers could be identified, and in the event of a significant decline or other trigger, NMFS would work with the appropriate management forums to review and select the specific response actions most suitable for Snake River fall Chinook salmon, while considering the implications of those actions for other ESUs and other relevant factors. As part of this effort, intermediate goals and time frames for meeting them might also be established as needed to indicate whether the species is making meaningful progress toward ESA recovery.

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7. Research, Monitoring, and Evaluation

This chapter describes the research, monitoring, and evaluation (RM&E) plan for Snake River fall Chinook salmon. The RM&E plan plays an important role in the adaptive management framework of this recovery plan, in which actions are designed, prioritized, implemented, and adapted based on the best available science. Key objectives of the RM&E plan are to provide research and information to identify the driving factors for the recent improvements in species abundance and productivity, assess the status and trends in population viability, evaluate critical uncertainties, and monitor the effectiveness of management actions in addressing threats and bringing Snake River fall Chinook salmon to recovery. The detailed RM&E plan (see Appendix B) contains more information, including descriptions of current monitoring efforts and additional needs. The RM&E plan will continue to be updated during Plan implementation as new information emerges regarding potential new threats and critical uncertainties. A priority during Plan implementation will be to prioritize and sequence RM&E activities and strategically fill gaps in monitoring to inform critical uncertainties and gain needed assurance that the ESU meets the recovery objectives and can be self-sustaining in the wild.

This RM&E plan is based in part on principles and concepts laid out in the NMFS documents *Guidance for Monitoring Recovery of Pacific Northwest Salmon and Steelhead Listed Under the Federal Endangered Species Act* (Crawford and Rumsey 2011) and *Adaptive Management for ESA-Listed Salmon and Steelhead Recovery: Decision Framework and Monitoring Guidance* (NMFS 2007). These 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). The listing status decision framework reflects the factors that NMFS considers in evaluating ESU listing status. In addition, the RM&E plan borrows from RM&E plans developed for other ESA-listed Columbia Basin salmon and steelhead and includes information from the Columbia Basin Anadromous Salmonid Monitoring Strategy (CBFWA 2010).

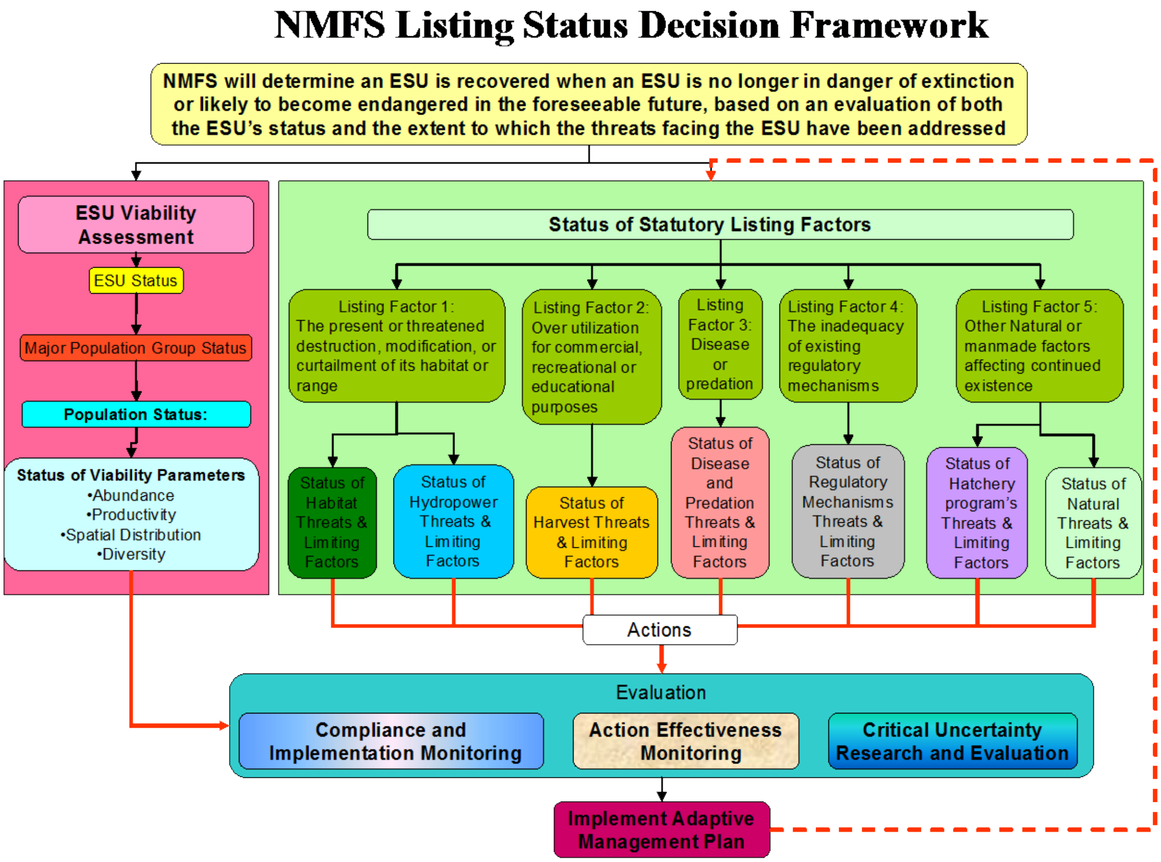

Figure 7-1. Decision framework used by NMFS to assess listing status.

7.1 Role of Research, Monitoring, and Evaluation in Adaptive Management

RM&E plays a critical role in the recovery planning adaptive management framework. A priority during implementation of this recovery plan will be to prioritize and sequence RM&E activities and strategically fill gaps in monitoring to inform critical uncertainties and gain needed assurance that the ESU meets the recovery objectives and can be self-sustaining in the wild. These critical uncertainties include questions regarding the driving factors for the recent increases in Snake River fall Chinook salmon abundance and productivity, and whether those increases will persist into the future across a range of changing environmental conditions. There is also uncertainty about the effects of the high proportions of hatchery-origin spawners on species productivity and diversity. RM&E associated with the recovery plan will be framed through the adaptive management framework to gather the information that will be most useful in evaluating these and other critical uncertainties.

Adaptive management works by coupling decision making with data collection and evaluation. Overall implementation plans for recovery actions incorporate monitoring and evaluation, and then link the RM&E results explicitly to feedback on the design, revision, and implementation of actions. Figure 7-2 illustrates the role of RM&E in the adaptive management cycle.

Figure 7-2. The role of RM&E in the adaptive management cycle.

7.2 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 a population and its limiting factors at any given time. Trend monitoring tracks these conditions over time to provide a measure of the increasing, decreasing, or steady state of a status metric 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.

7.3 Monitoring Framework and Objectives

The desired outcome of this recovery plan 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.[93] In order to determine if the desired outcome has been achieved, answers to two general questions are needed.

- What is the status of the ESU relative to the ESA recovery goal, objectives, and biological viability criteria (see Chapter 3)?
- What are the combined and relative effects of limiting factors and threats, and have they been ameliorated such that the species has attained its desired status and delisting is unlikely to result in a decline in species status?

Although these two general questions provide the basis for the RM&E plan, several specific objectives, listed below, attend each of the two general questions:

1. Assess the status and trends in abundance and productivity of natural- and hatchery-origin fall Chinook salmon within the Lower Snake River population.
2. Assess the status of the spatial structure of the Lower Snake River population based on current and historically used habitat.

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[93] A self-sustaining, viable ESU depends on the status of its component populations and major population groups 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 artificial propagation measures to achieve its viable characteristics (see Chapter 3).

3. Assess the status and trend in genetic and life-history diversity of the Lower Snake River population.
4. Assess the status and trend of current and historically used adult holding, spawning, and juvenile rearing mainstem and tributary habitats used by the Lower Snake River population.
5. Determine the effects of habitat limiting factors and associated management efforts in the major spawning and rearing areas on the Lower Snake River 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, changes in food web, 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 programs on the viability of Lower Snake River natural-origin 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 pollutants on the viability of Snake River fall Chinook salmon.
15. Determine the feasibility of restoring passage and habitat conditions to support reintroduction of naturally producing fall Chinook salmon upstream of the Hells Canyon Complex.

The following section identifies and describes specific RM&E questions associated with each of the monitoring objectives listed above. The more detailed description of the RM&E plan in Appendix B 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.

7.4 Monitoring Objectives and Questions

As noted earlier, the overall goal of this RM&E plan is to determine the status of the ESU relative to the ESA recovery goal, objectives, and biological viability criteria, to evaluate the combined and relative effects of limiting factors and threats, and to determine whether they have been ameliorated such that the species has attained its desired status and delisting is unlikely to result in a decline in species status (see Chapter 3). There are several monitoring programs already in place to evaluate the status of the population and its limiting factors.

This RM&E plan is designed to identify the full suite of RM&E objectives related to Snake River fall Chinook salmon, identify and describe specific RM&E questions associated with each of the monitoring objectives, and then identify the monitoring approaches and analyses that could be used to answer the questions, as well as the status of current monitoring efforts associated with each monitoring question, and gaps in those efforts (see Appendix B). Current monitoring efforts include those being conducted as ongoing actions under the FCRPS biological opinion (NMFS 2008b, 2010, 2014c), the Snake River fall Chinook Hatchery and Genetics Management Plans, and the 2012 biological opinion on Snake River fall Chinook salmon hatchery programs (WDFW et al. 2011; NPT 2011; WDFW et al. 2011; NMFS 2012a). Examples of specific activities 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 scroll case temperatures; and turbidity), juvenile dam passage performance evaluations, transportation evaluations, redd surveys, genetic sampling, tagging studies, and fishery assessments (see Appendix B for detail on existing efforts). Where there are gaps in monitoring, this RM&E 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 Snake River population.

The viability status of a population is determined by estimating the VSP parameters: abundance, productivity, spatial structure, and diversity (as shown in Figure 7-1 and described in Section 2.5.2). 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 (see ICTRT 2007). Adult abundance is expressed as the most recent 10-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 improve understanding of the influence of changes in density, environmental conditions, climate, harvest, artificial production, 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 Lower Snake River major spawning areas?

> This monitoring question focuses on generating annual estimates of abundance of natural- and hatchery-origin fall Chinook salmon that pass upstream of Lower Granite Dam to the different major 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, artificial production, and other factors on productivity.

What is the current estimate of intrinsic productivity for the Lower Snake River population?

> This information is needed to assess the status of the population. The ICTRT approach pairs estimates of recent natural-origin abundance and productivity to compare population status against ICTRT viability criteria (ICTRT 2007). The ICTRT defines population-level intrinsic productivity as the average return per spawner at low to moderate spawning densities. The alternative viability criteria metrics described for Snake River Fall Chinook salmon in Chapter 4 of the Recovery Plan require estimates of productivity at either of two different spatial levels: (1) the aggregate population or (2) for a targeted set of one or more major spawning areas.

Objective 2: Assess the status of the spatial structure of the Lower Snake River population based on current and historically used habitat.

The major spawning areas that the ICTRT identified within the Snake River fall Chinook salmon ESU are the Upper Hells Canyon MaSA (mainstem Snake River, Hells Canyon to Salmon River confluence), Lower Hells Canyon MaSA (Salmon River confluence to upper end of Lower Granite Reservoir), Grande Ronde River MaSA, Clearwater River MaSA, and Tucannon River MaSA. Redd counts indicate that 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 natural spawning in the lower Selway River in the South Fork Clearwater River. By using estimated spawner escapement over Lower Granite Dam as a starting point, it is possible to derive estimates of adult abundance associated with each MaSA. Specific approaches and analyses are not detailed for the Tucannon River under Objective 1 (or any other objective unless noted), but those described have been 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 the same among all 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 geographic distribution of redds does not accurately reflect the spatial distribution of natural-origin spawners. To fully understand the status of the population relative to spatially explicit delisting 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 individual spawning areas.

How are estimates of the spawning distribution of natural-origin adults validated?

> Two approaches are being explored to directly estimate natural-origin production from the mainstem Snake River and large tributary MaSAs comprising the extant Lower Snake River population. The first approach involves collecting representative samples of adults and/or carcasses from each MaSA using previously untried methods (e.g., angling). The second approach uses otolith microchemistry (Hegg et al. 2013). Otolith microchemistry has demonstrated the ability to differentiate unmarked returns as either hatchery- or natural-origin and to differentiate among the spawning or early rearing reaches of returning natural-origin adults to the mainstem Snake River, the Clearwater River, and the Grande Ronde/Imnaha Rivers (Hegg et al. 2017a). While current techniques do not allow for differentiation of fish from the upper and lower Snake River mainstem segments, there are indications that further refinements (through incorporating additional chemical signatures and employing alternative statistical techniques) will support discrimination between fish produced from redds above and below the Salmon River confluence (Jens Hegg, pers. comm. August 2017).

Objective 3: Assess the status and trend in genetic and life-history diversity of the Lower Snake River 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.

Hatchery programs have considerable potential to affect genetic and life-history diversity, but can also affect the natural-origin population in a variety of other ways. Thus, effects of the hatchery programs are explicitly considered as a separate objective (Objective 12), although there will be considerable overlap between activities associated with this objective and those associated with Objective 12.

While many genetic monitoring methods will be identical or nearly so to those used for status monitoring of other populations, some methods will be customized because of logistical constraints imposed by Snake River fall Chinook salmon 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 interest in life-history diversity is currently 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 Snake River population?

> Answering this monitoring question will help 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 over time, and how the population may be changing genetically in key life-history traits. This suite of measures allows for the standard whole genome assessment of diversity, but also for assessing life-history changes at the genetic level. It also addresses a key issue specific to recovery of the Lower Snake River 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 question 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., whether 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 yearling 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 the Lower Snake River 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 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 actions identified 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 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 the high priority opportunities are 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 spawning areas?

Answering this question will provide a standardized assessment of rearing habitat in the major spawning areas, which 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.

Objective 5: Determine the effects of habitat limiting factors and associated management efforts in the major spawning and rearing areas on the Lower Snake River 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 Chapter 5, spawning and rearing habitat is currently affected by altered flows 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, higher mortality for rearing juveniles, and incidence of gas bubble disease. Also, altered flows (on a seasonal, daily, and hourly basis) result in altered migration patterns and in stranding and entrapment of juvenile fish. Interruption of geomorphological processes (through entrapment of sediment behind dams) results in potential reductions in spawning gravels and in reduced turbidity, which can increase 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 of, 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?

> Cumulative temperature exposure of adults passing from Bonneville Dam to spawning areas upstream of Lower Granite Dam affects the rates of premature spawning, prespawning mortality, and embryo mortality. Any increases in temperature will increase such mortality. Continued evaluation and refinement of structures or operations at all eight FCRPS lower Snake River and lower Columbia River mainstem dams 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 Project Federal Power Act relicensing are needed (NMFS 2006). 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 help to determine how hatchery artificial production 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 Chapter 6 of this 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 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 historical 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 on the migration timing and survival of migrating juvenile and adult fall Chinook salmon, including factors that could contribute to the delayed or latent mortality of migrants passing through the mainstem hydropower system.

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.

What is the effect of hydropower operations (including transportation) on naturally produced Snake River fall Chinook salmon emigrants that enter the ocean as either subyearlings or yearlings?

Since the early 1990s, a series of changes has been made in 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. Investigations also need to assess factors that could contribute to the latent mortality of fish passing through the hydropower system. 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. 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.

What are the effects of Columbia River hydropower operations on flow, temperature, total dissolved gas levels, and turbidity in the mainstem Snake and Columbia Rivers?

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 floodplain habitat and the production of macrodetritus (the base of the food web) and invertebrate 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 consumed by 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?

Small numbers of Snake River fall Chinook salmon have been observed in shallow-water habitats downstream of Bonneville Dam (Sather et al. 2009; Teel et al. 2014). There is evidence that they derive benefits from these areas (e.g., food adequate for growth and the ongoing physiological transition to salt water; refuge from predators) whether they enter the wetland or just feed on insects and amphipods transported from shallow-water habitats to the main migration 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 (i.e., below Bonneville Dam) 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 Columbia River basin 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 lower estuary and plume, and (2) bird and fish predation on juvenile salmonids. With respect to the latter, 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 in Washington, and that predation, especially by birds, might be a major factor in these areas.

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 abundant 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 (Appendix F). 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 salmon once the 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 during the first year in the ocean.

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[94] 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 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 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, which could result in a loss or reduction in the Snake River fall Chinook salmon yearling life-history strategy for the species.

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[94] 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.

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 RM&E 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 monitoring 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 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 yearling life-history patterns to natural production changing over time? Are the changes consistent 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 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 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 of delayed passage, leading to increased mortality, reduced spawning success, or reduced egg viability. Gaining information on current levels of, 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 effectively 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 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. 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. Implementation of harvest reductions in ocean and in-river fisheries since ESA listing, coupled with other survival improvements throughout the system, have 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?

Ocean and Columbia River fisheries have been managed for more than twenty years to reduce morality of Snake River fall Chinook salmon and other ESA-listed species. 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 coincided with significant increases in the abundance of hatchery- and natural-origin fish, suggesting that it may be adequately protective. However, the observed increase in abundance is confounded by the large contribution of hatchery-origin fish. 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 could 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, changes in food web, 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 their interactions with predators and competitors. Juvenile fall Chinook salmon encounter many different environments during their life cycle, each replete with distinct predators, competitors, and prey communities that support juvenile growth. 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 non-native 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 vulnerability to predators. The high abundance of non-native predators like smallmouth bass and walleye in the Snake and Columbia Rivers may be an important cause of mortality to 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 and 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 research 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 (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 are affected by prey resources (Connor et al. 2013).

How will alterations to the food web (e.g., increases in 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 the ecological consequences of this invasion are 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 they may be prey themselves, but their role in the food web and in relation to fall Chinook salmon is poorly understood (Tiffan et al. 2014). Finally, the native sand roller (*Percopsis transmontana*) 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. 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 on 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 mainstem rearing habitats often overlap with, 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, along with northern pikeminnow, are probably the main predator of fall Chinook salmon. Past studies of smallmouth bass predation in the Snake River documented relatively low consumption of juvenile fall Chinook salmon (0 to 11 percent 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. Recent research indicates that current consumption of Snake River fall Chinook salmon by smallmouth bass is significantly higher than it was in the past. The highest consumption rates observed for bass have been in the lower portion of Lower Granite Reservoir, which have ranged from 0.21 to 0.35 Chinook/bass/day (Tiffan and Erhardt unpublished). 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 of 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 need to re-list the species. Therefore, monitoring the status and trend of existing regulatory mechanisms and their enforcement 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 limiting factors associated with habitat, hydropower, harvest, disease and predation, and hatcheries?

> Several regulatory mechanisms are in place to protect the species and/or reduce the risk of the limiting factors associated with the abundance, productivity, diversity, and spatial structure of Snake River fall Chinook salmon. There are requirements associated with habitat and hydropower (e.g., FERC licenses, the FCRPS biological opinion, and the Clean Water Act), harvest (e.g., requirements under *U.S. v Oregon* and the Pacific Salmon Treaty), and hatcheries (e.g., HGMPs). A complete listing of the regulatory mechanisms, including those implemented through ESA mechanisms, 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?

> Several regulatory programs, such as section 7 consultations and section 10 permits, are 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 a 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 programs on the viability of Lower Snake River natural-origin 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 mitigation program was adapted to include a directed supplementation effort that shifted a significant proportion of releases upstream of Lower Granite Dam. The goals of the program 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-origin population, and to evaluate the effects of the program on genetic or life-history characteristics of the natural-origin population. Monitoring is also needed to assess the degree that naturally produced juveniles are influenced by or are interacting with hatchery smolts. That is, the presence of hatchery smolts in natural rearing and migration reaches may adversely affect natural-origin production through increased competition for high-quality rearing habitats or through increased exposure to or attraction of predators.

Monitoring Questions:

How is artificial production affecting the natural production of Snake River fall Chinook salmon?

> As with other supplementation efforts, 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 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 artificial production altering natural development of genetic or life-history characteristics of the natural-origin Snake River fall Chinook salmon population?

> Evaluating the effects of the hatchery programs 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 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 affected by artificial 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 hatchery-origin juveniles 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 above under Objective 1. As previously mentioned, in the early 1990s, substantial numbers of out-of-ESU hatchery-origin fish were identified in Snake River fall Chinook salmon broodstock. Measures have been taken to dramatically reduce this risk, but inclusion of out-of-ESU fish in Snake River fall Chinook salmon hatchery programs continues to be a concern, especially with the expected increase in Columbia fall Chinook salmon releases associated with John Day mitigation programs (see *U.S. v Oregon* Management Agreement ─ U.S. District Court [D. Oregon] 2008; NMFS 2008f).

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 climate change projection scenarios.

Multi-stage life-cycle models 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. The models will be used to assess "what if" scenarios. For example, changes in natural 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 Lower Snake River 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 and would help determine 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 the ESA recovery goals, objectives, and 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 (very low risk) for the Lower Snake River 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 Lower Snake River fall Chinook salmon to alternative management strategies and actions under alternative climate scenarios.

How would the Lower Snake River 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 the 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 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 Complex. The most important areas were generally in the mainstem Snake River from Auger Falls downstream to near the Burnt River mouth. Large groundwater inflows associated with discharge from the Eastern Snake River Plain Aquifer strongly influenced the thermal regime favoring a subyearling life-history strategy of fall Chinook salmon. Several large tributaries enter into the middle Snake River, including the Bruneau, Boise, Owyhee, Payette, Weiser, Malheur, Burnt, and Powder Rivers. 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 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 is 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 the Hells Canyon Complex under present-day conditions?

> This question focuses on identifying river segments upstream from the Hells Canyon Complex 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 egg-to-emigrant survival rates are 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 historical 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 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 fall Chinook salmon 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 expected under present-day conditions is necessary to assess the 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 satisfactory. This failure ultimately led to the discontinuation of the passage effort and creation of 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 ensure that the threats to the species have been adequately addressed and that regulatory and other programs are in place to conserve the species in the event it is delisted.

This chapter proposes a framework for achieving coordinated implementation of this Plan. The framework aims to build on and enhance existing partnerships. It proposes processes for achieving coordinated evaluation, reporting, and implementation of future recovery actions. It also describes processes for revisiting and updating the Plan and its proposed strategies and actions as implementation progresses over time. This framework will add value to the suite of existing management programs and actions. It will provide a comprehensive, life-cycle context for prioritizing additional site-specific and RM&E actions, evaluating the collective and relative effectiveness of management actions, examining uncertainties regarding the fish and their habitats, and determining the additional actions that will most benefit the fish and lead to ESA recovery.

While efforts to improve the status of the ESU began prior to its ESA listing in 1992, additional and accelerated actions since the listing have contributed to significant improvements in the species' status, as well as to enhanced 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 FCRPS action agencies, the U.S. Fish and Wildlife Service, other federal agencies, and stakeholders (in particular the Idaho Power Company) that have worked for many years on Snake River fall Chinook salmon research, monitoring, and conservation programs. Accordingly, this Plan builds upon the successes of these partnerships and agreements.

During implementation of this recovery plan, NMFS will rely, to a great extent, on the continued implementation of ongoing programs and management actions, as identified in Chapter 6. The Plan also acknowledges that additional actions are needed, and that determining the best path forward will require close coordination and communication among co-managers. The various fish and habitat managers will need to work together to prioritize and implement RM&E efforts, identified in Chapter 7, evaluate results, and then use the information to identify and implement the additional management actions most likely to bring the species to a point where we are confident that it can be self-sustaining in the wild for the long term. This chapter describes a process that will provide this structure for recovery plan implementation.

This chapter proposes additions to existing management structures with the objective of facilitating the sharing of RM&E information and coordinating decisions regarding implementation of recovery actions among existing forums and throughout the species life cycle. Such a framework is especially important for Snake River fall Chinook salmon because this species has tangible potential to be delisted in the foreseeable future. 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

The recovery plan implementation framework presented below is intended to begin discussion about the best way to implement this Plan and engage with and coordinate among interested parties. The framework relies heavily on existing forums and seeks to facilitate coordination among those forums. It anticipates close working relationships with existing groups, builds on the conservation work already underway, and seeks continued collaboration.

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

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

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

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

8.2 Implementation Roles and Responsibilities

Effective implementation of recovery actions for Snake River fall Chinook salmon will require coordinating the actions of diverse federal, state, tribal, and private entities and management forums. Multiple existing forums are responsible for managing the species and its habitat throughout different phases of its life cycle. These include the forums established for *U.S. v. Oregon*, the FCRPS biological opinion, the Hells Canyon Project Federal Power Act relicensing process for the Hells Canyon Complex operations and mitigation programs, the Lower Snake River Compensation Plan, and the Pacific Salmon Treaty and other harvest management forums. Also involved are other entities that coordinate, oversee, and implement fish and habitat restoration actions (e.g., the Northwest Power and Conservation Council, the Nez Perce Tribe, Idaho Power Company, U.S. Fish and Wildlife Service, Shoshone-Bannock Tribes, Snake River Salmon Recovery Board, Oregon Watershed Enhancement Board, Idaho Governor's Office of Species Conservation, U.S. Forest Service, Bureau of Land Management, the Lower Columbia Estuary Partnership, soil and water conservation districts, private landowners, and others.). We need to ensure that adequate coordination exists so these diverse forums 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 chapter proposes additions to these existing management structures with the objective of facilitating the sharing of RM&E information and coordinating decisions regarding implementation of recovery actions among existing forums and throughout the species life cycle. Such a framework is especially important for Snake River fall Chinook salmon because this species has tangible potential to be delisted in the foreseeable future. The rate at which we achieve delisting depends, at least in part, on coordination across the many management entities that influence the species' survival.

The proposed implementation framework links efforts for scientific review, policy review, and overall coordination of efforts by the many players with management responsibilities across the species' life cycle. The components of this implementation framework include the following teams (Figure 8-1):

- Snake River Fall Chinook Salmon Science Team;
- Snake River Fall Chinook Salmon Policy Group; and
- Snake River Coordination Group.

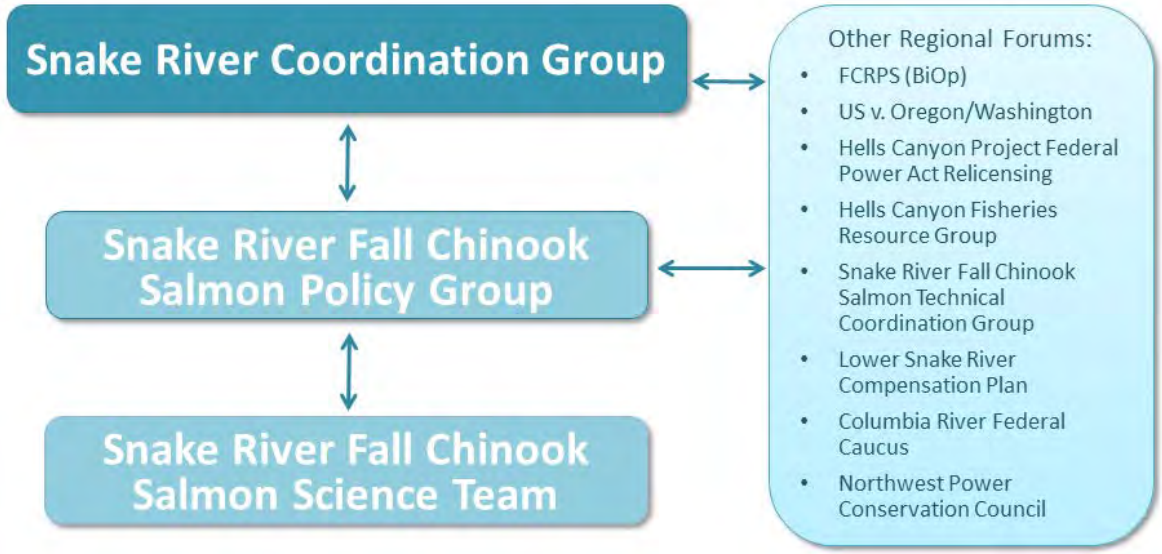

Figure 8-1. Proposed Snake River Fall Chinook Salmon Recovery Plan Implementation Framework.

Two of the entities in the implementation framework are new and focus on coordination of Snake River fall Chinook salmon recovery efforts: a Snake River Fall Chinook Salmon Science Team and a Snake River Fall Chinook Salmon Policy Group. Potential roles for these groups are described below. The existing Snake River Coordination Group, convened by NMFS, covers all Snake River ESA-listed salmon and steelhead species and addresses basinwide communication and issues related to multiple species. All of these groups are information sharing and coordination groups. Decision-making authority is retained by the state, tribal, and federal co-managers and within existing management processes.

Snake River Fall Chinook Salmon Science Team

We envision the Snake River Fall Chinook Salmon Science Team as a relatively small, focused technical team with expertise in Snake River fall Chinook salmon, to be convened by NMFS. The primary purpose of this team would be to ensure that rigorous and best available science informs implementation and is applied in research and monitoring activities. The team would help guide implementation of the RM&E plan, help coordinate and report on key RM&E results, and help guide continued evaluation of RM&E priorities and needs. Based on RM&E results, including results from life-cycle modeling, the team would also consider and 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 managers. NMFS would help facilitate the team and assist with communicating its work to various management 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, USFWS, WDFW, IDFG, ODFW, and

NMFS and other parties, including Idaho Power Company. The Team will interact with the Snake River Fall Chinook Salmon Policy Group.

Key tasks might include, but not be limited to, the following:

- Prioritizing implementation of the RM&E plan for Snake River fall Chinook salmon (see Chapter 7 and Appendix B).
- As appropriate, assembling and summarizing new information gained from RM&E efforts (e.g., through RM&E carried out under the FCRPS biological opinion, the HGMP biological opinion, and other programs, and including status monitoring, hatchery monitoring, and other relevant scientific information).
- 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.
- Developing recommendations, based on new information, for potential additional management actions and potential adjustments to ongoing management actions.

Snake River Fall Chinook Salmon Policy Group

The Snake River Fall Chinook Salmon Policy Group would be composed of policy representatives from NMFS, the tribes, states, FCRPS action agencies, USFWS, and the Idaho Power Company. Ideally, group members would overlap with policy representatives in the existing forums mentioned above (e.g., *U.S. v. Oregon*, the FCRPS biological opinion, Federal Power Act relicensing process for the Hells Canyon Complex operations and mitigation programs, the Lower Snake River Compensation Plan, the Pacific Salmon Treaty and other harvest management forums, and groups that implement tributary habitat actions). Group members might provide staffing resources to help implement key tasks. The group would be convened by NMFS. The primary objective for this group would be to provide coordinated input and recommendations to the Snake River Coordination Group and to management and decision-making forums, and to facilitate recovery plan implementation.

Key tasks might include, but not be limited to, the following:

- Discussing and recommending additional management actions and adjustments to ongoing management actions, based on input from the Snake River fall Chinook Salmon Science Team.
- Discussing options for evaluating and achieving recovery scenarios, based on input from the Snake River fall Chinook Salmon Science Team.
- Discussing communications needs and strategies for communicating with existing management forums regarding Snake River fall Chinook salmon recovery needs.
- Developing intermediate targets for recovery that will show the species is trending toward recovery in the expected time frame.

- Developing and confirming contingency plans and actions in the event of significant declines or if the species does not trend toward recovery in expected time frames (see Section 6.3).
- Identifying and developing conservation agreements and regulatory processes that would ensure conservation of the species after ESA delisting.

Snake River Coordination Group

The Snake River Coordination Group, convened by NMFS, will continue to be responsible for coordination across the Snake River recovery domain. While there is no established membership for participation in the Coordination Group, it brings together representatives from the tribes, states, other federal agencies, local recovery planning, and other implementing entities to coordinate policy and technical issues across the four listed Snake River salmon and steelhead ESUs and DPS. The group provides organizational structure for communication and coordination on a tri-state and multi-tribal level across the Snake River recovery domain.

Specific functions include the following:

- Facilitating coordination and communication between federal agencies, the Northwest Power and Conservation Council, states, tribes, management unit leads, and local recovery boards.
- Advocating for the recovery of Snake River salmon and steelhead.
- Promoting the application of adaptive management.
- Providing recommendations for resource prioritization.
- Networking with other multi-jurisdictional Columbia recovery planning groups (e.g. Mid-Columbia, Lower Columbia, and Upper Columbia) and Northwest Power and Conservation Council subbasin planning efforts.
- Coordinating and synthesizing RM&E efforts and activities as appropriate within the Snake River basin.

The Snake River Coordination Group will coordinate with broader efforts to develop common indicators for measuring trends. It may also identify legislative, Congressional, and other funding opportunities for management actions and RM&E within the Snake River basin. Policy issues will be resolved within respective local, state, federal, and tribal authorities and agencies.

8.3 NMFS’ Role in Recovery Plan Implementation and Coordination

NMFS’ role in implementation of this recovery plan is threefold: (1) to ensure that our statutory responsibilities for recovery under the ESA are met; (2) to ensure coordination of recovery planning efforts with and among other related management efforts in the Columbia River basin;

and (3) to serve as the convening partner of the Snake River Coordination Group and, as practicable, the new entities described above.

NMFS' ESA Statutory Responsibilities

NMFS' recovery planning responsibilities include the following:

- Ensuring that the recovery plan meets ESA statutory requirements, tribal treaty and trust responsibilities, and agency policy guidelines.
- Conducting ESA 5-year status reviews.
- Making determinations regarding listing, changes in listing status, and delisting.
- Coordinating with other federal agencies to ensure compliance with the ESA.
- Implementing the actions in this recovery plan for which NMFS has the authority and funding to do so, and seeking additional opportunities as appropriate and needed.
- Reporting on the implementation of the management and RM&E actions in this Plan, and preparing updated findings during 5-year status reviews, or sooner if new information warrants.
- Using this recovery plan to provide information and context for other activities under the ESA, including ESA section 4(d), section 7, and section 10(a)(1)(A).

NMFS' Coordination Role

NMFS will work through existing management and coordination forums, including those described above in Section 8.2, to ensure that implementation of this recovery plan is closely coordinated with related regional efforts.

NMFS' Convening Role

As convening partner for the Snake River Coordination Group, NMFS' West Coast Region will:

- Coordinate with state, tribal, and federal partners to implement this ESA recovery plan and work with partners to produce 5-year implementation schedules.
- Convene Snake River Coordination Group meetings on a regular basis (once or twice a year) and convene additional meetings as needed.
- Provide meeting facilitation services and manage the meeting process.
- Provide Coordination Group meeting venues.
- Prepare and distribute meeting notes and follow up on tasks agreed to by the Coordination Group.
- Serve as central clearinghouse for information, to include: ESU/DPS-wide stock status, relevant federal scientific research, and ESU/DPS-wide gaps in recovery efforts.
- Coordinate with state, tribal, and federal partners to assure that NMFS' ESA 5-year reviews are based on the best available scientific information.

- As requested by the Coordination Group, establish and facilitate state, federal, and tribal meetings necessary for the coordination of recovery activities.

NMFS will also convene and, depending on available resources, provide coordination, facilitation, and administrative support for the Snake River Fall Chinook Science Team and Policy Group.

8.4 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) (threats criteria). Together these make up the "objective, measurable criteria" required under ESA section 4(f)(1)(B). Chapter 3 of 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.

5-Year Status Reviews

Under the ESA, NMFS is required to review the status of listed species at least every five years. The 5-year status review is used to determine whether an ESA-listed species should (1) be removed from the 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 5-year intervals, NMFS will conduct status reviews of Snake River fall Chinook salmon. These reviews will consider information that has become available through RM&E since the most recent status review and that informs assessment of the biological status of the ESU and/or of the limiting factors and threats affecting the ESU. The reviews will make recommendations regarding whether there is substantial information to suggest that a change in listing status may be warranted. If a change in status may be warranted, NMFS will conduct a more in-depth, status review consistent with section 4(a) of the ESA. Any status reviews will be based on the NMFS Listing Status Decision Framework (see Figure 7-1) and will be informed by the information obtained through implementation of relevant monitoring, research, and evaluation programs.

Similarly, new information considered during 5-year status reviews may also compel more in-depth assessments of implementation and effectiveness monitoring and associated research to inform adaptive management decisions to guide Snake River fall Chinook recovery efforts.

Modifying or Updating the Recovery Plan

Joint NMFS and U.S. Fish and Wildlife Service guidance for conducting 5-year status reviews suggests that following a 5-year status review, an approved recovery plan should be reviewed in conjunction with implementation monitoring to determine whether the plan needs to be updated (USFWS and NMFS 2006).

Recovery planning guidance provides for three types of plan modifications: (1) an update, (2) a revision, or (3) an addendum (NMFS and USFWS 2010). 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 delisting 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' West Coast Region, which will seek input from co-managers and implementing partners prior to making any update. An update would not require a public review and comment period.

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 NMFS West Coast Region. 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.

Implementation Schedules

Given the large number of economic, biological, and social uncertainties involved in implementation of this recovery plan, NMFS and the Snake River fall Chinook salmon co-managers will focus recovery actions in 5-year intervals. Specific actions, and costs as appropriate, will be identified based on the best information available at the time for these 5-year implementation periods. The implementation schedules developed for these periods will identify and prioritize site-specific actions and RM&E needs, determine costs and time frames, and identify responsible parties for action implementation, based on the strategies and actions in this recovery plan. Table 6-1 provides preliminary input on an implementation schedule for the 5-year implementation period from 2018-2022, but additional refinement will be needed. Over the longer term, the recovery plan relies on ongoing monitoring and periodic Plan review regimes to add, eliminate, modify, and prioritize actions through the adaptive management process as information becomes available, and until such time as the protection of the ESA is no longer required.

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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 chapter is intended to meet this ESA requirement.

9.1 Time Estimates

The time to recover Snake River fall Chinook salmon will likely differ depending on which recovery scenario is ultimately pursued and successful (see Section 3.2.1). Under any scenario, the time to recovery will depend on several variables, including the following:

- whether ongoing actions continue to be implemented and are updated as appropriate to enhance their effectiveness;
- whether additional actions are identified and implemented in a timely manner, and whether they are effective;
- how the species responds to both ongoing and additional actions;
- whether RM&E activities are adequate to inform key uncertainties and to determine the status of natural-origin spawners and the effectiveness of management actions;
- whether a functioning and funded adaptive management implementation system is in place; and
- how ecological factors, such as ocean conditions and climate, impact the species.

Finally, the time to recovery will include the time needed to have effective regulatory mechanisms in place, including binding agreements, so that we have a high level of confidence that once the species is delisted, its recovered status will be maintained and it will not need to be listed again in the foreseeable future.

Achieving Scenario A would most likely take many decades, 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 currently underway to determine the feasibility of reestablishing a population above the Hells Canyon Complex. These feasibility studies would first need to be completed, and then actions would need to be carried out based on study findings. These actions would need to (1) provide adult and juvenile fish passage to and from spawning and rearing areas above the Hells Canyon Complex; and (2) restore habitat conditions in areas upstream of the Hells Canyon Complex to support a naturally self-sustaining fall Chinook salmon population.

Scenario B, which relies on the single extant population, could conceivably be achieved in a shorter time frame; however, it would require substantial reductions in current levels of hatchery releases (see Chapter 3), which would affect the ability to meet tribal treaty and trust obligations regarding harvest and current hatchery mitigation goals. Scenario C, which also relies on the single extant population, would include Natural Production Emphasis Areas (NPEAs) to provide a substantial portion of the natural-origin production, with only low proportions of hatchery-origin spawners in those areas. Under this scenario, total hatchery production would not be reduced, but hatchery releases would be shifted to areas outside the NPEAs. Thus, recovery could likely be achieved under Scenario C sooner than under Scenario A and current levels of hatchery production could be maintained, unlike under Scenario B, which would require reduced hatchery production.

By way of example, implementation of actions targeted to achieve either Scenario B or Scenario C 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 hydropower system, habitat, and harvest strategies consistent with Scenarios B or C. If these actions were 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 ESA recovery. Of course, delays in implementation or incremental implementation of actions would extend this timeline. In addition, it is possible that policy choices regarding acceptable levels of risk or confidence in the ESU's status could influence this overall timeline.

9.2 Cost Estimates

This section provides 5-year and total cost estimates as called for under ESA section 4(f)(1)(B) and Recovery Planning Guidance (NMFS and USFWS 2010). Based on the limiting factors and threats identified in this Plan, staff from NMFS West Coast Region and the Northwest Fisheries Science Center, with input from tribal, state, and other federal agency staff, identified ongoing and potential additional actions to recover ESA-listed Snake River fall Chinook salmon. These recovery actions (see Section 6.2 and Table 6-1) were developed using the most up-to-date assessment of Snake River fall Chinook salmon status and recovery needs, without consideration of cost or potential funding.

To prepare cost estimates for these recovery actions, NMFS staff worked with tribal, state, 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. To estimate the total cost of each action we used the scale described for each action, where available, together with unit costs for each action type, where applicable. For some actions, no estimate of scale was available, in which case we either documented the assumptions used to develop estimates or determined that it was not possible to provide a cost estimate at this time.

Table 6-1 in this document provides the estimated costs for actions set forth in this recovery plan. As also indicated in Table 6-1, costs are not provided in the following situations:

> *Baseline actions*: Baseline actions are part of ongoing, existing programs that will be carried out regardless of this recovery plan. No cost estimate is provided for these actions because they do not represent new actions or new costs that are a direct result of this Plan.
>
> *To Be Determined*: For some actions, information is insufficient at present to develop costs estimates. For these actions, additional information is needed, including unit costs and/or project scale estimates before it is sufficiently detailed to support a cost estimate. These costs will be developed during the implementation phase and total recovery costs 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.

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.

Table 6-1 also identifies potential implementing entities for each action. 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).

As described in Chapter 2 and in Chapter 6, multiple entities have implemented significant actions since the ESU was listed in 1992 that have benefitted Snake River fall Chinook salmon. 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 5-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 to add, eliminate, or modify actions through adaptive management as information becomes available and until such time as protection under the ESA is no longer required.

The total cost estimated for all actions identified in Table 6-1 during the 5-year period from 2018-2022, where costs are available, and excluding baseline actions, is approximately $1.845 million. This includes costs for expansion of several ongoing 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 also do not include costs of baseline actions. 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. For example, 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, rearing and migration conditions for fall Chinook salmon, as specified in the FCRPS biological opinion (NMFS 2008b, 2010, 2014c).
- Hatchery programs at Lyons Ferry Hatchery, the Fall Chinook Acclimation Project, 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 for these hatchery programs (NMFS 2012a). The biological opinion also includes a detailed RM&E program.
- Idaho Power Company activities to maintain or improve spawning, incubating, and rearing conditions for fall Chinook salmon 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 Federal Power Act 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, including actions 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 2008b, 2010, 2014c).[95]
- 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 2017b).

As also noted previously in Sections 6.2 and 8.4, 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 based on the best information available at that time.

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[95] 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 status of the Snake River fall Chinook salmon 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.

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